



GRADO EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES

TRABAJO FIN DE GRADO

Development of a bio-inspired claw compatible with
collaborative robotics.

Desarrollo de una pinza bio-inspirada compatible con
un robot colaborativo.

Autor: Alberto Quintana Criado

Director: José Antonio Rodríguez Mondejar

Codirector: Jose Daniel Muñoz Frias

Madrid, Julio 2022

Declaro, bajo mi responsabilidad, que el Proyecto presentado con el título
“Development of a Bio-Inspired Claw Compatible with Collaborative Robotics”
en la ETS de Ingeniería - ICAI de la Universidad Pontificia Comillas en el
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El Proyecto no es plagio de otro, ni total ni parcialmente y la información que ha sido
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Fdo.: Alberto Quintana Criado

Fecha: 04/07/2022



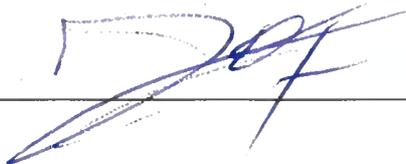
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Acknowledgments:

This year has been quite the journey. It has been tough and demanding, but thanks to some people, I have gathered the strength to finish this amazing year.

I would like to thank my friends and family first and foremost. For their unwavering support and kind council.

I would also like to thank José Antonio, for allowing and directing this weird and unorthodox project with patience.

DEVELOPMENT OF A BIO-INSPIRED CLAW COMPATIBLE WITH COLLABORATIVE ROBOTICS

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Supervisor: Rodríguez Mondejar, José Antonio.

Collaborating Entity: ICAI – Universidad Pontificia Comillas

ABSTRACT

This Project consists of the development of a bio-inspired claw compatible with collaborative robotics. Its planned tasks will encompass manipulating lab-related objects, as well as fragile materials. This way, a soft gripper will be designed to meet these requirements. Materials, manufacturing, design, and final assembly will be discussed.

Keywords: robotics, claw, bio-mimetics, actuators, passive actuation, additive manufacturing, simulation, SLA, gripping, pneumatic.

1. Introduction:

Collaborative robotics has been a very popular field of study in the current I+D. Although a lot of effort has gone into developing robots capable of completing tasks as humans would, there is still a long way to go in this field.

Noting this clear difference between man-made robotics and bio-mechanisms, development strives for imitating natural constructs to mimic their properties and behaviour. In this spirit, the layout of fish extremities presents an interesting structure, that is already being employed. This benefits from the FinRay effect [1].

2. Project Definition:

This project will capture the process of designing the fingers of a bio-inspired claw. This fingers will be compatible with collaborative robotics and be able to grasp fragile lab-related materials. This means that it will be destined to be used in an environment where a robotic actuator (in this case an arm) cooperates with a human worker.

This active environment means that the claw will have to, not only accomplish its task but also behave by the European laws and international regulations for this type of technology.

Along with that, these designs will be tested in a lab environment and if working properly will be used further in multiple tasks. This is why another focus of this project will lie in additive manufacturing. 3D printing or additive manufacturing in industrial environments can help develop big quantities of these robotic grippers allowing for easier repairs, more upgradeability, and conforming to Sustainable Development Goals.

This project has been divided into sections that will conform to the roadmap for the development of the project, and the sections of the following paper. These sections of the paper are divided into chapters. The following table will explain each one.

<i>Chapter 1: Introduction</i>	In this chapter, the spotlight will be in the aim and basic information for the project. We will discuss the scientific basis and the goals and legislation.
<i>Chapter 2: Claw Design</i>	Once the basis for the has been set, the design phase starts. In this chapter, the focus will be on the phenomenon behind the most basic prototype and the plans to expand upon it.
<i>Chapter 3: Ansys and CAD</i>	As the name implies chapter 3 will mainly feature the CAD design phase and the simulation of the theorized prototypes in the previous chapter.
<i>Chapter 4: Additive Manufacturing</i>	This chapter is a short discussion on 3D printing techniques, mainly FDM and SLA, and how the 3D printing of the final piece will be carried out.
<i>Chapter 5: Final Assembly and Results</i>	In this <i>Chapter 5</i> , the last part of the project is explained. The tests were executed to try the fingers and the results of those tests.
<i>Chapter 6: conclusion and Final Projects</i>	As its name implies a brief conclusion will be developed as well as potential future branches of this project explained.

3. Tool Definition:

The claw will consist of a robotic arm, pneumatic gripper actuator, and passive adaptation fingers. During design and development, the focus will be on designing and testing the fingers for the robotic claw. For this, we will do an in-depth study of the state-of-the-art soft-gripper technology and materials, to design a set of fingers for a given robot-compatible actuator.

I have been given two robotic arms grippers with different morphology and actuation, from the company SCHUNK. Apart from designing the fingers, which “head” is more suitable for the project parameters, will be discussed.

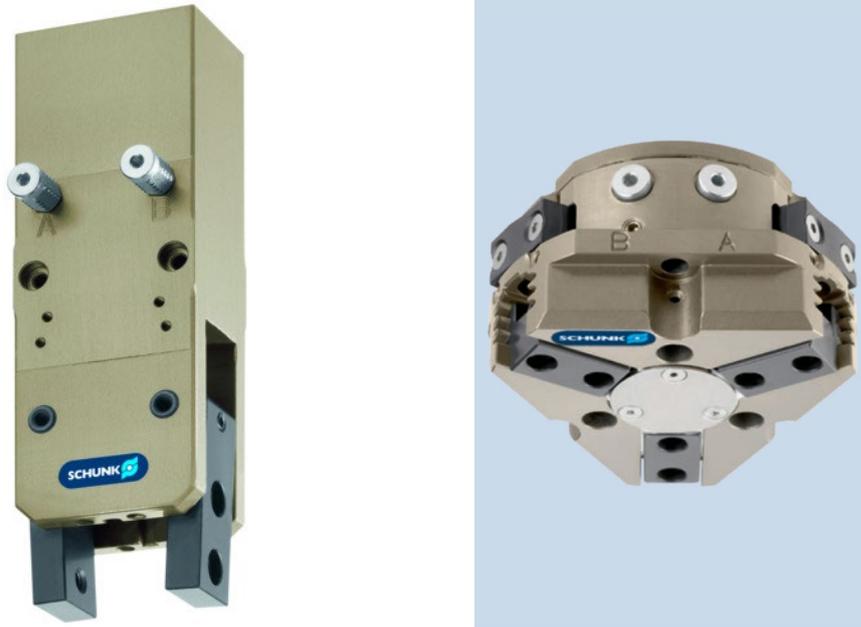
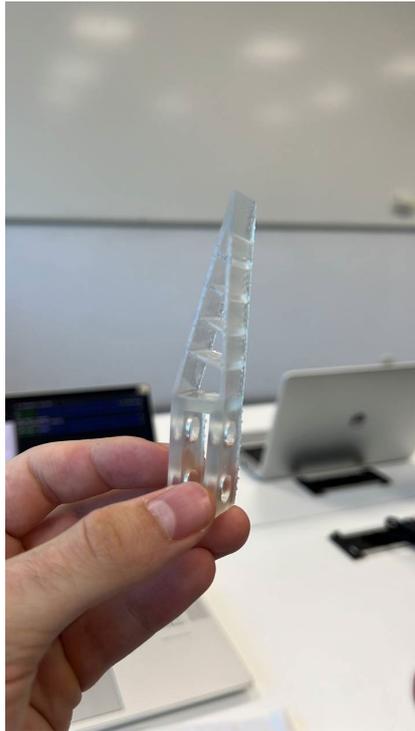


Figure 1: both robotic universal grippers are employed in the paper. PRG and PZN. Courtesy of SCHUNK webpage. [2] and [3]

4. Results:

The final product of the printing process of the design called *progressive_4v*, which we will be calling *final_finger*, is assembled in the previously discussed SCHUNK PRG 42-30 and fitted to a robotic ABB arm. (ID: CRB 15000).

Gripping with the claw designed in this project proves successful as the claw passes multiple tests from multiple objects in lab-like conditions. During these tests we observe not only that the claw performs as expected, but also that *layer jamming* on the vertebrae of the finger produces a tighter and more efficient grip proportional to the passive adaptation.



Figures 2 and 3: (left) final result of the printing and post-processing in additive manufacturing and CAD/ANSYS design. The design is called “final_finger”. (right) One of the many gripping and movement tests performed with success.

5. Conclusion:

Capable of working on the original objective devised for its use and proven to work on even more classes of objects than expected, the design of the finger can be called a success. The phenomenon of *layer jamming* provides more tightness to the structure the more it deforms easing the grip the more difficult the situation unless the object exceeds the *operating limits* stated at the end of *Chapter 5*.

Despite the results of the project showing the correct execution of the same, through development more possible experiments and branching of this project came through.

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DESARROLLO DE UNA PINZA BIO-INSPIRADA COMPATIBLE CON UN ROBOT COLABORATIVO

Autor: Quintana Criado, Alberto.

Supervisor: Rodríguez Mondejar, José Antonio.

Entidad Colaboradora: ICAI – Universidad Pontificia Comillas

ABSTRACTO:

Este Proyecto consiste en el desarrollo de una garra bio-inspirada compatible con robótica colaborativa. Esta ideado para abarcar la manipulación y el transporte de material de laboratorio y materiales frágiles. De esta manera, el *soft gripper* estará diseñado para lacnazar estos requerimientos. Materiales, manufactura, diseño y el ensamblaje final se discutirán.

Palabras Clave: robótica, garra, bio-mimética, actuadores, adaptación pasiva, manufactura aditiva, simulación, SLA, agarre, actuación neumática.

7. Introducción:

La robótica colaborativa ha sido un campo muy popular en el actual I+D. Aunque mucho trabajo ha sido dedicado al desarrollo de mejores soluciones robóticas para cumplir tareas igual o mejor que los humanos, todavía queda un largo camino.

Esta diferencia tan marcada entre mecanismos artificiales y mecanismos orgánicos o naturales obliga al progreso a imitar los constructos naturales en aras de emplear dichas propiedades. Bajo este paraguas, la estructura cartilaginosa de ciertos peces presenta una estructura prometedora que ya esta comenzando a ver uso. Dicha estructura se beneficia del efecto FinRay [1].

8. Definición del Proyecto:

Este Proyecto capturará el proceso de diseño de dicha garra bio-inspirada. Esta garra será compatible con un robot colaborativo y capaz de agarrar material de laboratorio, así como material frágil relacionado. Esto significa que será destinado a actuar en un entorno colaborativo.

Este entorno cooperativo activo significará que la garra deberá, no solo cumplir su tarea, sino también respetar las normas europeas y las regulaciones internacionales en dicho campo de operación.

Es por ello que otro foco de este proyecto estará en la fabricación aditiva. La impresión 3D o la fabricación aditiva, en entornos industriales, pueden ayudar a desarrollar

pequeñas cantidades de estas pinzas robóticas precisas, lo que permite reparaciones más sencillas, más capacidad de actualización y conformidad con los Objetivos de Desarrollo Sostenible.

Este proyecto se ha dividido en secciones que se ajustarán a la hoja de ruta para el desarrollo del proyecto, y las secciones del siguiente documento. Estas secciones del documento se dividen en capítulos. La siguiente tabla explicará cada uno.

<i>Chapter 1: Introduction</i>	En este capítulo, el centro de atención estará en el objetivo y la información básica para el proyecto. Discutiremos la base científica y los objetivos y la legislación.
<i>Chapter 2: Claw Design</i>	Una vez que se han establecido las bases para el, comienza la fase de diseño. En este capítulo, el enfoque estará en el fenómeno detrás del prototipo más básico y los planes para expandirlo.
<i>Chapter 3: Ansys and CAD</i>	Como su nombre lo indica, el capítulo 3 presentará principalmente la fase de diseño CAD y la simulación de los prototipos teorizados en el capítulo anterior.
<i>Chapter 4: Additive Manufacturing</i>	Este capítulo es una breve discusión sobre las técnicas de impresión 3D, principalmente FDM y SLA, y cómo se llevará a cabo la impresión 3D de la pieza final.
<i>Chapter 5: Final Assembly and Results</i>	En este <i>Capítulo 5</i> se explica la última parte del proyecto. Se ejecutaron las pruebas para probar los dedos y los resultados de dichas pruebas.
<i>Chapter 6: conclusion and Final Projects</i>	Como su nombre indica, se desarrollará una breve conclusión y se explicarán las posibles ramas futuras de este proyecto.

9. Definición de la herramienta:

La garra consistirá en un brazo robótico, un actuador hidráulico y dedos de accionamiento pasivo. Durante el diseño y desarrollo, la atención se centrará en diseñar y probar los dedos de la garra robótica. Para ello, haremos un estudio en profundidad de la última tecnología y materiales de agarre suave, para diseñar un juego de dedos para un determinado actuador compatible con robots.

Me han entregado dos “cabezas” de brazos robóticos con diferente morfología y actuación, de la empresa SCHUNK. Además de diseñar los dedos, se discutirá qué “cabeza” es más adecuada para los parámetros del proyecto.

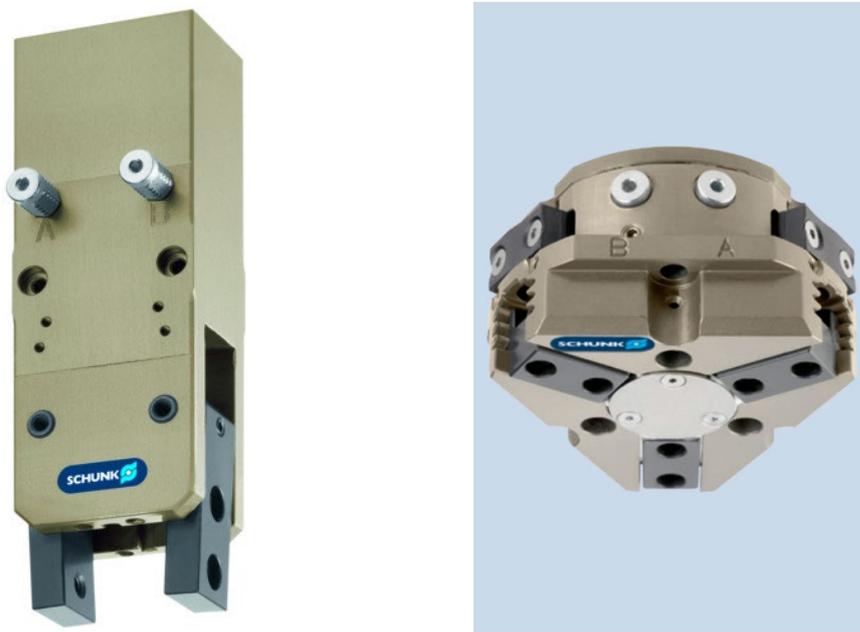
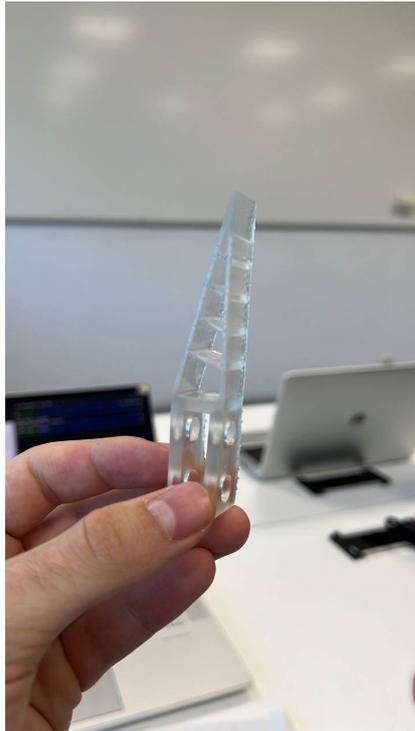


Figure 3: both robotic universal grippers are employed in the paper. PRG and PZN. Courtesy of SCHUNK webpage. [2] and [3]

10. Resultados:

El producto final del proceso de impresión del diseño denominado *progressive_4v*, que llamaremos *final_finger*, se ensambla en el SCHUNK PRG 42-30 mencionado anteriormente y se ajusta a un brazo robótico ABB. (Número: CRB 15000).

El agarre con la garra diseñada en este proyecto resulta exitoso ya que la garra pasa múltiples pruebas de múltiples objetos en condiciones similares a las de un laboratorio. Durante estas pruebas, observamos no solo que la garra funciona como se esperaba, sino también que el atasco de la capa en las vértebras del dedo produce un agarre más firme y eficiente proporcional a la adaptación pasiva.



Figures 4 and 3: (left) final result of the printing and post-processing in additive manufacturing and CAD/ANSYS design. The design is called “final_finger”. (right) One of the many gripping and movement tests performed with success.

11. Conclusión:

Capaz de trabajar en el objetivo original diseñado para su uso y probado para trabajar en incluso más clases de objetos de lo esperado, el diseño de la pinza puede considerarse un éxito. El fenómeno de *layer jamming* proporciona mayor estanqueidad a la estructura cuanto más se deforma, facilitando el agarre cuanto más difícil es la situación, a menos que el objeto exceda los límites de operación establecidos al final del Capítulo 5.

A pesar de que los resultados del proyecto muestran la correcta ejecución de este, a través del desarrollo surgieron más posibles experimentos y ramificaciones de este proyecto.

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Chapter 1: Introduction

In this chapter, a small description of the scope of the project will be provided. We will discuss non-technical fields such as motivation, legislation, and sustainability.

1.1 Project Aim & Motivation:

The aim of this project is double fold.

First, in this paper, an investigation will be performed on collaborative robotics. The field of soft grippers is a growing field of study. In the world of collaborative robotics, some tasks that require meticulous precision, or a mix between finesse and rigidity, cannot be performed by current technology. These are the reasons why industrial design and science have been turning to nature for answers to the ever-growing challenges faced today. Artificial bio-inspired structures or biological materials, provide elegant and effective ways to solve the limitations of artificial technology.

In the field of collaborative robotics, this current of engineering is reflected in the aforementioned soft grippers.

Throughout this project, a functioning soft gripper will be designed according to international regulations, to manipulate fragile objects in lab-like conditions. To do this, studies on materials, actuation, regulations, etc will be carried out.

Secondly, as an industrial engineer specializing in electronics, I felt compelled to delve deeper into this technology. It is due to my growing passion for biomedical engineering and bionics, that I feel “Collaborative robotics” or at least the current studies of these fields of engineering can tie in into future studies in bio-structures, bionics, or even transhumanism.

1.2 State-of-the-art Questions & Solutions:

Grasping and manipulation conform to two of the most fundamental functions of robots in any industrial field. Grasping can be defined as clasping or embracing an object with fingers and/or arms. Most robotic systems perform this action through actuation. Rigid components such as claws, or mandibles adjust through joint actuation to the outer perimeter of a part. Then exert force to grasp this component. Such a method yields enormous structural robustness, due to not needing any active components in contact with the manipulated objects but misses when this same object presents an irregular shape, is not rigid, or is highly flexible. Objects that present a non-convex outer perimeter, also pose a challenge for this technology, since the shape of the claws cannot easily take hold of them.

Soft grippers as discussed previously combine nature with robotic advances. Soft grippers mimic natural structures such as human hands or octopus tentacles. These simpler mechanical structures, combine both active components like actuators (previously mentioned DC motors, servos, etc) and passive components like semirigid structures or soft/compliant materials.

These soft grippers simply aim to mimic human versatility and accuracy of movement. In most cases, redundancy will appear when mixing with collaborative robotics, where the human component carries out these tasks, but in some others the need for the robotic claw to share abilities with the operator is vital. [4]

Examples of this lay not in normal fabrication but in more specific niches of the industry. Fields where toxic materials need to be handled carefully or very fragile components/instruments are moved constantly. The opportunity to relieve some of the workloads in labs and more specialized environments can be very beneficial.

As a solution to these bleeding-edge questions, numerous studies have been carried out. In our case, and for this particular project, the focus will be held on gripper technologies. It is important to note that the scope of this project will encompass materials as well as actuation during the design phase.

Gripping has been previously mentioned and said to be the key to development in related fields. Many researchers have categorized gripping into different “families” that differentiate from each other not only in concept but in the application as well. I prefer the classification made by Jun Shintake and Vito Cacucciolo in 2018. [5]. In this classification, grippers are separated into “actuation” grippers, “stiffness” grippers, and “adhesion” grippers.

Actuation grippers are the most common type of grippers, being the most intuitive of all gripping technologies. We have already defined gripping by actuation as the use of mandibles or claw-like components that through mechanical movement grasp objects. Actuation is helpful when the object presents rigidity and a convex outer shell or structure. With concave-shaped grippers, the object can be easily captured between the fingers. Problems appear when the object does not present rigidity along the process, meaning that its shape is deformable just with the force present in the actuation, and it’s difficult, thus, to be grasped. Objects that are non-convex or flat also pose a great difficulty to this group of grippers.

Stiffness grippers shine where actuation lacks. Controlled stiffness grippers are based on materials and structures with variable stiffness. These structures have two dispositions. A “soft” and mouldable disposition and a “hardened” one, where the internal structure of the material stiffens and locks in any configuration. This allows the gripper to contact any object in the “soft” configuration, it moulds to the shape of the object, and when it does, it enters “hard” mode and locks the object in place. Controlled stiffness not only performs well with a convex object but also with non-convex objects due to being highly adaptable. It still finds some difficulty during the manipulation of flat or deformable objects.

Finally, the third classification is adhesion grippers work by changing the adhesive properties of the surfaces in contact with the object. This phenomenon is explained due to shear adhesion, where there is a proportionality between the normal force exerted by the grasping and the friction coefficient of the surfaces in contact. Electro adhesion and adhesion based on animal skin structures are very popular.

In the following picture (*figure 1.1*) taken from [5], there is a diagram separating these categories and the most common object shapes.

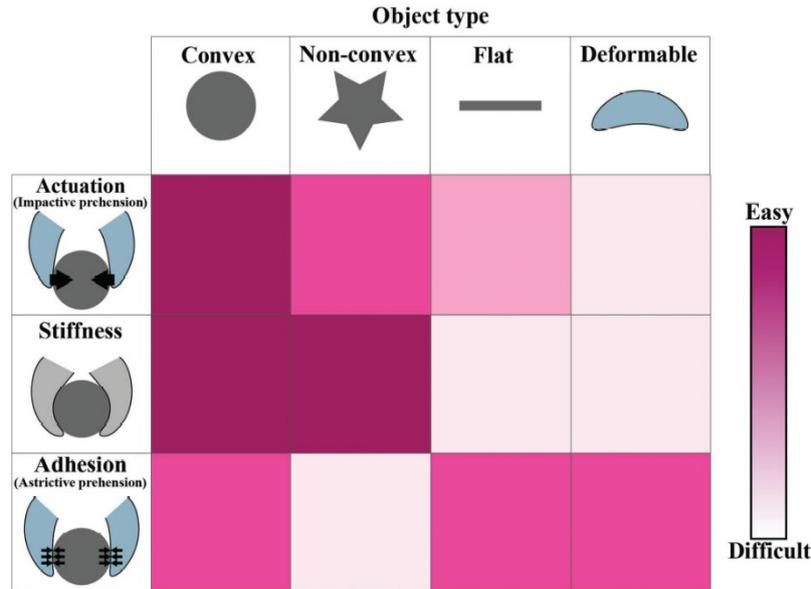


Figure 1.1: Object-gripper heat matrix designed by J. Shintake. [5]

For the project, the goal was for the claw to perform grasping and manipulating lab-like tools and materials. During a quick overview of the available objects in the lab at the university campus, it was decided that most lab-related objects present convex areas of contact. Those that had non-convex areas were scarce, and deformable ones were usually held on convex containers. It was also noted that many of these tools and vials used in experimental conditions are fragile and could not perform under great stresses upon their structures, to not permanently deform or break. This perfectly aligned with the purpose of the investigation.

1.3 Collaborative Robotics Regulations:

Robotic Systems are very powerful structures. They are capable of generating huge loads and torques in very sharp and precise moves. In cases where there is an operator, unanticipated or fast movements can pose a serious threat to the health and well-being of the operators that work in proximity to these robots. When the development of robotics caused the space between the operator and the robotic arm to narrow, then collaborative robotics was born, as well as the threat spoken about.

To ease Human-Robot Collaboration, or HRC for short, and protect the human facet, questions arose about the safety of operators in hybrid working environments. Some regulatory agencies (ISO, CSA, etc) have redacted a set of standards to regulate this interaction and further facilitate the development of robotic systems.

Given that this project takes place at Comillas Pontifical University, and for this project, we are working on European grounds. Robotic systems available in Europe should be referred to the Machine Directive [6], and the Use of Work Equipment Directive of the same year. Moreover, the document issued from ISO [7], presents a broken-down validation process for robotic systems that can be very easily tackled.

For this project and thanks to the work of Carlos Faria, Ana Colin, and their team [8] that studied the legal base of these extensive documents. Following, are written the checks that need to be followed through to verify the full quality assurance procedure of any of these systems.

“The manufacturer or integrator of the robot system shall conduct a risk assessment procedure and meet the relevant essential health and safety requirements from Annex I of the Machine Directive. Moreover, the technical files (indicated in Annex VII, part A), as well as any other necessary information, shall be provided. Once appropriate procedures to assess conformity are carried out, the EC declaration of conformity can be drawn up and the CE marking consequently affixed.

If the robot application is not listed in Annex IV – categories of machines capable of inducing severe injuries – the system integrator shall apply the procedure for assessment of conformity with internal checks on the manufacture of the machinery (Annex VIII). Instead, if the robot system is listed in Annex IV, the integrator shall conduct one of the following procedures:

1. Internal checks on manufacture (Annex VIII).
2. EC type-examination (Annex IX) combined with the internal checks on manufacture (Annex VIII, point 3).
3. Full quality assurance procedure (Annex X).

“– Legal Base from Safety Requirements for the Design of Collaborative Robotic Workstations in Europe, [8]

The ISO standards mentioned before are born from a consensus between governing bodies such as ECS (European Committee for Standardization) or the IEC (International Electrotechnical Commission). Standards are separated into A, B, and C categories.

Type A norms establish the most basic concepts. As defined in the document itself “conception principles and general requirements applicable to machinery” [7]. Type C norms are normally used as templates over more generalist standards. Type B norms are related to specific aspects or safeguards on the technology, mainly for prevention. This type B is often divided into B1 and B2, safety and safeguard, respectively. This can be better explained through the diagram in the *figure 1.2*.

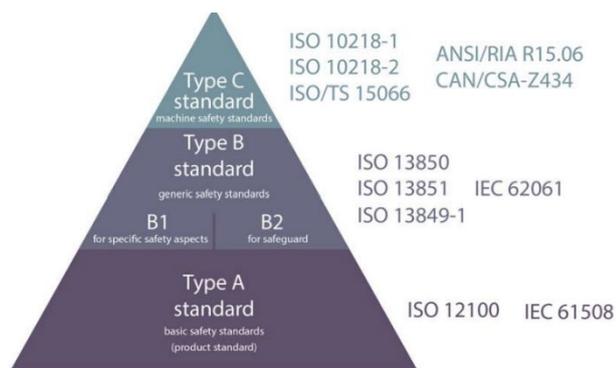


Figure 1.2: Standard classification for [7] as devised by [8]

In this pyramid diagram, the Types above take precedence over the Types below.

For more information in the Annex lies a relevant fraction of the machine directive to be read additionally.

1.4 Sustainable Development Goals:

Sustainable Development Goals are the UN initiative to promote prosperity and equal opportunities, as well as protect the planet.

This project will promote 3 of these 17 goals.



SDG 3: Good Health and Well-Being. UN states that “ensuring healthy lives and promoting well-being at all ages is essential to sustainable development.” [4]. As it has been mentioned previously, normal mass fabrication methods take a heavy toll on operators, and so, as one of the many reasons, collaborative robotics was born. This project in particular, as it carries out repetitive tasks and helps the user relieve excess workload and tedious small tasks, can be labelled in the category of ergonomic studies, as it tackles human body limitations and comfort.



SDG 8: Decent Work and Economic Growth. “Sustainable and economic growth can drive progress, create decent jobs for all and improve living standards.” [9]. This goal is related to the previous one. It is through the improvement of working conditions and well-being that this standard is met.



SDG 9: Industries, Innovation, and Infrastructure. [10]. As straightforward as it is, biomimicking and collaborative robotics is still very young, and as such innovation is key. We will also employ bleeding-edge methods of additive manufacturing to design and manufacture the components of these projects and meet these SDGs.

Chapter 2: Claw Design

In this chapter, the choice of design will be discussed as well as the advantages of such choice and the materials employed. In the materials section, the fabrication method will also be briefly discussed leaving more in-depth points to later chapters (Chapters 3 and 4).

2.1 Study of Actuation:

Briefly discussed in *Chapter 1.2.: State of the art questions and solutions*, the framework, in which to classify grippers, has already been set up. Actuation, Stiffness, and Adhesion have multiple advantages and disadvantages, some of which we have mentioned, and others into which we will delve.

The combination of Actuation Gripping and Biomimetics nowadays has two main branches of study. These differ from classical actuation, where the actuating fingers are solid non-variable in shape. Presenting an additional level of sophistication, fingers from these two branches present further adaptation in each of these appendages that provides more gripping versatility.

The first classification can be defined as a passive structure with external motors. The actuation lies in joints outside of the structure of the “fingers”, while the appendages themselves adapt to shape when contacting an object. This “contact-driven deformation” [5], is based on compliant structures forced to adapt by external mechanical loads. A natural example of this are the roots and branches of climbing plants that adapt to the shape of the objects. In biomimetics, one example of a contract-driven compliant structure is the patented Fin-Ray structure.

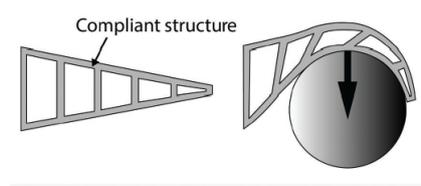


Figure 5.1: Example of contract-driven deformation (Fin-Ray structure). [5]

The second passive structure is a tendon-driven deformation, where the same actuation that clasps the fingers also deforms them. Natural counterparts to this phenomenon can be easily found on human or animal fingers and extremities where tendinous materials are abundant.

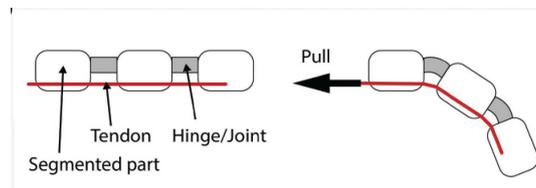


Figure 2.2: Example of tendon-driven deformation in a double-jointed finger. [5]

Other methods yield similar behaviour, such as shape-memory alloys or fluidic elastomer actuators, but both explained methods are most interesting.

Gripping by controlled stiffness can result in high holding forces with minimal compression applied to the object. When manipulating objects under these conditions, they should present convex or non-convex surfaces instead of flat or deformable ones. This change in performance can be attributed to the impossibility of the “soft” configuration to get a hold of a flat facet or a deformable surface.

The most prominent method of stiffness control is via granular jamming. A method in which a bag filled with granular material takes advantage of the physical phenomenon of the same name to change from “soft” to “hard” configuration and back. The change in solidity in the structure happens when this bag of granules depressurizes. When it is at environmental pressure, the granules are free to move and, in some cases, behave like a fluid moulding to the surfaces in contact or the container, but when the bag is vacuumed the differential pressure between the granules varies and the structure solidifies, behaving

like a rigid object. This technology was proven in its early development by Rienmüller in 1988, [11], and developed further by many investigators like Brown's "universal soft gripper" shown in the *figure 2.3* below [12].

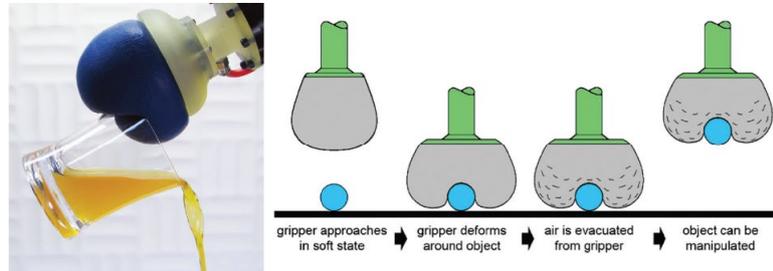


Figure 2.3: explanation of the "universal soft gripper" and showcase, developed by [12] and as shown in [5].

The last of the three grippers that we are going to showcase works by modifying or controlling the adhesive properties of their surfaces. These work in a very clear and intuitive way. Electro-adhesion works by enhancing the Coulomb force's effect via an applied electrical field, while gecko-adhesion or dry adhesion employs van der Waals forces on minuscule microfibers to achieve a similar effect. This last one is very common in many animals, the most prominent being the gecko. There are other adhesion technologies like vacuum-induced suction surfaces, that are being studied but do not apply to the scope of this project.

The definition of this project states that the conclusion of the development will result in a gripper capable of manipulating fragile objects in lab-like conditions. Lab tools such as a flask or test tubes, which are made of glass (usually borosilicate glass according [13]), are highly resistive to the chemicals employed and heat, but develop fragility throughout their life. Thus, we are dealing with regularly shaped objects, mostly convex and with high fragility. Under these conditions, we can choose either actuation grippers or controlled stiffness.

The core of this project is the manipulation of objects by the gripper and as such, one would think the best choice to be the controlled-stiffness gripper. Nevertheless, for this purpose an actuation gripper has been chosen for the following vital properties:

- **Mechanical Actuation:** Actuation is the most common and explored the field of gripping. As such, there are many external actuators already available, some of which are also available at the campus and can be made ready for modifications.
- **Material Choice:** Controlled-stiffness grippers outperform actuation grippers but are composed of non-conventional materials. This means fabrication is constrained by materials or time.
- **Movement Versatility:** Similar to the field before, the controlled-stiffness grippers are very bulky unless built with bleeding-edge technology, as such for a close collaboration environment and following European Legislation, the robotic arm should take as less space as possible.

Having chosen actuation grippers we must also choose which type, and it has been determined that passive structures with external actuators are the best choice. They provide good gripping and better adaptation than most actuation grippers due to its passive structure.

From now starts the design of an actuation gripper consisting of a passive bio-inspired structure and external mechanical actuation. It will be based on the Fin-Ray effect, due to its adaptability and easiness to manufacture, via the preferred method of additive manufacturing as explained in the section *Chapter 1.4: Sustainability Goals*.

2.2 Working Mechanics of Fin-Ray:

Leif Kniese, who patented the basis for this technology in 2012, discovered the Fin Ray Effect during a fishing trip in Norway. While capturing some bony fish native to those waters he noticed that upon contact, the cartilaginous structures of the fins in the animal did not push back, and instead bent and adapted to the contacting object. Curiosity struck, and with studies of the appendage, he discovered that the bony fins presented a cartilaginous structure consisting of two longitudinal rays protruding from the body of the fish and connected between them by elastic tissue, that in the event of a load being applied to would transmit almost perfectly the load and deformation from one ray into the other and generate this adaptation.

The most basic structure for a Fin-Ray finger is an acute triangle with rib-like connections made in flexible material as shown in [14]. This being the case, and to prove the technology, a model was constructed during the early stages of the process, to better understand this phenomenon and formulate the possible improvements that could be made on this basis. This model would also serve as a prototype template for the CAD designs and as the proof of concept that made this project viable.

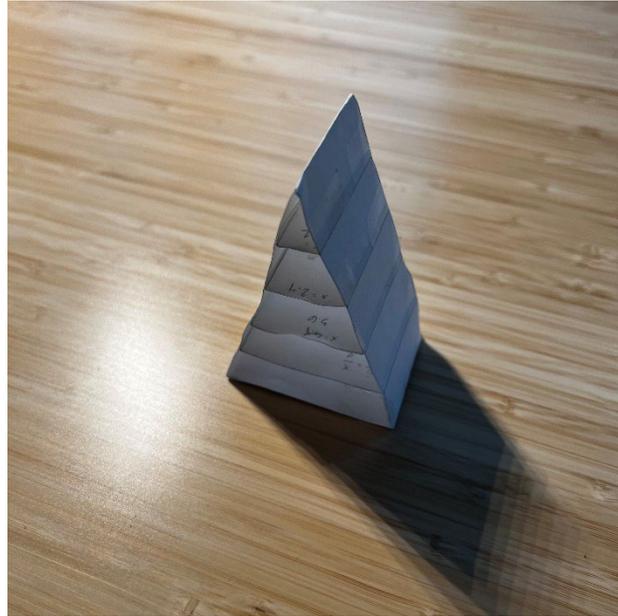


Figure 2.4: Showcasing of the paper model designed as a proof-of-concept for the project. Based on the Fin Ray Effect.

The model was built out of a standard Din-A4 paper. The design was previously dimensioned to prove the foundation of the project and be easily built as well. It features an acute triangle with the following characteristics (*table 2.1*).

Table 2.1: specifications of the prototype paper model based on the Fin Ray Effect

Component	Measure
Base	60 mm
Side	100 mm
Vertebrae	4 vertebrae ranging from 50mm to 1.3 mm

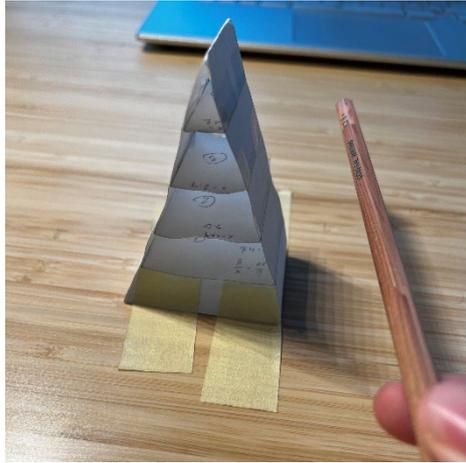


Figure 2.5: Stage 1 of the deformation experiment.

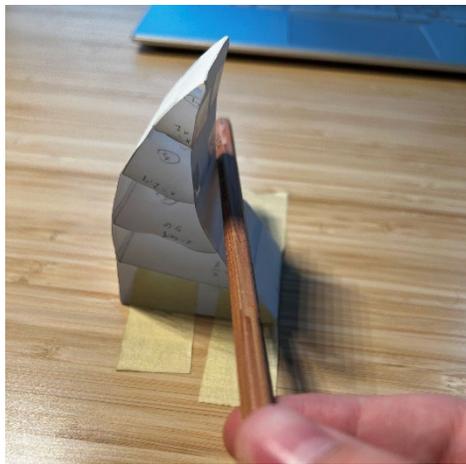


Figure 2.6: Stage 2 of the deformation experiment.

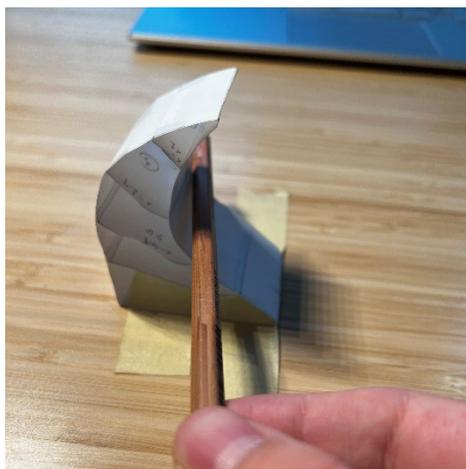


Figure 2.7: Stage 3 of the deformation experiment.

To prove that the Fin-Ray model was capable of behaving like the effect states and to prove its usefulness a couple of experiments took place.

In figures 2.5 to 2.7 feature subsequent stages of a deformation experiment upon the prototype of the finger.

In the first image (figure 2.5) the load still has not been applied and as such the structure lies in its original distribution. To simulate a rigid and fixed base, I needed the use of carpenter's tape.

In the second picture, a not-uniform load is applied on the right surface of the finger. This load is represented by the pencil held, and as expected generates a structural response. This comes in the form of the expected deformation.

In the third picture we can appreciate that upon further pressure being applied, both surfaces comb towards the de side where the load meets the structure.

Another fascinating phenomenon can be seen in this picture. Over further analysis of the vertebrae, a "jamming" between the different vertebrae can be seen. This event will be called "laminar jamming" throughout the paper.

“Laminar jamming” is responsible for the variable stiffness of the structure. Being compliant during the first contact and, with further deformation, improving the grasping capabilities and clasping without transmitting too much force to the object grasped.

In the following picture (*figure 2.7*), “laminar jamming” can be better appreciated when the finger meets a bigger object. In this case a big mug.



Figure 2.7: better look at the phenomenon of “laminar jamming” when the Fin Ray Effect takes place.

2.3 Materials:

The Fin Ray technology was based on the effect of the same name.

As explained before this effect belongs to the field of biomechanics. And during the original study, it was stipulated that the cartilaginous structure was flexible and capable of holding a shape [14].

To conform to the laws of this effect, flexible material with similar properties to cartilaginous tissue and capable of additive manufacturing had to be chosen. To facilitate this task and the individual research I carried out, the department in charge of additive manufacturing at the campus provided information sheets, catalogues, and sources. In parallel, the subject of *Fundamentos de Fabricación* in its Spanish name provided a basis on which to research this technology of additive manufacturing.

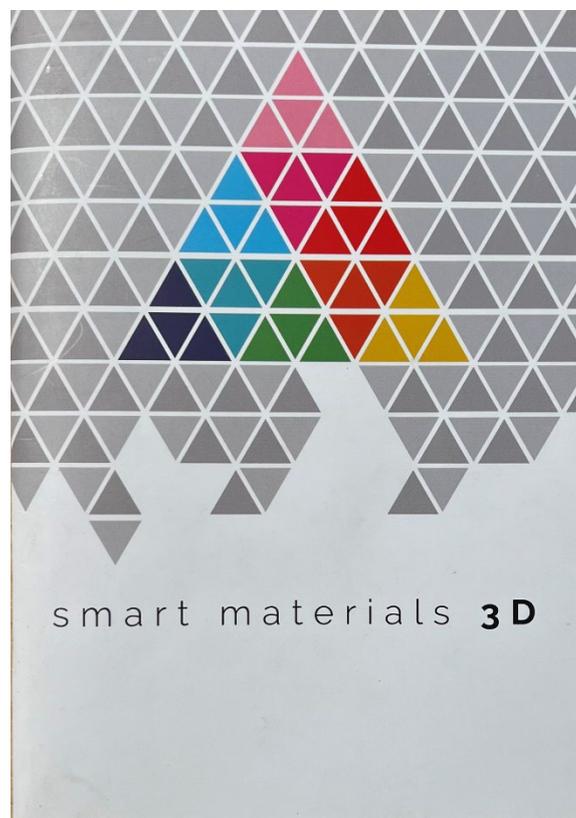


Figure 2.8: example of catalogue given by the department in charge of additive manufacturing at ICAI.

[15]

The key characteristics of the material employed are the following:

- **Flexibility and rigidity:** flexibility is the most important factor in the material choice. The Fin Ray Effect cannot take place without deformation, and we do not desire the material to be soft or the structure to be flaccid. The material must be, thus, flexible but not completely soft. A material will be found that can be deformed but, without interference, keep its original shape or return to it.
- **Printing technology:** this constraint is quite important, being the availability of 3D print components on campus vital. In the labs, the technology available allows for both resin printing (SLA, stereolithography printing) and FDM (Fused Deposition Modelling).
- **Sustainability and quality of the materials:** in this project, we are also adhering to the SDGs we have chosen to defend, and as such a material that poses a bigger operating life and is better for the environment would be encouraged.

In the end, we chose to work with two materials:

Flexible 80 A Resin by FormLabs® (specification sheet in the Annexes)

NinjaFlex® 3D Printing Filament by NinjaTek® (specification sheet in the Annex)

It is important to note that each of these materials belongs to different printing techniques. While the Form Labs Resin belongs to STL technology, the NinjaFlex® is a coil of filament employed in FDM.

Although belonging to different technologies, both materials belong to the family of TPU or share properties with this family of polymers, facilitating, thus, the choice of material and additive manufacturing technology. This point will be further discussed in the following chapters, most prominently in *Chapter 4: Additive Manufacturing*.

Chapter 3: Ansys and CAD

Once the choice of materials has been made, and the scope of the project is established, this chapter, *Chapter 3: Ansys and CAD*, explains the complete step-by-step process of design and simulation for the fingers of the gripper.

3.1 Initial Design Parameters:

When designing the claw, we had to take a couple of important things into account. This project is not a complete design of a robotic arm, just a gripper, and in particular, the gripper's fingers. This project will include prototyping of the fingers, design, and optimization from the basis of the Fin Ray gripper, for our needs.

To start with, we have available a series of components such as external pneumatic actuators and an already available robotic arm, which we will use later, during the final trials of the design. These pneumatic actuators upon which we will apply our finger design are the following:

Both robotic arm heads have been provided by the staff on campus, for the task at hand.

These robot-compatible external actuators belong to the company SCHUNK, which manufactures this family of components.

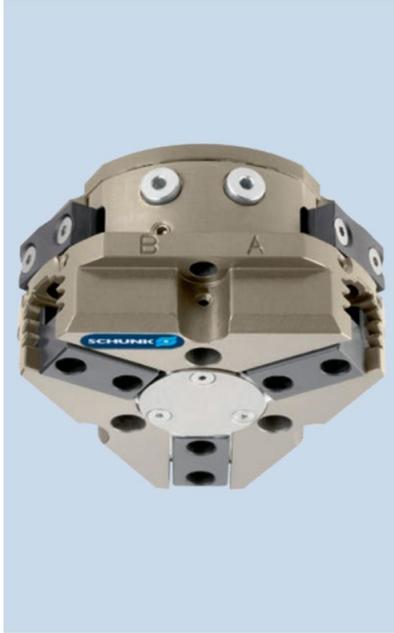


Figure 3.1: Schunk gripper model PZN Plus-64.
Courtesy of [3]

Both actuators are pneumatic, but differ in the finger disposition, being *figure 3.1* a 3-fingered gripper with a radial distribution and finger displacement, and *figure 3.2*, a 2-fingered gripper with a rotative motion to the clasping actuation.

Both actuator heads have similar functions. They are both compatible with the same range of robotic arms, but one shines where the other does not.

For this project, I have chosen to design the robotic head model PRG 46-30.



Figure 3.2: Schunk gripper model PRG 46-30.
Courtesy of [2]

The main reason for this choice lies in the size and versatility of the actuator. The component, present in *figure 3.2*, has a narrower head aligning with the initial objectives to occupy as less space as possible in the operational room. Also, the disposition of two rotative fingers instead of three radial fingers provides a more interesting range of gripping.

Model PRG 46-30's specifications and assembly instructions can be accessed in the annexes of this project. Nevertheless, in *figures 3.4 and 3.5* aspects important to the design of the gripper will be featured.

Gripping force O.D. gripping

0303653 PRG 42-30

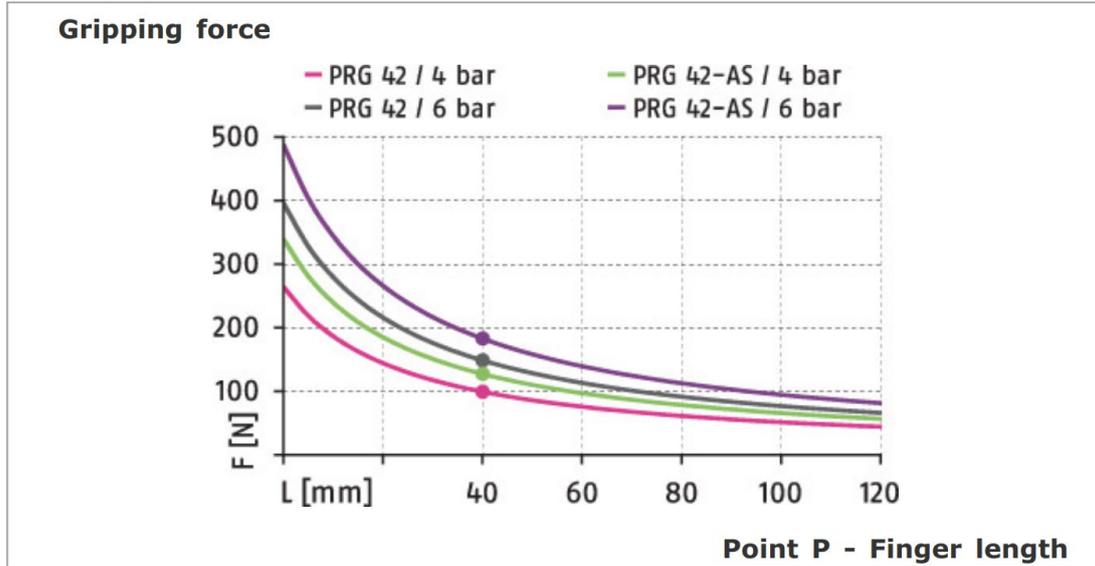


Figure 3.4: graph courtesy of [2], containing the force applied by finger length of each member of the PRG 42-30 family.

Max. permissible inertia J^*

0303653 PRG 42-30

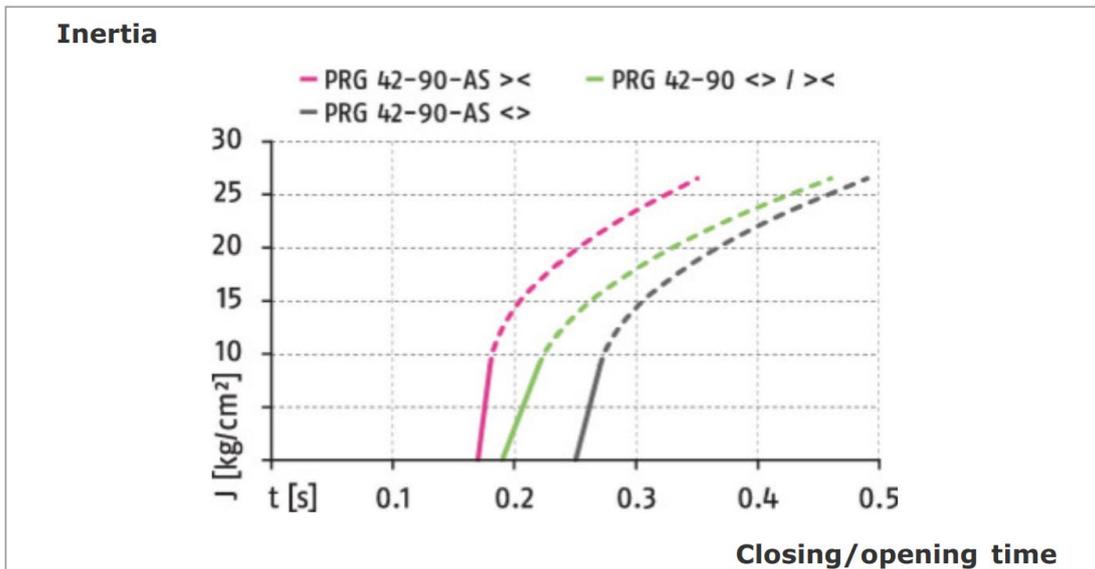


Figure 6.5: graph courtesy of [2], with the limitations in the inertia of each member of the PRG.

These two graphs in *figures 3.4 and 3.5*, represent additional data to account in the design of the gripper. The forces exerted in the furthest reaches of the fingers must be taken into consideration when designing the gripper, but not all the graph's domain is vital. The maximum permissible finger length is of up to 40 mm, according to the specifications available in the manufacturer's webpage, [2] as well as in the *Assembly and Operating Manual* (Annexes). This technical data is gathered in *table 3.1*.

Table 3.1: table of technical data from the gripper SCHUNK series PRG 26-30, courtesy of [2]

ID	0303651
Closing force (with finger lengths of 0 mm) [N]	137
Opening angle per jaw [°]	30
Closed angle per jaw [°]	3
Closing moment [Nm]	2
Weight [kg]	0.13
Recommended workpiece weight [kg]	0.3
Fluid consumption double stroke [cm³]	6.5
Min. operating pressure [bar]	2
Max. operating pressure [bar]	8
Nominal operating pressure [bar]	6
Closing time [s]	0.06
Opening time [s]	0.06
Max. Permissible finger length [mm]	40

Max. Permissible mass moment of inertia per chuck jaw [kgcm²]	0.86
IP Protection class	20
Min. ambient temperature [°C]	5
Max. Ambient temperature [°C]	90
Repeat accuracy [mm]	0.05
Length X [mm]	26
Width Y [mm]	22
Height Z [mm]	76
Moment Mx max. [Nm]	3
Moment Mz max. [Nm]	1
Max. Force axial Fz max. [N]	140

3.2 Prototyping in CAD:

Once we have established the restraints placed on design, characterizing the design in a CAD environment is the next logical step.

(From this section and until the end of this paper, work will be done in digital platforms, and as such at the beginning of each section a table will show the software employed and the versions and distributions at work.)

Table 3.2: specifications of the software employed in Chapter 3.2: Prototyping in CAD

Software name	Use	Version	Platform
SOLIDWORKS 2021 SP03	3D CAD design and prototyping	29.3.0.59	Windows 11 2022, 64-bit version
Procreate	Diagram design	v. 5.2.6	iPad OS 15.4.1

The first design was a 3D representation of the same structure that was built in the initial model. A basic acute-triangled-shaped FinRay finger. It featured the same number of vertebrae than the physical model.

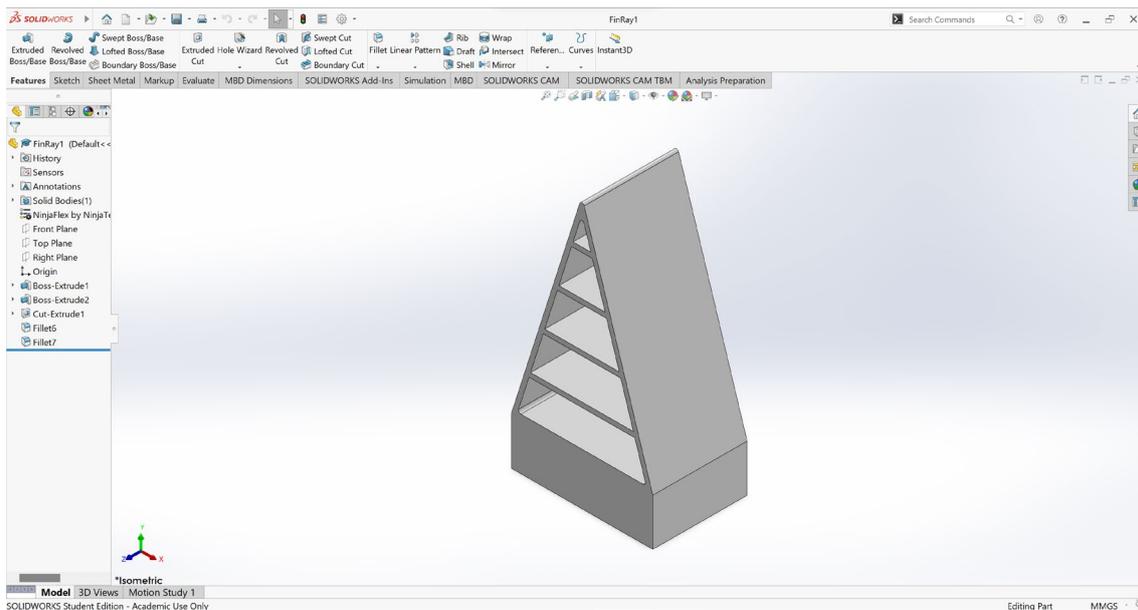


Figure 3.6: snapshot of the CAD creation process. First 3D representation of the prototype. Source: SOLIDWORKS 2021 SP03

In figure 3.6, these characteristics can be better appreciated as well as the origin of a base starts to be seen below the FinRay structure. Although the design seemed promising, a key feature was noticed in the relationship between the original FinRay shape and the way the actuation behaves on our robot-compatible head.

The diagram in *figure 3.7*, represents the theoretical loads exerted on the surface of a convex object upon first contact with the gripper.

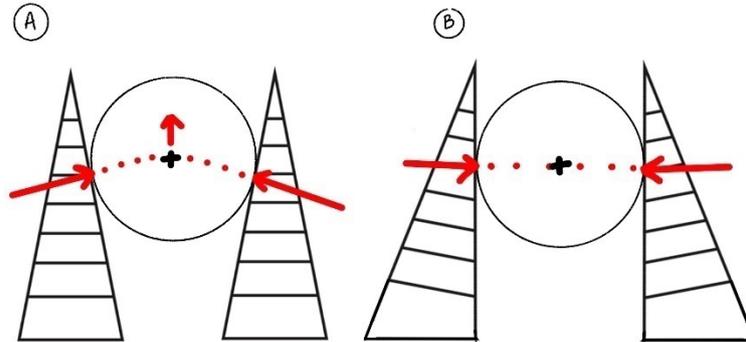


Figure 3.7: diagram showing 2 potential architectures for a FinRay design, and the forces exerted on the initial contact. On side A, the classical acute triangle structure. On side B, the new rectangular triangle distribution. Source: Procreate

On distribution A, the vectorial sum of the theoretical forces exerted presents a component that does not get annulled and pushes the object outside the grasp of the fingers. One could assume that the passive adaptation this gripper is so famous for shall play a role in favour of capturing the object. Even though this phenomenon plays a part, the bigger the graspable object the more probable that it will slip.

On distribution B, on the opposite, the loads cancel by being completely perpendicular and coaxial forces. The only downside is the fact that we are deviating away from the original disposition of the FinRay structure into not so compliant structures.

To trump this probable lack of passive adaptation, experimentation will take place analysing the phenomenon of “layer jamming”. Following additional theoretical studies published by Whitney Crooks and her team members at Tufts University, [1], and analysing the behaviour of our prototype paper model, “layer jamming” effect on the gripping ability can depend upon three characteristics: the quantity of vertebrae per finger,

the inclination of this vertebrae from the horizontal plane of the base, and in some cases were it exists, the progressive variation of this angled structures.

To test the effect of this theories, we have designed different 3D CAD structures to probe on a testbench in Ansys.

For this testing, we have built a group of 4 additional structures, aside from the original CAD explained on *figure 3.6*.

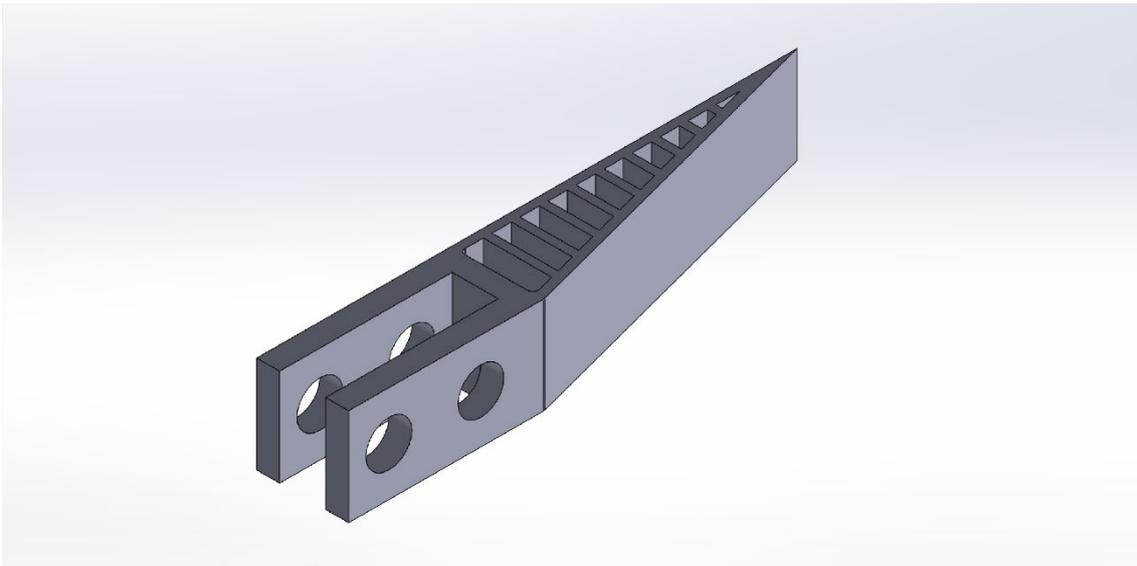


Figure 3.8: CAD representation of the finger prototype “horizontal” with 9 vertebrae in a horizontal distribution. Source: SOLIDWORKS 2021 SP03

Figure 3.8 features the immediate first prototype of the finger, shaped in the rectangular triangle disposition that has been discussed. The vertebrae are parallel to the base of the finger and completely perpendicular, as well, to the vertical side of the triangle. These vertebrae distribution mimics the original FinRay.

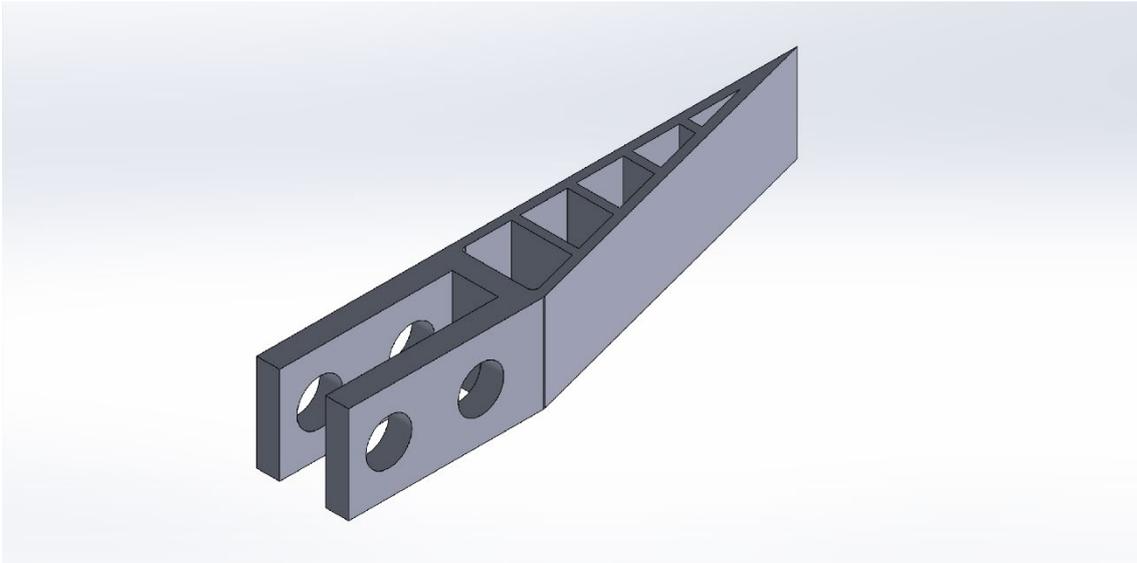


Figure 3.9: CAD representation of the finger prototype “horizontal_4v” with 4 vertebrae in a horizontal distribution. Source: SOLIDWORKS 2021 SP03

Figure 3.8 will serve as the base reference and control element for all the tests to follow. We will come back from every deviation of this design, to *figure 3.8’s* results for comparison.

In *figure 3.9*, the first of the mentioned deviations is shown when the quantity of vertebrae is changed from 9 to 4. With this prototype (which during the experiments we have called *horizontal_4v*, in contrast to *figure 3.8’s* “call name” *horizontal*) the resulting change in passive adaptation, when changing vertebrae, will be studied.

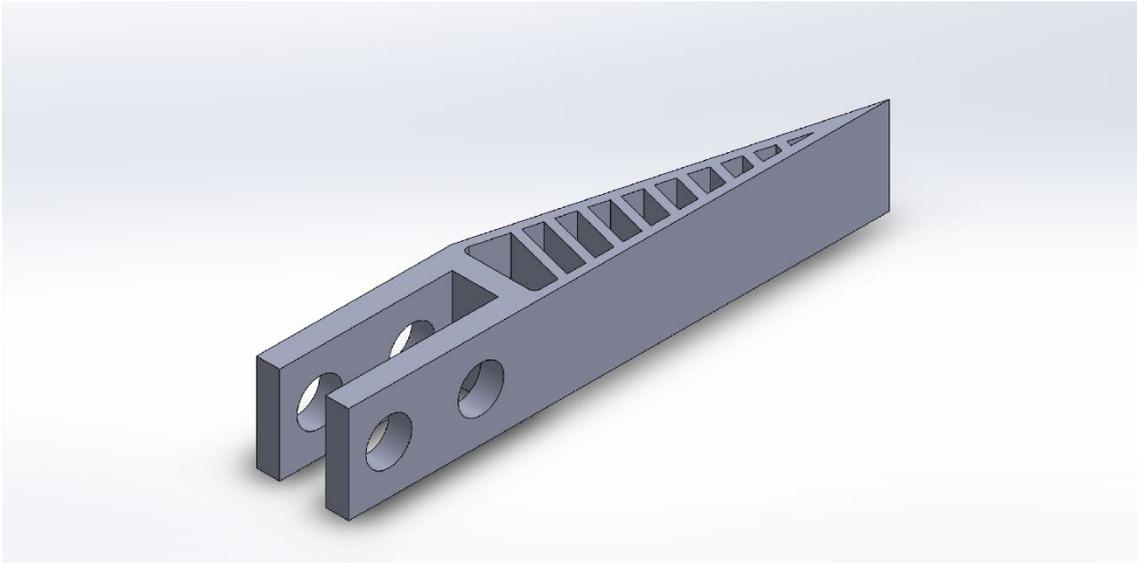


Figure 3.10: CAD representation of the finger prototype “angular” with 9 vertebrae in an angular distribution, with 15°. Source: SOLIDWORKS 2021 SP03

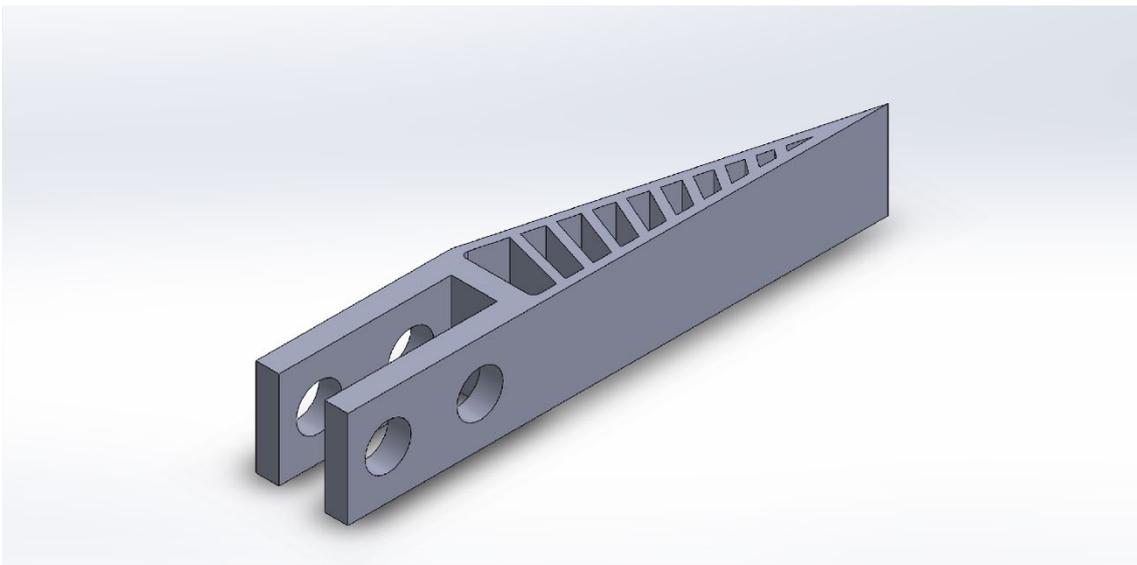


Figure 3.11: CAD representation of the finger prototype “progressive” with 9 vertebrae in an angular distribution with a variation in angle between them of 3°. Source: SOLIDWORKS 2021 SP03

Figure 3.11 and 3.10’s designs follow a similar pattern than *horizontal_4v*’s. Both being variations of *horizontal*. *Angular* (figure 3.10) and *progressive* (figure 3.11) will test the effect in adaptation of angular variation on the vertebrae and progressive angular variation in between the vertebrae respectively. The base angle, prevalent in all *angular* and the first vertebrae in *progressive*, corresponds to 15°. While, only in *progressive*, vertebrae variate in 3° from the previous ligament.

These angle variations and angle values were not chosen arbitrarily, and simply were chosen to better fit the vertebrae inside the structure. As a base value, 15° is considered a significant enough value to show a difference in the simulation results from 0°. And a differential variation between vertebrae of 3° amounts to a total final angle in the last vertebrae of near below 45°, which we will state to be our maximum permissible angle.

(In the annexes, the blueprints for all these prototypes are available. “Horizontal”, “horizontal_4v”, “angular” and “progressive”, as well as future designs and redesigns.)

3.3 Creating the Ansys workbench and preparing the tests:

To determine the behaviour and conditions which a structure suffers under any load we need to analyse how the load spreads through the structure. In this case, we are presented with a flexible material that cannot be analysed with a simple mechanical load study. For this purpose, we are going to simulate a Finite Element Analysis in the digital environment of Ansys.

A Finite Element Analysis, FEA, is according to Autodesk: “a computerized method which aims to predict how a real-world object reacts to real-world forces, vibration, heat, and many other physical effects. FEA shows whether a product will break, wear out, or work the way it was designed...” - [16]

A FEA uses the Finite Element Method to predict these behaviours. FEM is a method for solving partial differential equations and in this case, it is used to solve boundary problems in each node, being each of these nodes a discretization of the space a component occupies.

Table 3.3: Specifications of the software employed in Chapter 3.3: Creating Ansys testbench and simulations.

Software name	Use	Version	Platform
ANSYS Workbench	Testbench design, execution and managing.	2022 R1	Windows 11 2022, 64-bit version
ANSYS Mechanical	Finite Element Analysis and solution generation		
ANSYS SpaceClaim	3D design and organization.		

Ansys not only offers tools for FEA but also adjusts simulation elements to different types of materials. Thus, it is important for us to create a material library that caters to our material choice in *Chapter 2.3*.

The technical sheets for each material are available on each manufacturer’s webpage, as well as important information that will be useful later during additive manufacturing in *Chapter 4*.

Mechanical Properties			
Tensile Strength, Yield	ASTM D638	580 psi	4 Mpa
Tensile Strength, Ultimate	ASTM D638	3,700 psi	26 Mpa
Tensile Modulus	ASTM D638	1,800 psi	12 Mpa
Elongation at Yield	ASTM D638	65%	65%
Elongation at Break	ASTM D638	660%	660%
Toughness (integrated stress-strain curve; calculated stress x strain)	ASTM D638	12,000 in·lbF/in ³	82.7 m*N/m ³ x10 ⁶
Hardness	ASTM D2240	85 Shore A	85 Shore A
Impact Strength (notched Izod, 23C)	ASTM D256	2.0 ft.lbf/in ²	4.2 kJ/m ²
Abrasion Resistance (mass loss, 10,000 cycles)	ASTM D4060	0.08 g	0.08 g

Figure 3.12: Section from the Technical Specifications for the NinjaFlex® 3D Printing Filament, mechanical properties. Courtesy of: NinjaTek. Complete specifications on the annexes.

	MÉTRICO ¹		IMPERIAL ¹		MÉTODO
	No poscurada	Poscurada ²	No poscurada	Poscurada ²	
Propiedades mecánicas					
Resistencia a la rotura por tracción ³	3,7 MPa	8,9 MPa	539 psi	1290 psi	ASTM D 412-06 (A)
Esfuerzo de alargamiento al 50 %	1,5 MPa	3,1 MPa	218 psi	433 psi	ASTM D 412-06 (A)
Esfuerzo de alargamiento al 100 %	3,5 MPa	6,3 MPa	510 psi	909 psi	ASTM D 412-06 (A)
Alargamiento de rotura	100 %	120 %	100 %	120 %	ASTM D 412-06 (A)
Dureza Shore	70A	80A	70A	80A	ASTM 2240
Deformación permanente por compresión (23 °C durante 22 horas)	No sometida a ensayo	3 %	No sometida a ensayo	3 %	ASTM D 624-00
Deformación permanente por compresión (70 °C durante 22 horas)	No sometida a ensayo	5 %	No sometida a ensayo	5 %	ASTM D 395-03 (B)
Resistencia al desgarro ⁴	11 kN/m	24 kN/m	61 lbf/in	137 lbf/in	ASTM D 395-03 (B)
Fatiga de flexión Ross a 23 °C	No sometida a ensayo	>200 000 ciclos	No sometida a ensayo	>200 000 ciclos	ASTM D1052, (IZOD), flexión de 60°, 100 ciclos/minuto
Fatiga de flexión Ross a -10 °C	No sometida a ensayo	>50 000 ciclos	No sometida a ensayo	>50 000 ciclos	ASTM D1052, (IZOD), flexión de 60°, 100 ciclos/minuto
Resiliencia Bayshore	No sometida a ensayo	28 %	No sometida a ensayo	28 %	ASTM D2632

Figure 3.13: Section from the technical specifications for Flexible 80A Resin. Courtesy of: FormLabs. Complete specifications on the annexes

To create a library, we must first create a workbench. The tool called *Engineering Data* provides a library full of materials ready to simulate such as Structural Steel as shown in *figure 3.15*. Since we are going to do a mechanical analysis, the creation of a *Static Structural* testbench is vital.

A *Static Structural* study is one of the many testbench options available in Ansys. In *figure 3.14*, it is possible to see the workbench, with the all the tests designed in this project. Blocks B, D, H, F and G, represent the testbenches created with the tool *Static Structural*. Blocks A, C, E, G and I, hold the geometry of each testbench in the distribution present in *figure 3.14*. All *Static Structural* blocks present 6 cells:

- Cell 2 in each testbench is called *Engineering Data*. In *Engineering Data*, the properties of each material are stored in a database-like format as shown in *figure 3.15*. Also, the ability to create our own library and export it, is available. Also, in *figure 3.15* it is possible to see the properties assigned to one of our materials, and the source (our library) where it comes from.

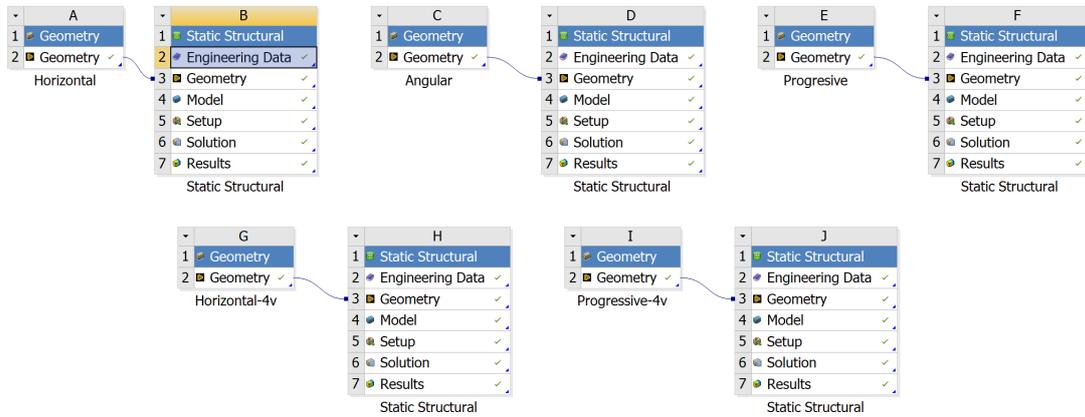


Figure 3.14: Complete schematics of the workbench designed in Ansys for this project. Courtesy of: ANSYS Workbench.

A		R	C	D	F
1	Contents of Engineering Data			Source	Description
2	Material				
3	NINJAFLEX			C:\Users\quint\OneDrive\Documents\ICAI\Alber	NinjaFlex by Ninjatek
4	Structural Steel			General_Materials.xml	Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material				

A		R	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Isotropic Elasticity		
4	Derive from	Young's Modulus and...	
5	Young's Modulus	1.2E+07	Pa
6	Poisson's Ratio	0.45	
7	Bulk Modulus	4E+07	Pa
8	Shear Modulus	4.1379E+06	Pa

Figure 3.15: Picture taken from the material library interface available in Engineering Data. Courtesy of: ANSYS Workbench

- Cell 3 corresponds to the geometry. This geometry can be imported from other instances of CAD software or can be created directly in ANSYS SpaceClaim, which is Ansys own proprietary CAD software. In this case prototype CAD models were already created in SOLIDWORKS, but due to incompatibilities between the latest version of CAD and Ansys, they would have to be imported first into SpaceClaim. Also, the creation of a cylindrical model reminiscent of a test tube was needed to test the fingers in the most realistic way possible. This probe will take the properties of the standard material: Structural Steel.
- Cells 4, 5, 6 and 7, all have the same purpose. From ANSYS Workbench, these cells execute ANSYS Mechanical, to read the geometry, state the forces, loads and other phenomenon, and state the output of the experiments. These will be further explained down the line.

Once the *geometry* for the experiment has been established in each of the testbenches, in the *model* section (cell 4), the displacement of the probe and the variables to measure in the experiment are assigned. As you can see in the following *figure 3.16*, it is important that the distancing of the steel cylinder used as probe from the finger, and the position of it be kept constant in all testbenches. This will grant the certainty to compare the results among each other.

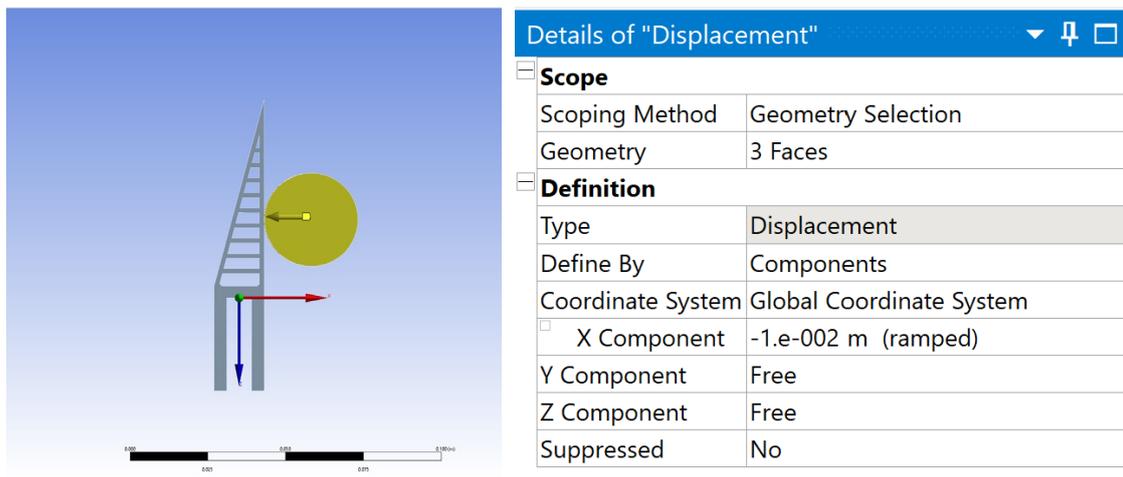


Figure 3.16: probe and finger ("horizontal") geometry distribution and displacement data for the probe.

Source: ANSYS Mechanical

Due to the original distribution of the geometry in the CAD editor and the need to use *SpaceClaim* to create the assembly of probe and finger, the axis system has been inverted.

This event poses no problem and can be easily solved by, instead of assigning a positive value to the displacement of the probe, adding a negative value. In this case -1 cm is the value chosen, as seen in *figure 3.16*.

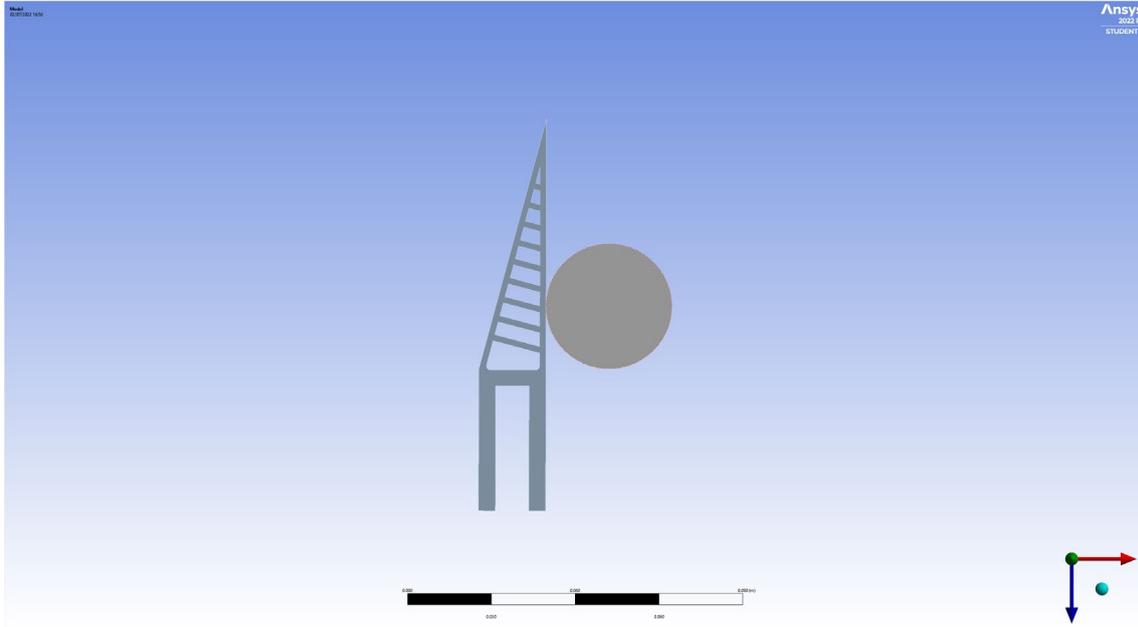


Figure 3.17: finger-probe disposition for the “angular” testbench. Source: ANSYS Mechanical

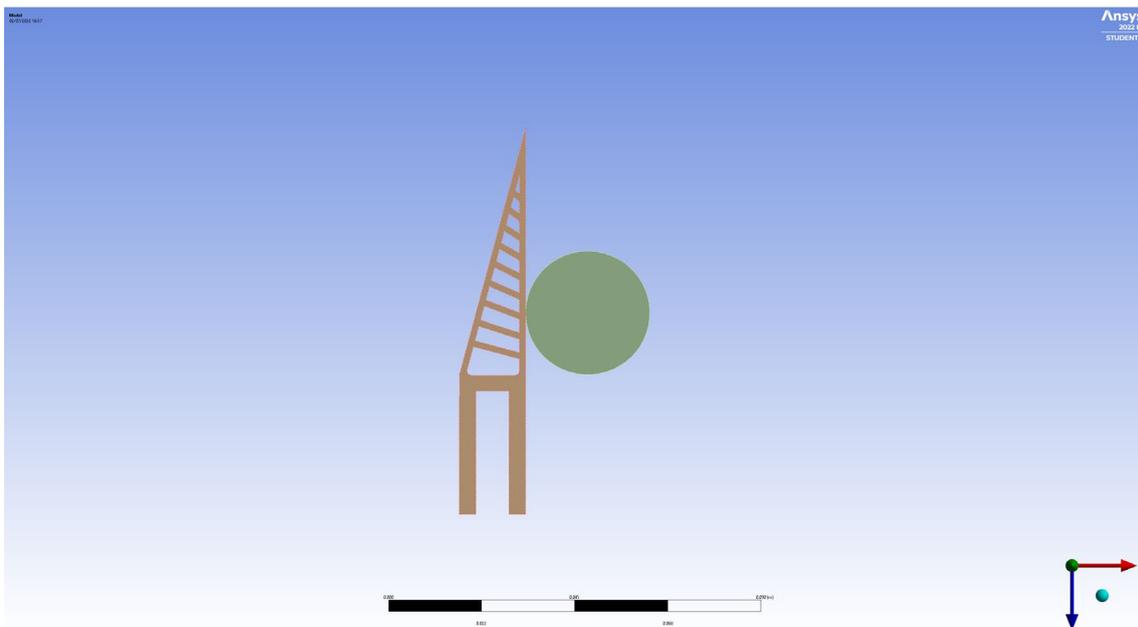


Figure 3.18: finger-probe disposition for the “progressive” testbench. Source: ANSYS Mechanical

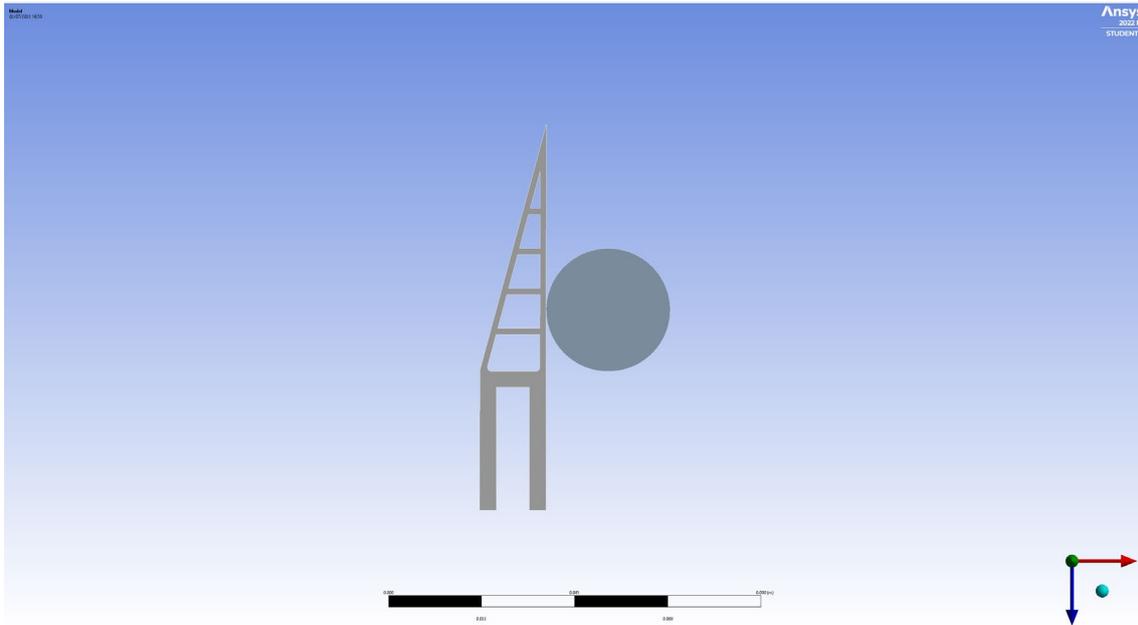
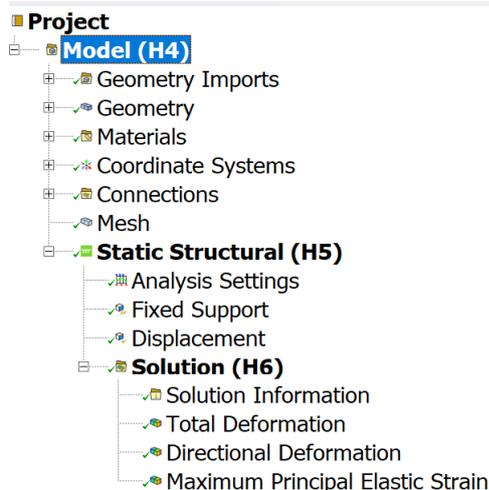


Figure 3.19: finger-probe disposition for the “horizontal_4v” testbench. Source: ANSYS Mechanical

In the *model* section of each testbench apart from the displacement, which is the phenomenon that generates the deformation, it has been stated that we need to also establish the measurements to be taken in the solution. From a wide array of measurements three most significant have been selected: total deformation, directional deformation and maximum principal elastic strain. (Figure 3.20)



Since we are looking for a finger that grants us the highest passive adaptation possible, total deformation is an important parameter to evaluate this property. As well as total deformation, directional deformation in the axis the displacement takes place can help us identify how much

Figure 3.20: Snapshot of the working tree from the “model” cell in a generic in al testbenches. Source: ANSYS Mechanical.

the structure gets displaced by the probe in the direction the probe is moving.

Maximum principal elastic strain, on the other hand, shows us the points in the structure where most strain takes place, important information that will be taken into consideration during the manufacturing stage.

Once all these parameters have been studied, the workbench in *figure 3.14* and all its individual testbenches can be executed.

3.4 Ansys results:

The results from any Ansys testbench come in the format of a written solution with parameters. This solution is extensive and as such will be attached in the Annexes.

Table 3.4: Specifications of the software employed in Chapter 3.4: Ansys results.

Software name	Use	Version	Platform
ANSYS Workbench	Testbench design, execution and managing.	2022 R1	Windows 11 2022, 64-bit version
ANSYS Mechanical	Finite Element Analysis and solution generation		
ANSYS SpaceClaim	3D design and organization.		

The first testbench from the workbench corresponds to the *horizontal* geometry and the probe shown in *figure 3.16*. From that initial testbench, as discussed in previous chapters, a comparison will be made among all results to determine the best passive adaptation.

The best passive adaptation will be measured through the directional displacement variable. Due to this structure’s behaviour, it is expected that the best passive adaptation brings the least directional deformation in the axis of the probe’s displacement. This phenomenon is key to assessing the correct “*gripping deformation*”. A correct *Gripping Deformation* under our standards is such passive adaptation that keeps the point of the finger as close to the original position as possible. This, as a visual interpretation, will be acknowledged when the finger bends like a “claw” to grab the object as it is pressured by it.

Table 3.5: Directional Deformation results for each model. Source: ANSYS Mechanical

Model Codename	Minimum DD [m]	Maximum DD [m]	Average DD [m]
<i>Horizontal</i>	-1.0068e-002	4.6115e-005	-7.2608e-003
<i>Angular</i>	-1.0044e-02	5.8327e-005	-7.3633e-003
<i>Progressive</i>	-1.0074e-002	5.5681e-005	-7.2986e-003
<i>Horizontal_4v</i>	-1.0282e-002	4.0103e-005	-7.0491e-003

Table 3.5 represents the values returned in the console after each simulation, for the individual parameter of *Directional Deformation*. In this table, the biggest deformation values can be perceived to be the ones from experiment *horizontal_4v* followed closely by experiments *horizontal*, *angular* and *progressive*. It can be deduced that *horizontal_4v* answers with much more deformation, to the same load as the other three experiments, but these values can lead to a misunderstanding. Average values do not hold information for the deformation of the whole structure and its behaviours, they can only serve as an indicator of potentially possessing the wanted behaviour.

The following pictures, from *figure 3.21* to *figure 3.24*, represent the deformation when maximum displacement of the probe takes place. We will compare these pictures, with *table 3.5* and asses if our previous affirmation was true and what is the best vertebrae distribution possible.

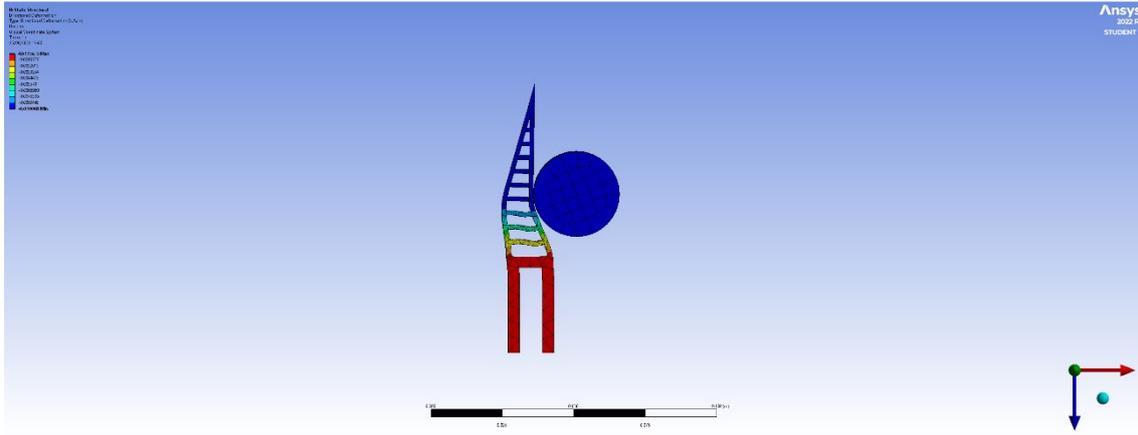


Figure 3.21: Maximum directional deformation on experiment “horizontal”. Source: ANSYS Mechanical

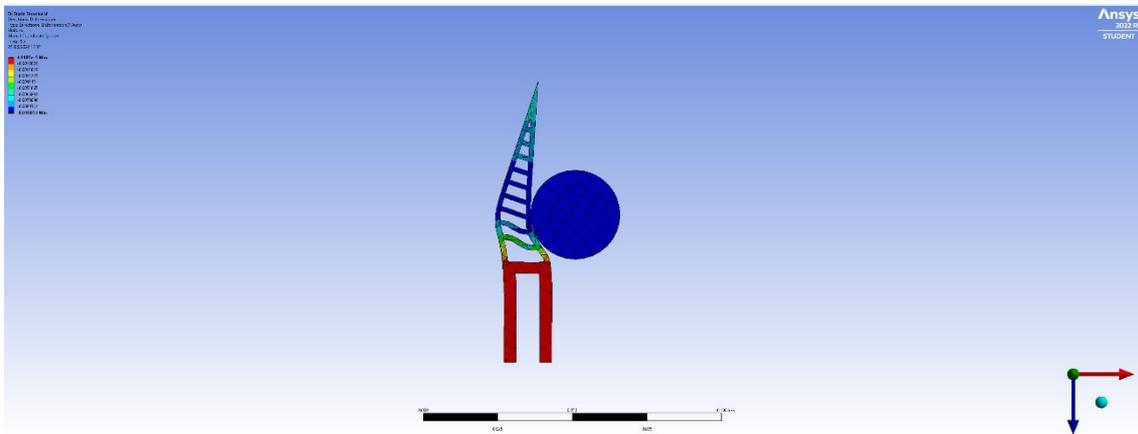


Figure 3.22: Maximum directional deformation on experiment “angular”. Source: ANSYS Mechanical

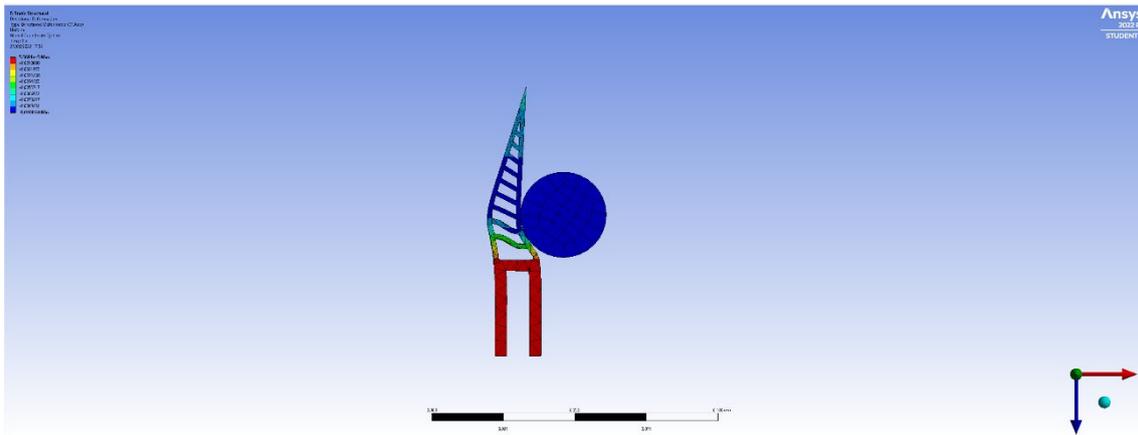


Figure 3.23: Maximum directional deformation on experiment “progressive”. Source: ANSYS Mechanical

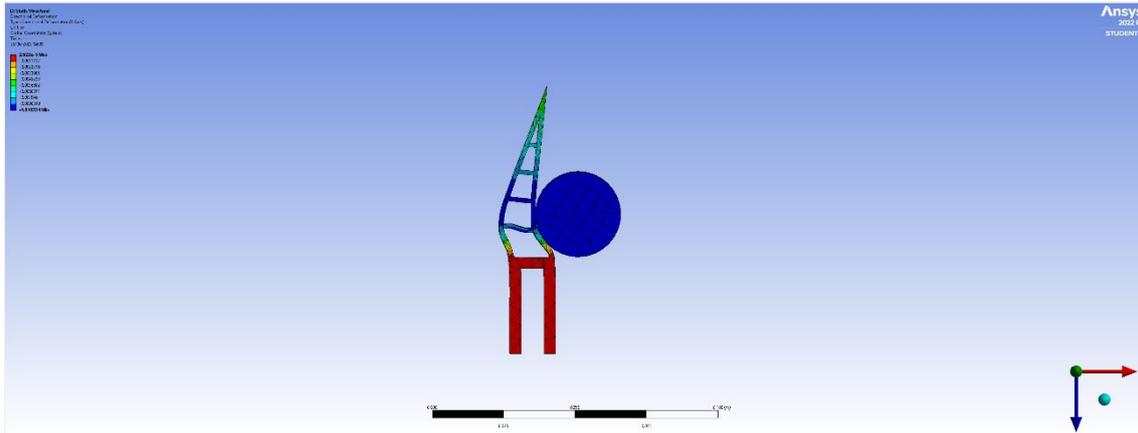


Figure 3.24: Maximum directional deformation on experiment “horizontal_4v”. Source: ANSYS Mechanical.

For reference, in all total deformation experiment, dark blue signifies maximum deformation in the negative value of the horizontal axis. The blue cylindrical probe is dark blue in colour due to it having displaced the maximum distance in the negative from its original point.

From *table 3.5*, we extracted that *horizontal_4v* had the most promising results. When comparing the pictures, it gets proven right, as *figure 3.24* not only adapts its internal structure to the shape of the probe but also flexes the fingertip. The heatmap shown in the picture demonstrates that the fingertip displaces as much as the base and unlike *figure 3.21*, does not follow the displacement of the cylindrical probe.

As a result, we can affirm with certainty that less vertebrae proves more interesting for our experiment at hand. But since we also saw that, experiments *angular* and *progressive*, had better results than simply *horizontal*, another experiment arose in the idea to replicate this result with less vertebrae.

As such the final design for the experiment would consist in a 4-vertebraed claw with a progressive disposition. This experiment in the workbench corresponds to blocks I and J, from *figure 3.14*, codenamed “*progressive_4v*”. This design was thought to be an evolution of *horizontal_4v* and *progressive* and holds the most significant characteristics of both in their design. 4 vertebrae instead of 9, and 6° angle variation (instead of 3°) from an initial angle of 15°.

Table 3.6: Directional Deformation results for the final model. Source: ANSYS Mechanical

Model Codename	Minimum DD [m]	Maximum DD [m]	Average DD [m]
<i>Progressive_4v</i>	-1.0059e-002	2.3661e-005	-6.8589e-003

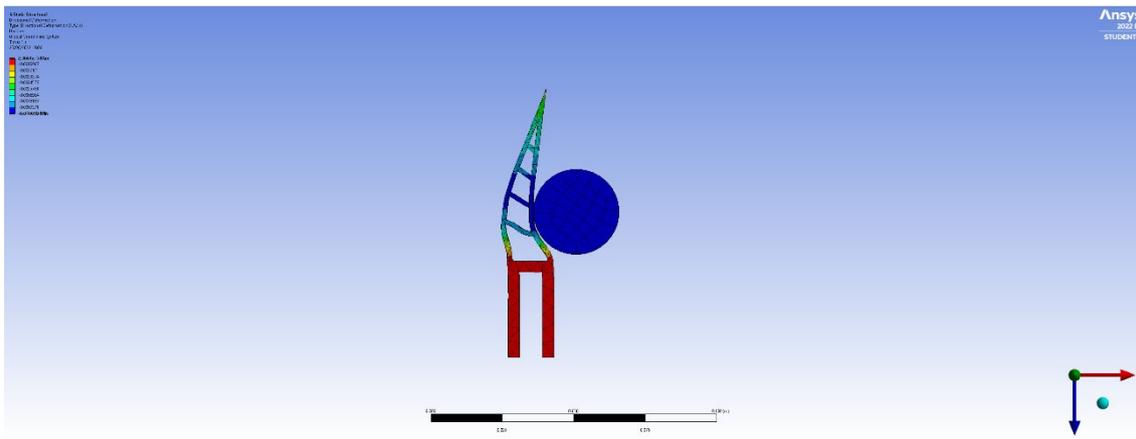


Figure 3.25: Maximum directional deformation on experiment “*progressivel_4v*”. Source: ANSYS Mechanical.

Table 3.6 and figure 3.25, as expected, demonstrate that the last design performs better than each individual original design. With better values overall and more passive adaptation.

This last design will thus be prepared for additive manufacturing and used for trial.

Chapter 4: Additive Manufacturing

This chapter is a short discussion on 3D printing techniques, mainly FDM and SLA, and how the 3D printing of the final piece will be carried out.

The first step is to choose the technology between the discussed FDM (NinjaTek) and STL (FormLabs resin).

4.1 FDM vs SLA:

Fused Deposition Modelling is the most popular and representative of all additive manufacturing technologies. FDM, as a “standard” process consists of a material extrusion method of layered manufacturing. Through a heated nozzle the material gets extruded and deposited in a layer of this material. Multiple layers are stacked over each other to form the volume of the object being printed. While still warm the layers melt and join in one object.

On the other hand, stereolithography or SLA, is a more advanced and less divulged method. SLA is based in the same method of 2D layering to create a 3D volume, but the method of layering is fundamentally different. In this case the material is in a vat where it stays in liquid form. A platform lowers down just to contact the surface and a beam of light excites the liquid resin that starts to transition to a solid structure layer-by-layer on this platform as it lifts.

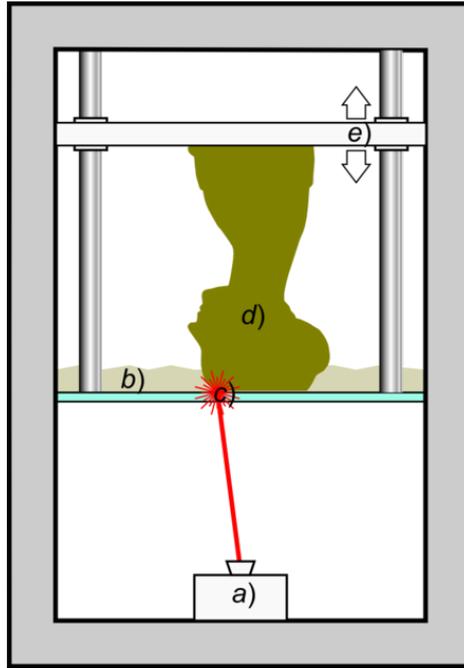


Figure 7.1: Representation of the SLA method. A) beam emitter, B) bottom of the resin tank where the beam focuses and excites the material, C) beam incision point, D) printed object and E) movable platform with 1 degree of freedom. Source: [17]

Both these technologies have their advantages and disadvantages, but SLA was a better suited technology for this purpose. The main reason was the precision granted by SLA against the one granted by FDM. While in the simulations we assumed that the material was going to have isotropic properties, in real life, 3D printed objects do not possess these characteristics. They are anisotropic, as the layers created during manufacturing, even after fusing, prevent the material from maintaining properties in any direction.

SLA will be used for having less layer height due to the laser precision and for having better fused properties after all post-processing is done, in contrast to FDM.

4.2 Preparations, printing, and post-processing:

Table 4.1: Specifications of the software employed in Chapter 4.2: Preparations, printing, and post-processing.

Software name	Use	Version	Platform
SOLIDWORKS 2021 SP03	3D CAD design and prototyping	29.3.0.59	Windows 11 2022, 64-bit version
Preform	Printer Job communication and printer management	3.23.0	

While it is true that SLA is a precise technology there are still some particularities to take into consideration:

- As previously stated in *Chapter 4.1: FDM vs SLA*, SLA technology still presents anisotropic properties, and the layers must be aligned in order to optimize their properties as much as possible.
- A digital model can have almost infinite precision on critical manufacturing areas such as corners, but when translated to real life, it is possible that defect accumulates in these sections of the pieces manufactured. Specially after the CAD archive goes through formatting changes like STL and through the slicer, and finally it is printed.
- Due to post-processing maltreatment the piece can lose some of its final expected qualities and can also accumulate defect.

With the previous points taken into consideration we will adapt the 3D CAD design from *figure 3.25* into a design which can more easily be printed by thee chosen technology.

Also, to print SLA in the manufacturing department on campus, a Form3 printer from FormLabs will be employed. The same printer shown in the following *figure 4.2*.



Figure 4.2: FormLabs printer Form3 working in campus.

The first printing done was executed as a test to take a hold on defects and also to try to perceive if the material employed would behave in real life as it would in simulations. To this end, a raw unprepared CAD of the *horizontal* model was exported as STL and then opened in the Preform interface to print.

As this was the first contact with the technology, the printing settings were not important being the defects, the aspects under the spotlight.

Upon first printing of this prototype trial, the most noticeable were the imperfections developed in the outer perimeter of the object. At the point where the base met the platform there happened instances of capillarity, creating defects on this face. Another printing issue that had to be considered was the lack of precision in the edges of the figures that were not rounded. In *figure 4.3* this can be easily seen.



Figure 4.3: Defect accumulation on the prototype fingertip as seen during post-processing.

To solve these issues two measures were taken:

- During the redesign of *progressive_4v* all edges that were exposed or not inside the structure of the fingertip would be rounded with a radius of 0.5 mm. The only notable exceptions would be the base of the finger that would need to exactly fit the actuators assembly points and some inside edges were rounding would lead to changes in vertebrae function. (Figure 4.4)
- During the Preform preparation to print the main structure of the finger, to be printed, will be separated from the base, as to not generate this capillarity effect. The printing of a previous support structure will be needed. (Figure 4.5)

Going back to the design for *progressive_4v* featured in the previous chapter, the redesign will be featured in the annexes as well as the prototype designs for all experiments.

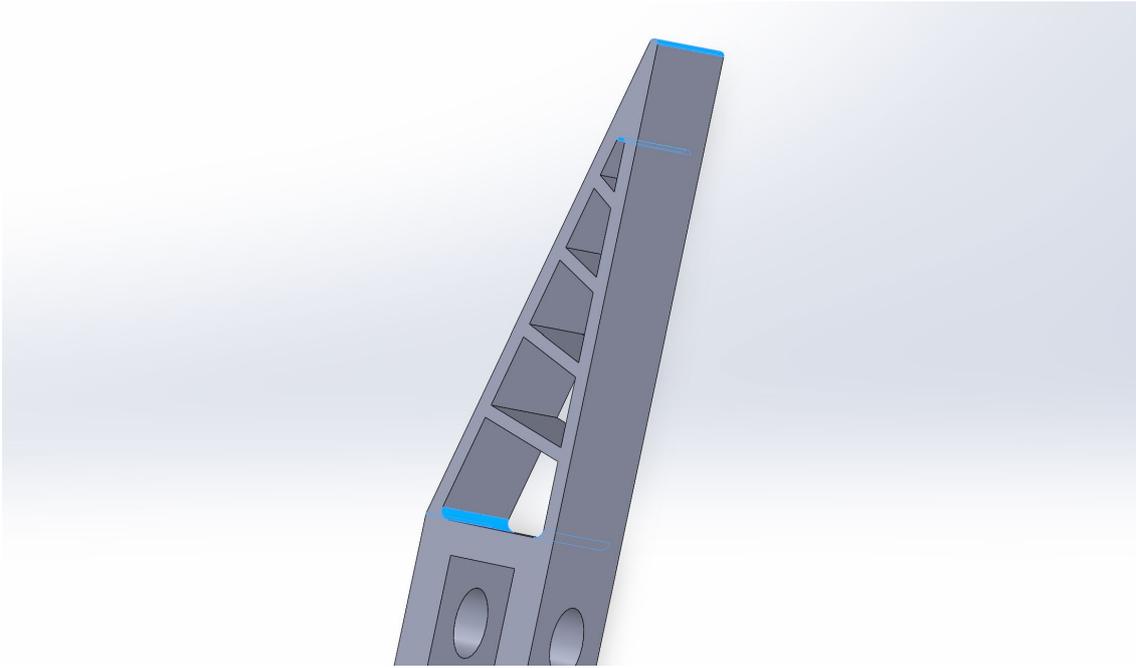
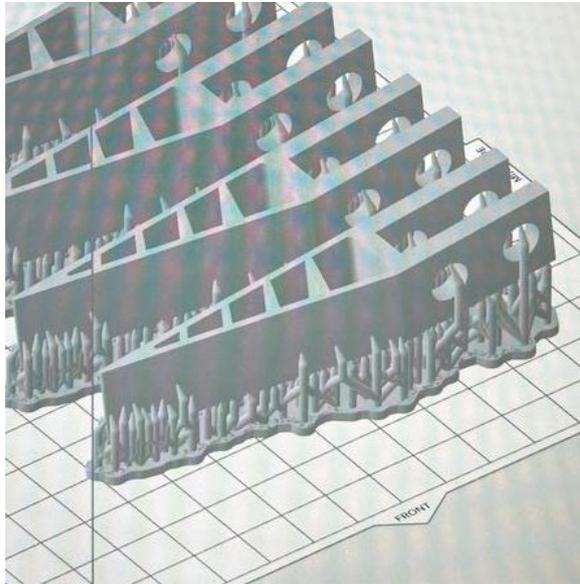


Figure 4.4: Detail of the redesign for “progressive_4v” with the additional rounding highlighted. Source: SOLIDWORKS 2021 SP03



Figures 4.5 and 4.6: (Left) Detail of the Preform printing generated structure. Manually taken as access to this computer is not available. (Right) Detail from the same panel but from the control section where the printing data is shown. Source: Preform.

The printing process took as can be seen in *figure 4.6* a total of 7 hours and 57 minutes, and a volume of 86.26 ml of resin.

Once the printing finished (*figure 4.7*) the first step was to separate the structure beneath the fingers from the base. Alcohol was applied to get rid of the build-up of unused resin around the volume, and with a scrapper the printing was separated. Good praxis states that when the platform is separated from the printing it should be cleaned and stored, risking otherwise dry resin that might interrupt future printings.



Figure 4.7: recently printed 3d volumes. The excess of resin can be seen in the shine of the pieces, and the structure beneath them still attached to the printing base.

After separating the fingers from the holding structure (*figure 4.8*), which is the next step, they will go through an alcohol bath. These repeated alcohol baths have the purpose of removing all the resin in the cracks and crevices of the printing, maximizing the effects of the posterior curation of the piece.

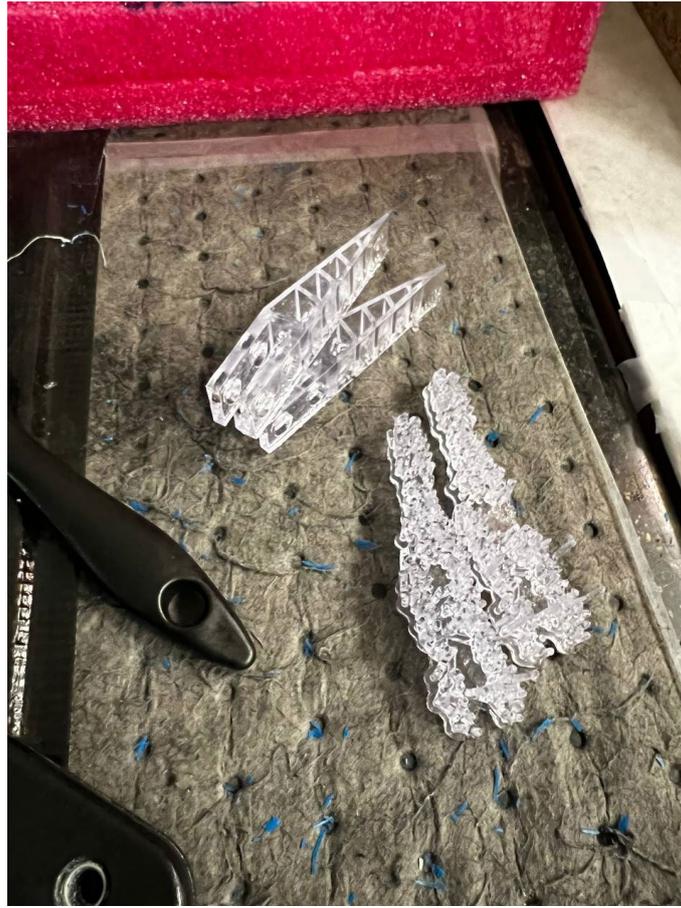


Figure 4.8: Detail of the post-processing. Two of the fingers printed in the batch, from figure 4.7, and their respective structures.

Curation is the most important process during the latest manufacturing stages of the piece. This curation time makes sure the properties of the material stay as optimal as possible and even improves some of them. (The difference from non-curated resin and curated resin properties are in the corresponding annex). Curation is tightly supervised by the material manufacturer and there is a set of instructions for each material curation time available in the webpage of the seller. This curation time and heat values are introduced in an UV curating machine, where the pieces are heated to that temperature and bombarded in UV. Curating machines are also manufactured by the same company as the printers and the material employed, being production streamlined.

The final product presents the best mechanical properties as well as a less glossy-and-sticky finish, more suitable for distribution.

Chapter 5: Final Assembly and Results

In this *Chapter 5*, the last part of the project is explained. The final product of the printing process of the new version of *progressive_4v*, which we will be calling *final_finger*, is assembled in the previously discussed SCHUNK PRG 42-30 and fitted to a robotic ABB arm. (ID: CRB 15000).

5.1 Assembly and trials:

The assembly of the fingers was designed to be intuitive and straightforward, as during the whole design we were provided with a 3D CAD model of the claw that would be employed during the trials.

A set of screws and bolts was used to fit the fingers to the actuator through the 4 screw-holes available in all designs. And the actuator itself was fitted to a robotic ABB arm and connected pneumatically to a pump to provide actuation (*figure 5.1*). To account for legislation and since I am not fitted to operate the robotic arm, the whole process was supervised by the José Antonio Rodríguez Mondejar.

Once the whole claw was properly fitted and all systems online, we devised a set of experiments with objects found in the laboratory to test the limits of the fingers passive adaptation. Going back the classification referenced in *Chapter 1.2: State-of-the-art Questions and Answers* by [5], this actuator was very effective on convex and non-convex and presented failure in the rest of the objects discussed in *figure 1.1*.



Figure 8.1: Final assembly detail of the SCHUNK actuator and the designed “final_finger”. Blue tubes are part of the pneumatic circuit and the SCHUNK actuator is assembled to the claw through Allen head screws.

This being the case, the set of objects would test every aspect and possible points of failure for the claw’s performance. Before showing the pictures with the results, it is important to note that the claws performance was exceptional on the first and second tries of each of the following objects and as such proves that the interpretation and the angle taken when devising the simulations were correct.

Although these results are positive, there are still some improvements upon this project and those will be discussed further in *Chapter 6: Conclusion and Future projects*.

Given that the original purpose and the design main drive in this project was for the claw to be used in lab-like conditions, the first experiment to be performed took place with lab material borrowed on campus.

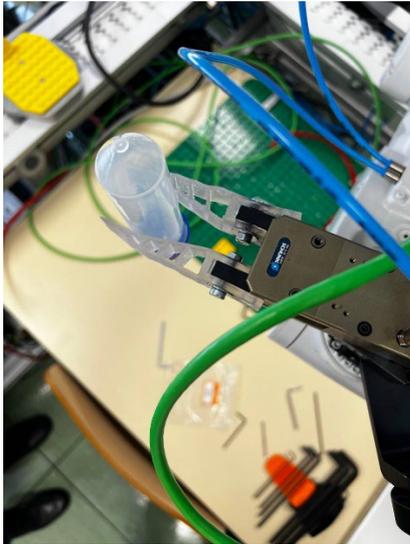


Figure 5.2: Gripping of a convex cylindrical laboratory-grade plastic container. TEST 1

Figure 5.2 features the gripping demonstration of this object where the claw performed as expected grabbing the object with tightness but not enough force to break. Also, successive movement was tested, to force the object to fall and test the grip. The object stood in the grasp.

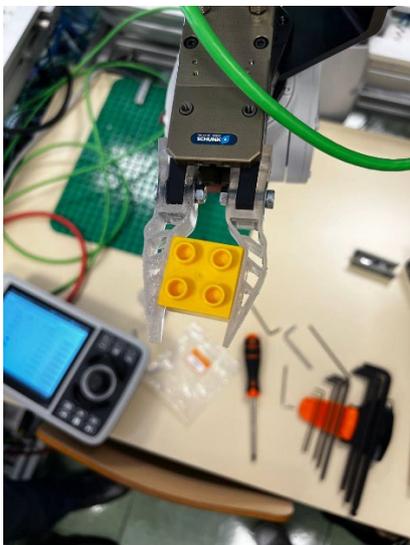


Figure 5.3: Gripping of a convex Lego piece 2x2. Parallel to the ground. TEST 2.1

In *figure 5.3* and *figure 5.4*, we tested the grip against a convex object like the original one but without a cylindrical contact surface. The objective of this test was to assess the deformation of the fingers designed and to test the gripping against irregular objects.

In this second test the idea consists of providing the Lego piece to the claw in different angles and positions. Both pictures demonstrate the easiness with which the claw grasps small objects independent of the shape and contacting surface.

In both pictures as well, the phenomenon of *layer jamming* is clearly visible as the vertebrae deform and the shape of the fingers get distorted to accommodate the Lego piece. This second experiment also brought a different investigation approach to the spotlight. The grip

on the Lego piece in all positions tested was tighter than the grip placed upon the plastic tube.

Upon further observation of the fingers and their behaviour a theory was developed that stated that *layer jamming* contributed more to the gripping force when the fingers deformed the most. This theory will be further proven and explained following the next experiments.

Having done two objects with different surfaces but that presented flat contact areas, the next experiment would test the gripping properties of the claw against a convex object as well, but that presented a heavier weight than the two previous objects and also a non-flat contact surface, providing less contact surface.

For this purpose, a golf ball was chosen.

This golf ball as the third object presented a diameter bigger than the test tube and the largest Lego piece diagonal. Which in the case of rigid claws poses a probe, without accounting for the weight or the lesser contact surface.

As seen in *figure 5.5* the gripping on the ball, similarly in deformation and gripping strength to the plastic test tube, proved satisfactory under both the gripping and movement tests.

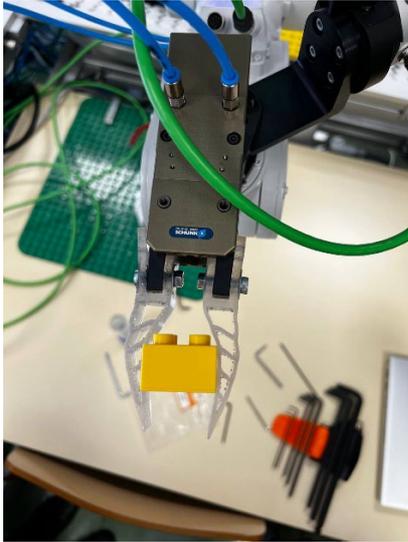


Figure 5.4: Gripping of a convex Lego piece 2x2. Not parallel to the ground. TEST 2.2

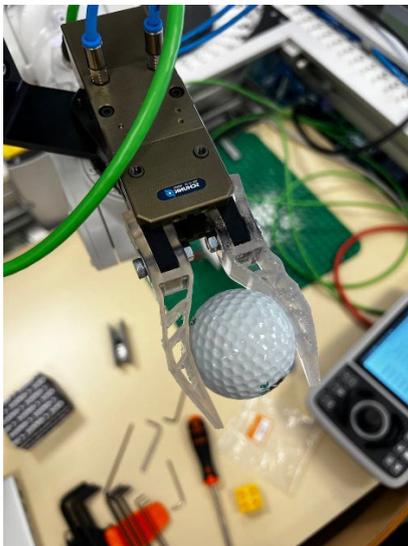


Figure 5.5: Gripping of a convex golf ball, with a textured surface. TEST 3



Figure 5.6: Gripping of a non-convex object in the shape of a pin. TEST 4

Experiment number 4's object was a non-convex shaped pin extracted from upon the laboratory material. This non-convex pieced did not present any problem on both movement and gripping tests as expected.

The most daunting object that can happen to be on laboratories are deformable objects.

While it is true that this technology fails under deformable and flat objects, we wanted to nevertheless try if the improvements made upon the finger in the design phase could break this barrier and provide gripping in not-so-ordinary materials.

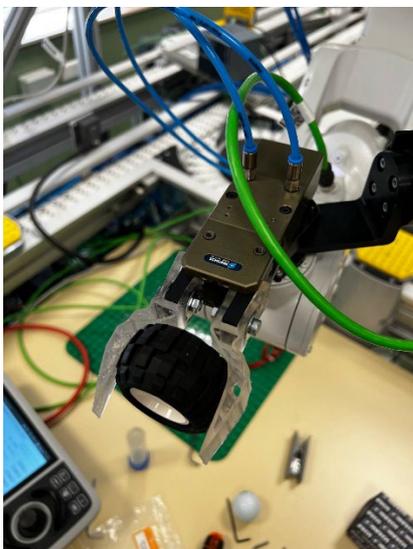


Figure 5.7: Gripping of a deformable Lego tire with a solid internal structure. TEST 5.1

The object to perform test number 4 was a classical Lego tire. The tire itself being of an elastic deformable material provided us with an experiment that could be doubled. Test number 4 would be subdivided in two. While the first part of this test would check the ability of the claw to grasp a deformable tire with a rigid Lego structure inside, the second part would attempt the same but without the reinforced interior.

In *figure 5.7* the successful gripping of the tire with an internal structure is demonstrated. The phenomenon repeated itself were this tire had the tightest grip from all previous experiments.

In this case *layer jamming* I very notable as all vertebrae are completely displaced to make room for the tires surface. *Layer jamming* improves tightness in the grip and not only

adaptation the more the structure deforms itself to account for the grasped object's surface.

Like the *controlled stiffness* discussed in the first chapter, this phenomenon seems to augment the structures rigidity when it happens providing tighter grip.

This phenomenon is important, and a massive discovery as it can ensure that the claw works even on very difficult objects and conditions.

Figure 5.8 shows that the claw also works with this deformable object.



Figure 5.8: Gripping of a deformable Lego tire without an internal rigid structure. TEST 5.2

It is important to note that this object does not represent all deformable objects as most deformable objects do not share these properties, but it could be a potential future experiment to test these limits.

Now that most types of objects have been tested and shown success in the numerous sets of these trials executed, two more tests were run to push the limits of the gripping capability of the claw.

In *figure 5.9* the successful gripping of a screwdriver can be seen that mimics a heavier lab test tube or probe. The gripping was tight but similarly to the plastic test tube from test 1, It did not have the strongest grip. Nevertheless, the screwdriver test passed both the movement and gripping test.

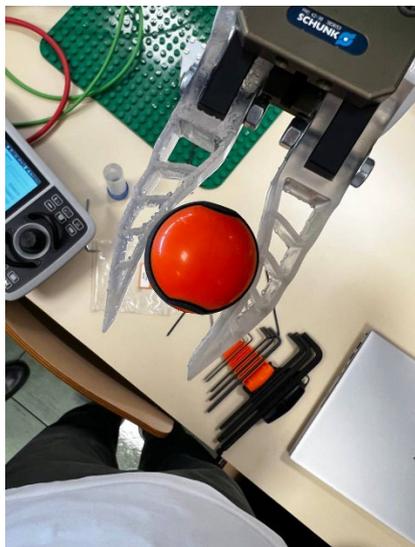


Figure 5.9: Gripping of a heavy convex screwdriver. TEST 6

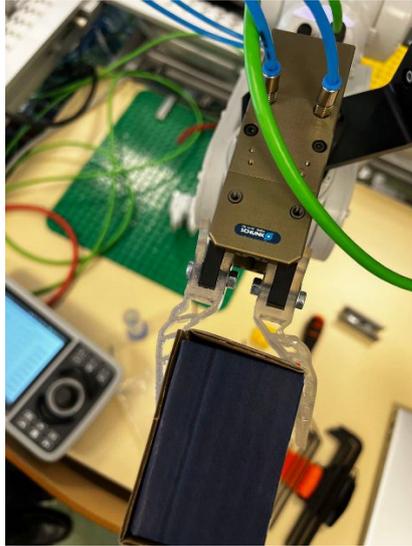


Figure 5.10: Gripping of a heavy box of components. TEST 7

Figure 5.10 shows the last test numbered 7. The last object to be tested was a heavy box of lab parts. A prism-shaped box, this object meant the most trouble to our claw that had most trouble when trying to take a hold of the exterior. Even though the test we run on gripping were successful, the movement test proved there were vibrations on the box. It never fell but felt like the operating limit of the claw. As we did not have another representative object to test a further limit to the claw, we declared the *operating limit* on objects this size, and as you can see on *figure 5.10* objects that surpass even the actuator size.

Chapter 6: Conclusion and Future Projects

As we have seen throughout *Chapter 5: Final Assembly and Results* and during the last tests run on that same chapter, the final optimized design that parted from the FinRay base gripper showed promising results.

Capable on working on the original objective devised for its use and proven to work on even more classes of objects than expected, the design of the gripper can be called a success. The phenomenon of *layer jamming* provides more tightness to the structure the more it deforms easing the grip the more difficult the situation unless the object exceeds the *operating limits* stated at the end of *Chapter 5*.

Despite the results of the project showing the correct execution of the same, through development more experiments and branching of this project came through. Some of these ideas were executed such as the development of the final *progressive_4v*, but some of them were left on the drawing board. These potential future projects are the following:

- Further simulation and exploration of the properties of the structure at hand. *Layer jamming* has been determined on a practical level through tests, but a deeper analysis could lead to more optimal adaptation and gripping.
- More testing of the limits of the current structure, as we only tested if it worked and did those tests on arbitrary objects. A more precise and lengthy test set can be devised and executed to find out the *operating limits* as precisely as possible, and link those with the structure design to be able to know the limits even during the design process.
- Material analysis, we chose this material for environmentally friendly means, and because of the limited material range at our disposition. Since our library of 3D printing materials is limited, the use of a more elastic material with better properties was not possible. In a future design, it might be.

Chapter 7: Economic Analysis

In this *Chapter 7* we will go through a brief analysis of the incurred costs during the project as well as its viability if the aim was to commercialise this technology.

The first thing to be considered is that this project has been a purely prototypical project design-wise. The aim being to prove one technology and manufacturing method as viable, engineering wise. Nevertheless, in *table 7.1* we see the cost of the most prominent technologies and materials employed:

Table 7.1: Most prominent raw cost sources for this project.

FormLabs Printer: Form3+ Basic Package	3499 €	To be amortized within a year's time.
Material: FormLabs	199 €/liter	Prize of a 1 Litter cartridge of material
Manhours	870 €/month	Minimum average salary for an engineer/operator in 2022 according to [18]

In this project each individual finger (from the data in *Chapter 4*) amounts to approximately 21.66 mL of material from each cartridge. Being a cartridge worth 199 €/L, a single finger during this project held a material cost of 4,31 €. Additionally, each batch has a post processing time to be taken into consideration where operator hours come into the picture.

Per post processing session there is a fixed time needed for UV curation of 12 minutes. This value is constant for batches of up to 6 fingers as that is the maximum storage capacity of printer and UV curating vat. The variable time depends on the number of fingers per batch, needing individual cleaning times of 15-20 minutes each. Assuming operator to be kept working in between hours, the cost amounts to 1,2 €/hour of working time.

Thus the total cost of the project would amount to the result of the following equation:

$$\begin{aligned} \text{COST} &= \text{Material Cost} + \text{manhours} * mh_{\text{cost}} = \\ 4.31 \frac{\text{€}}{\text{finger}} * 6 \text{ fingers} &+ (2\text{hours } 10\text{minutes}) * \frac{1.2\text{€}}{\text{hour}} = \\ &= 28.46 \text{ €} \end{aligned}$$

This value of 28,46 €, corresponds to the raw cost of each finger but it is not even a near estimate of the cost this component would have in real production. To approximate this value, we are going to make a series of hypotheses:

- The first hypothesis will be that the FormLabs printer used during this project is a unique buy for it. And thus, its operating time will solely be dedicated to printing these components.
- The second hypothesis consists of the printer being amortized in a year's worth of time. As such all the printer cost (3499 €) will be divided among its working hours.
- The third hypothesis consists of optimized manufacturing. The printer platform and post-processing vats can hold up to 6 fingers in one batch. As such we will calculate the manufacturing in groups of 6 fingers called *batches*.
- Hypothesis number four, lastly, will state that, since printer working time doesn't employ operators time it can work 24 hours. This will be important as energy costs also have to be taken into account.

Taken into the account this information we are going to do a simple proportionality rule from the information in *Chapter 4*, to deduce that a whole batch of 6 fingers would take approximately 14.10 hours total (processing and post-processing).

The next calculation will consider the need to amortize the printers value within one year's time. As 14.10 hours/batch equals to a production value of 1.7 batches per day we get the following:

$$\text{COST PER BATCH (AMORT)} = \frac{\text{Printer COST}}{360 \text{ days} * 1.7 \text{ batches/day}} = 5.71 \text{ €/batch}$$

The cost of manufacturing and fabrication changes a little bit as well:

$$\begin{aligned} \text{COST PER BATCH (FABRI)} &= \text{cartridge COST} * 130 \frac{\text{mL}}{\text{batch}} + \text{manhour COST} * 2\text{h}10\text{m} \\ &+ \text{energy COST} * 11\text{h}56\text{m} * \frac{\text{machine CONSUMPTION}}{30 \frac{\text{days}}{\text{month}} * \frac{24\text{hours}}{\text{day}}} \\ &= 26.31\text{€/batch} \end{aligned}$$

As of July 2022, the current average price of energy has been of 14€/100KWh according to [19]. Since the printer Fomr3+ consumes an average of 18KWh/month [20], we can assume the result to be = 26.31 €/batch.

This grand total of 5.71+28.51 €/batch equal to 34.22 €/batch and 5.7 €/finger.

Since most potential competitors in the market have price ranges around 10-15 € for similar products, this value might be accurate and even give room for potential benefit.

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ANNEXES:

In Order of Apparition along the project

Assembly and Operating Manual

PRG

Pneumatic Radial gripper



Imprint

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Dear Customer,

thank you for trusting our products and our family-owned company, the leading technology supplier of robots and production machines.

Our team is always available to answer any questions on this product and other solutions. Ask us questions and challenge us. We will find a solution!

Best regards,

Your SCHUNK team

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1 General

1.1 About this manual

This manual contains important information for a safe and appropriate use of the product.

This manual is an integral part of the product and must be kept accessible for the personnel at all times.

Before starting work, the personnel must have read and understood this operating manual. Prerequisite for safe working is the observance of all safety instructions in this manual.

Illustrations in this manual are provided for basic understanding and may differ from the actual product design.

In addition to these instructions, the documents listed under [Applicable documents](#) [► 6] are applicable.

1.1.1 Presentation of Warning Labels

To make risks clear, the following signal words and symbols are used for safety notes.



⚠ DANGER

Danger for persons!

Non-observance will inevitably cause irreversible injury or death.



⚠ WARNING

Dangers for persons!

Non-observance can lead to irreversible injury and even death.



⚠ CAUTION

Dangers for persons!

Non-observance can cause minor injuries.

CAUTION

Material damage!

Information about avoiding material damage.

1.1.2 Definition of Terms

The term "product" replaces the product name on the title page in this manual.

1.1.3 Applicable documents

- General terms of business *
- Catalog data sheet of the purchased product *
- Assembly and operating manuals of the accessories *

The documents marked with an asterisk (*) can be downloaded on our homepage schunk.com

1.1.4 Sizes

This operating manual applies to the following sizes:

- PRG 26
- PRG 34
- PRG 42
- PRG 52
- PRG 64
- PRG 80
- PRG 100
- PRG 125

1.1.5 Variants

This operating manual applies to the following variations:

- PRG without gripping force maintenance
- PRG with gripping force maintenance "O.D. gripping" (AS)
- PRG high-temperature (V/HT)

1.2 Warranty

If the product is used as intended, the warranty is valid for 24 months from the ex-works delivery date under the following conditions:

- Observe the specified maintenance and lubrication intervals
- Observe the ambient conditions and operating conditions

Parts touching the workpiece and wear parts are not included in the warranty.

1.3 Scope of delivery

The scope of delivery includes

- Pneumatic Radial gripper PRG in the version ordered
- Assembly and Operating Manual
- Accessory pack

1.3.1 Accessories kit

Content of the accessory pack:

- Centering sleeves (6x)
- from size 80: Centering sleeves (8x)
- O-rings (4x)
- Locking screws (2x)

ID.-No. of the accessory pack

Accessory pack for	ID number
PRG 26	5517554
PRG 26 High-temperature version (HT)	5517555
PRG 34	5517556
PRG 34 High-temperature version (HT)	5517557
PRG 42	5517558
PRG 42 High-temperature version (HT)	5517559
PRG 52	5517560
PRG 52 High-temperature version (HT)	5517561
PRG 64	5517562
PRG 64 High-temperature version (HT)	5517563
PRG 80	5517564
PRG 80 High-temperature version (HT)	5517565
PRG 100	5517566
PRG 100 High-temperature version (HT)	5517567
PRG 125	5517568
PRG 125 High-temperature version (HT)	5517569

1.4 Accessories

A wide range of accessories are available for this product
For information regarding which accessory articles can be used with the corresponding product variants, see catalog data sheet.

1.4.1 Seal kit

ID.-No. of the seal kit

Seal kit for	ID number
PRG 26	5521254
PRG 26 High-temperature version (HT)	5521255
PRG 34	5521256
PRG 34 High-temperature version (HT)	5521257
PRG 42	5521258
PRG 42 High-temperature version (HT)	5521259
PRG 52	5521260
PRG 52 High-temperature version (HT)	5521261
PRG 64	5521262
PRG 64 High-temperature version (HT)	5521263
PRG 80	5521264
PRG 80 High-temperature version (HT)	5521265
PRG 100	5521266
PRG 100 High-temperature version (HT)	5521267
PRG 125	5521268
PRG 125 High-temperature version (HT)	5521269

Contents of the sealing kit, [Drawings](#) [▶ 43].

1.4.2 Mounting kit for proximity switch

ID.-No. of the mounting kit

Mounting kit for	Proximity switch IN 40	Proximity switch IN 80
PRG 26	0303621	0304132
PRG 34	0303622	0304133
PRG 42	030623	0304134
PRG 52	0303624	0304135
PRG 64	0303625	0304136
PRG 80	-	0303626
PRG 100	-	0303627
PRG 125	-	0303628

Contents of the mounting kit [Drawings](#) [▶ 43].

2 Basic safety notes

2.1 Intended use

The product is designed exclusively for gripping and temporarily holding workpieces or objects.

- The product may only be used within the scope of its technical data, [Technical data](#) [▶ 16].
- When implementing and operating components in safety-related parts of the control systems, the basic safety principles in accordance with DIN EN ISO 13849-2 apply. The proven safety principles in accordance with DIN EN ISO 13849-2 also apply to categories 1, 2, 3 and 4.
- The product is intended for installation in a machine/system. The applicable guidelines must be observed and complied with.
- The product is intended for industrial and industry-oriented use.
- Appropriate use of the product includes compliance with all instructions in this manual.

2.2 Not intended use

It is not intended use if the product is used, for example, as a pressing tool, stamping tool, lifting gear, guide for tools, cutting tool, clamping device or a drilling tool.

- Any utilization that exceeds or differs from the appropriate use is regarded as misuse.

2.3 Constructional changes

Implementation of structural changes

By conversions, changes, and reworking, e.g. additional threads, holes, or safety devices can impair the functioning or safety of the product or damage it.

- Structural changes should only be made with the written approval of SCHUNK.

2.4 Spare parts

Use of unauthorized spare parts

Using unauthorized spare parts can endanger personnel and damage the product or cause it to malfunction.

- Use only original spare parts or spares authorized by SCHUNK.

2.5 Gripper fingers

Requirements for the gripper fingers

Stored energy within the product creates the risk of serious injuries and significant property damage.

- Arrange the gripper fingers in a way that the product reaches either the position "open" or "closed" in a de-energized state.
- Only exchange the gripper fingers when no residual energy remains in the product.
- Make sure that the product and the top jaws are a sufficient size for the application.

2.6 Ambient conditions and operating conditions

Required ambient conditions and operating conditions

Incorrect ambient and operating conditions can make the product unsafe, leading to the risk of serious injuries, considerable material damage and/or a significant reduction to the product's life span.

- Make sure that the product is used only in the context of its defined application parameters, [Technical data](#) [► 16].

2.7 Personnel qualification

Inadequate qualifications of the personnel

If the personnel working with the product is not sufficiently qualified, the result may be serious injuries and significant property damage.

- All work may only be performed by qualified personnel.
- Before working with the product, the personnel must have read and understood the complete assembly and operating manual.
- Observe the national safety regulations and rules and general safety instructions.

The following personal qualifications are necessary for the various activities related to the product:

Trained electrician

Due to their technical training, knowledge and experience, trained electricians are able to work on electrical systems, recognize and avoid possible dangers and know the relevant standards and regulations.

Qualified personnel

Due to its technical training, knowledge and experience, qualified personnel is able to perform the delegated tasks, recognize and avoid possible dangers and knows the relevant standards and regulations.

Instructed person

Instructed persons were instructed by the operator about the delegated tasks and possible dangers due to improper behaviour.

Service personnel of the manufacturer

Due to its technical training, knowledge and experience, service personnel of the manufacturer is able to perform the delegated tasks and to recognize and avoid possible dangers.

2.8 Personal protective equipment

Use of personal protective equipment

Personal protective equipment serves to protect staff against danger which may interfere with their health or safety at work.

- When working on and with the product, observe the occupational health and safety regulations and wear the required personal protective equipment.
- Observe the valid safety and accident prevention regulations.
- Wear protective gloves to guard against sharp edges and corners or rough surfaces.
- Wear heat-resistant protective gloves when handling hot surfaces.
- Wear protective gloves and safety goggles when handling hazardous substances.
- Wear close-fitting protective clothing and also wear long hair in a hairnet when dealing with moving components.

2.9 Notes on safe operation

Incorrect handling of the personnel

Incorrect handling and assembly may impair the product's safety and cause serious injuries and considerable material damage.

- Avoid any manner of working that may interfere with the function and operational safety of the product.
- Use the product as intended.
- Observe the safety notes and assembly instructions.
- Do not expose the product to any corrosive media. This does not apply to products that are designed for special environments.
- Eliminate any malfunction immediately.
- Observe the care and maintenance instructions.
- Observe the current safety, accident prevention and environmental protection regulations regarding the product's application field.

2.10 Transport

Handling during transport

Incorrect handling during transport may impair the product's safety and cause serious injuries and considerable material damage.

- When handling heavy weights, use lifting equipment to lift the product and transport it by appropriate means.
- Secure the product against falling during transportation and handling.
- Stand clear of suspended loads.

2.11 Malfunctions

Behavior in case of malfunctions

- Immediately remove the product from operation and report the malfunction to the responsible departments/persons.
- Order appropriately trained personnel to rectify the malfunction.
- Do not recommission the product until the malfunction has been rectified.
- Test the product after a malfunction to establish whether it still functions properly and no increased risks have arisen.

2.12 Disposal

Handling of disposal

The incorrect handling of disposal may impair the product's safety and cause serious injuries as well as considerable material and environmental harm.

- Follow local regulations on dispatching product components for recycling or proper disposal.

2.13 Fundamental dangers

General

- Observe safety distances.
- Never deactivate safety devices.
- Before commissioning the product, take appropriate protective measures to secure the danger zone.
- Disconnect power sources before installation, modification, maintenance, or calibration. Ensure that no residual energy remains in the system.
- If the energy supply is connected, do not move any parts by hand.
- Do not reach into the open mechanism or movement area of the product during operation.

2.13.1 Protection during handling and assembly

Incorrect handling and assembly

Incorrect handling and assembly may impair the product's safety and cause serious injuries and considerable material damage.

- Have all work carried out by appropriately qualified personnel.
- For all work, secure the product against accidental operation.
- Observe the relevant accident prevention rules.
- Use suitable assembly and transport equipment and take precautions to prevent jamming and crushing.

Incorrect lifting of loads

Falling loads may cause serious injuries and even death.

- Stand clear of suspended loads and do not step into their swiveling range.
- Never move loads without supervision.
- Do not leave suspended loads unattended.

2.13.2 Protection during commissioning and operation

Falling or violently ejected components

Falling and violently ejected components can cause serious injuries and even death.

- Take appropriate protective measures to secure the danger zone.
- Never step into the danger zone during operation.

2.13.3 Protection against dangerous movements

Unexpected movements

Residual energy in the system may cause serious injuries while working with the product.

- Switch off the energy supply, ensure that no residual energy remains and secure against inadvertent reactivation.
- Never rely solely on the response of the monitoring function to avert danger. Until the installed monitors become effective, it must be assumed that the drive movement is faulty, with its action being dependent on the control unit and the current operating condition of the drive. Perform maintenance work, modifications, and attachments outside the danger zone defined by the movement range.
- To avoid accidents and/or material damage, human access to the movement range of the machine must be restricted. Limit/prevent accidental access for people in this area due through technical safety measures. The protective cover and protective fence must be rigid enough to withstand the maximum possible movement energy. EMERGENCY STOP switches must be easily and quickly accessible. Before starting up the machine or automated system, check that the EMERGENCY STOP system is working. Prevent operation of the machine if this protective equipment does not function correctly.

2.13.4 Protection against electric shock

Possible electrostatic energy

Components or assembly groups may become electrostatically charged. When the electrostatic charge is touched, the discharge may trigger a shock reaction leading to injuries.

- The operator must ensure that all components and assembly groups are included in the local potential equalisation in accordance with the applicable regulations.
- While paying attention to the actual conditions of the working environment, the potential equalisation must be implemented by a specialist electrician according to the applicable regulations.
- The effectiveness of the potential equalisation must be verified by executing regular safety measurements.

2.14 Notes on particular risks



⚠ DANGER

Risk of fatal injury from suspended loads!

Falling loads can cause serious injuries and even death.

- Stand clear of suspended loads and do not step within their swiveling range.
- Never move loads without supervision.
- Do not leave suspended loads unattended.
- Wear suitable protective equipment.



⚠ WARNING

Risk of injury from objects falling and being ejected!

Falling and ejected objects during operation can lead to serious injury or death.

- Take appropriate protective measures to secure the danger zone.



⚠ WARNING

Risk of injury due to unexpected movements!

If the power supply is switched on or residual energy remains in the system, components can move unexpectedly and cause serious injuries.

- Before starting any work on the product: Switch off the power supply and secure against restarting.
- Make sure, that no residual energy remains in the system.

**⚠ WARNING****Risk of injury from crushing and impacts!**

Serious injury could occur during the base jaw procedure and when breaking or loosening the gripper fingers.

- Wear suitable protective equipment.
- Do not reach into the open mechanism or the movement area of the product.

**⚠ WARNING****Risk of injury from sharp edges and corners!**

Sharp edges and corners can cause cuts.

- Use suitable protective equipment.

**⚠ WARNING****Risk of injury due to spring forces!**

Parts are under spring tension on products which clamp using spring force or which have gripping force maintenance. While disassembling components can move unexpectedly and cause serious injuries.

- Disassemble the product cautiously.
- Make sure that no residual energy remains in the system.

**⚠ WARNING****Risk of injury from objects falling during energy supply failure**

Products with a mechanical gripping force maintenance can, during energy supply failure, still move independently in the direction specified by the mechanical gripping force maintenance.

- Secure the end positions of the product with SCHUNK SDV-P pressure maintenance valves.

3 Technical data

Designation	PRG
Pressure medium	Compressed air, compressed air quality according to ISO 8573-1: 7:4:4
Nominal operating pressure [bar]	6
Minimum pressure [bar] without maintenance of gripping force	2.0
with maintenance of gripping force	4.0
Max. pressure [bar] without gripping force maintenance	8
with gripping force maintenance	6.5

More technical data is included in the catalog data sheet. Whichever is the latest version.

Ambient conditions and operating conditions

Designation	PRG
Ambient temperature [°C] min.	-10
max.	+90 / HT: +130
Protection class IP *	20
Noise emission [dB(A)]	≤ 70

* For use in dirty ambient conditions (e.g. sprayed water, vapors, abrasion or processing dust) SCHUNK offers corresponding product options as standard. SCHUNK also offers customized solutions for special applications in dirty ambient conditions.

4 Assembly

4.1 Installing and connecting



⚠ WARNING

Risk of injury due to unexpected movements!

If the power supply is switched on or residual energy remains in the system, components can move unexpectedly and cause serious injuries.

- Before starting any work on the product: Switch off the power supply and secure against restarting.
- Make sure, that no residual energy remains in the system.

CAUTION

Damage to the gripper is possible!

If the maximum permissible finger weight or the permissible mass moment of inertia of the fingers is exceeded, the gripper can be damaged.

- A jaw movement always has to be without jerks and bounce.
- You must therefore implement sufficient reduction and/or damping.
- Observe the diagrams and information in the catalog data sheet.

NOTE

- Observe the requirements for the compressed air supply, [Technical data](#) [▶ 16].
- In case of compressed air loss (cutting off the energy line), the components lose their dynamic effects and do not remain in a secure position. However, the use of a SDV-P pressure maintenance valve is recommended in this case in order to maintain the dynamic effect for some time. Product variants are also offered with mechanical gripping force via springs, which also ensure a minimum clamping force in the event of a pressure drop.

- Check the evenness of the mounting surface, [Mechanical connection](#) [▶ 19].
- Only open the required air connections (main connection or direct connection), [Air connection](#) [▶ 22].
- Connect the product via the hose-free direct connection.
 - ✓ Use O-rings from the accessory pack.
 - ✓ Seal main air connections which are not required with locking screws.
- OR: Connect compressed air lines to the main air connections "A" and "B".
 - ✓ Screw in air connections (plug connections).
OR: Screw on throttle valve in order to be able to perform sufficient throttling and/or damping.
- Screw the product to the machine/system, [Mechanical connection](#) [▶ 19].
 - ✓ If necessary, use appropriate connection elements (adapter plates).
 - ✓ Use centering sleeves from the enclosed accessory pack.
- Secure the gripper fingers to the base jaws, [Mechanical connection](#) [▶ 19].
 - ✓ Use centering sleeves from the enclosed accessory pack.
- Connect the sensor, see assembly and operating manual of the sensor.
- Mount the sensor, [Mounting the sensor](#) [▶ 24].

4.2 Connections

4.2.1 Mechanical connection

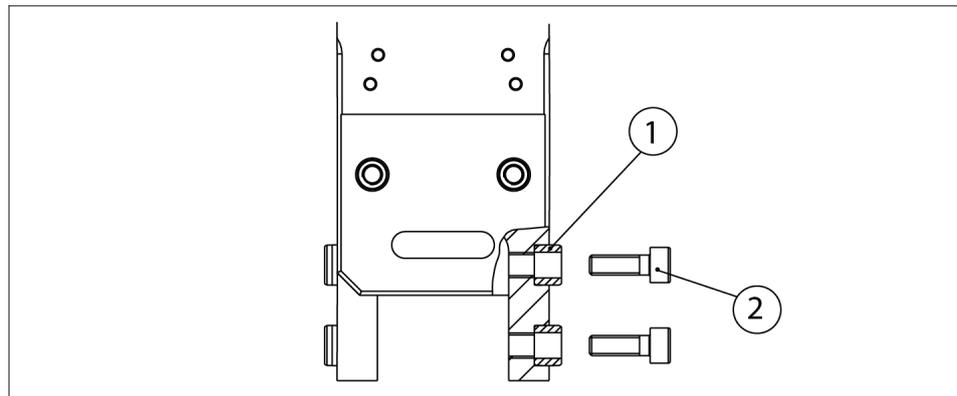
Evenness of the mounting surface

The values apply to the whole mounting surface to which the product is mounted.

Requirements for evenness of the mounting surface (Dimensions in mm)

Edge length	Permissible unevenness
< 100	< 0.02
> 100	< 0.05

Connections at the base jaws

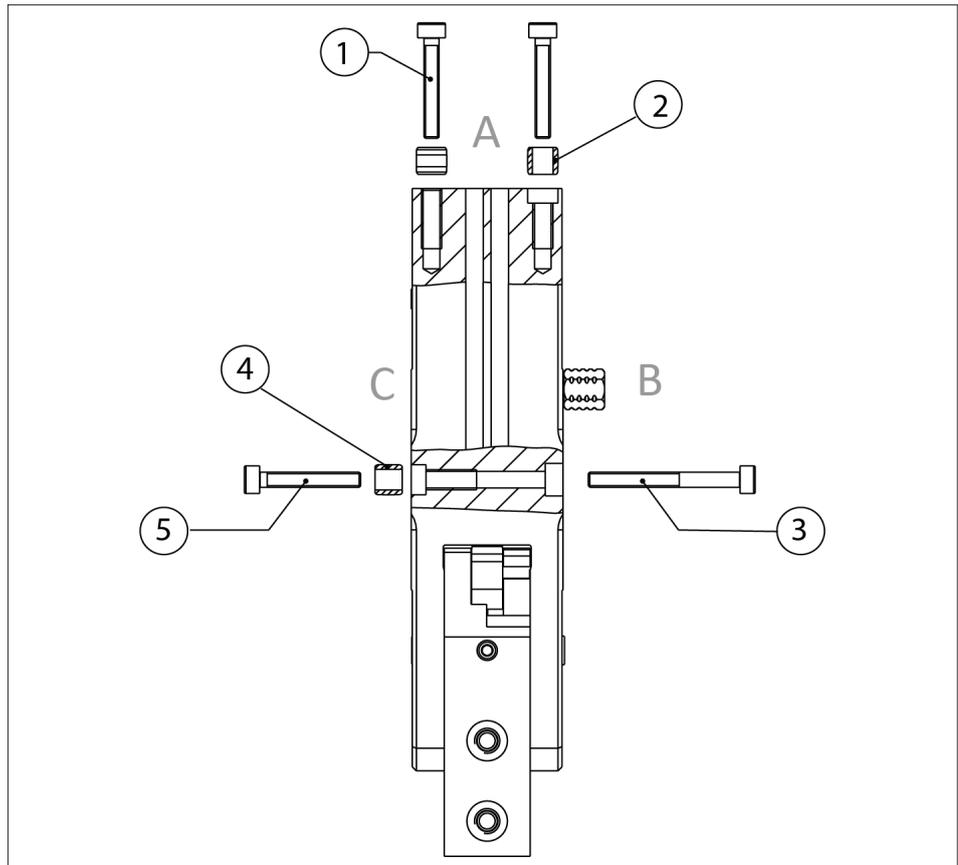


Connections at the base jaws

Item	Mounting	PRG							
		26	34	42	52	64	80	100	125
1 *	Centering sleeve	∅5 / 4.35	∅6 / 5.35	∅8 / 5.35	∅10 / 6.65	∅12 / 6.65	∅16 / 8.6	∅16 / 8.6	∅22 / 13.6
2	Thread in base jaws	M3	M4	M5	M6	M8	M10	M12	M16
	Max. depth of engagement from locating surface [mm]	6	7	8	10	13	16	20	25

Connections at the housing

The product can be mounted from three sides.



Connections at the housing

Item	Mounting	PRG							
		26	34	42	52	64	80	100	125
Side A									
1	Mounting screw	M3	M3	M4	M5	M5	M6	M8	M8
	Max. depth of engagement from locating surface [mm]	7	7	12	12	15	16	20	22
2 *	Centering sleeve	Ø5 / 4.35	Ø5 / 4.35	Ø6 / 5.35	Ø8 / 5.35	Ø8 / 5.35	Ø10 / 6.65	Ø12 / 6.65	Ø12 / 6.65
Side B									
3	Mounting screw	M2.5	M2.5	M3	M4	M4	M6	M6	M10
4 *	Centering sleeve	Ø5 / 4.35	Ø5 / 4.35	Ø6 / 5.35	Ø8 / 5.35	Ø8 / 5.35	Ø12 / 6.65	Ø12 / 6.65	Ø16 / 8.6
Side C									
5	Mounting screw	M3	M3	M4	M5	M5	M8	M8	M12
	Max. depth of engagement from locating surface [mm]	10	10	12	18	18	20	22	24
4 *	Centering sleeve	Ø5 / 4.35	Ø5 / 4.35	Ø6 / 5.35	Ø8 / 5.35	Ø8 / 5.35	Ø12 / 6.65	Ø12 / 6.65	Ø16 / 8.6

* Contained in accessory pack.

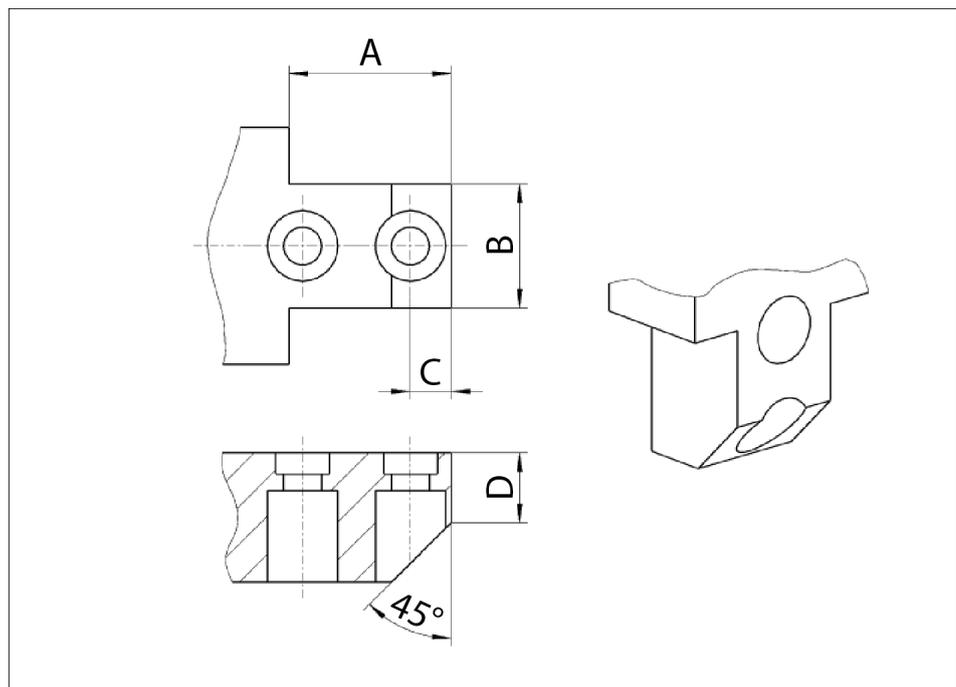
4.2.2 Gripper finger

The gripper fingers can only be mounted from the outside at the base jaws.

CAUTION

Damaging of the gripper, if the gripper fingers collide with the gripper!

In order to avoid a collision between gripper finger and housing, during opening and closing the gripper fingers, the dimensions A to D must be strictly adhered to



Design example of an gripper finger

Dimension	PRG							
	26	34	42	52	64	80	100	125
A_{\min} [mm]	10.0	11.0	14.0	16.0	24.0	16.0	20.0	30.0
B_{\max} [mm]	11.5	14.0	16.5	20.5	24.5	29.5	35.5	43.5
C_{\max} [mm]	3.7	5.0	6.5	8.0	15.0	12.0	15.0	19.0
D_{\max} [mm]	6.5	9.0	12.0	14.0	18.0	18.5	22.0	27.0

4.2.3 Air connection

CAUTION

Observe the requirements for the air supply
[Technical data](#) [▶ 16].

CAUTION

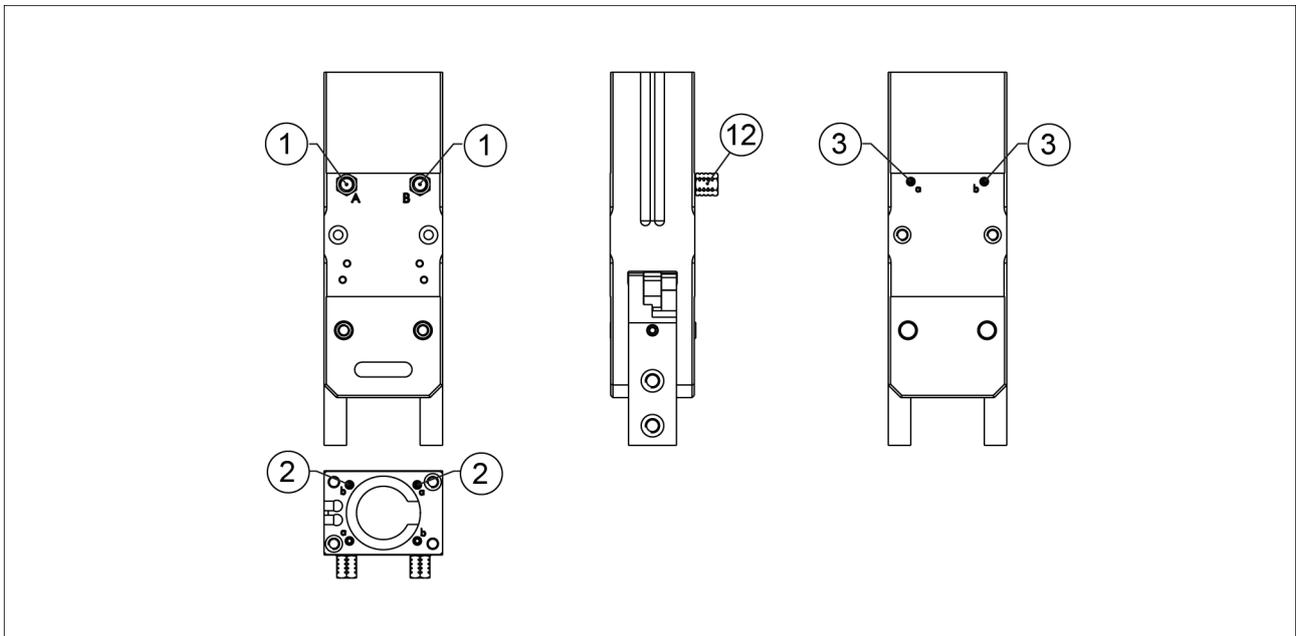
Damage to the gripper is possible!

If the maximum permissible finger weight or the permissible mass moment of inertia of the fingers is exceeded, the gripper can be damaged.

- A jaw movement always has to be without jerks and bounce.
- You must therefore implement sufficient reduction and/or damping.
- Observe the diagrams and information in the catalog data sheet.

NOTE

Already premounted fixed throttle screw connections may not be removed.



1	Main connections (Hose connection) (A = open, B = close)
2	Hose-free direct connection at the base (a = open, b = close)
3	Hose-free direct connection at the side(a = open, b = close)
12	Throttle screw connection

Thread diameter of the air connections

Item	PRG							
	26	34	42	52	64	80	100	125
1	M3 (2x)	M3 (2x)	M5 (2x)	M5 (2x)	M5 (2x)	G 1/8" (2x)	G 1/8" (2x)	G 1/8" (2x)
2	M2.5 (2x)	M3 (2x)	M3 (2x)	M3 (2x)	M5 (2x)	M3 (2x)	M5 (2x)	M5 (2x)
3	M2.5 (2x)	M3 (2x)	M3 (2x)	M3 (2x)	M5 (2x)	M3 (2x)	M5 (2x)	M5 (2x)

- Open only the air connections that are needed.
- Close unused main air connections using the screw plugs from the enclosed pack.
- For a hose-free direction connection, use the O-rings from the enclosed pack.

In case of exceeding the maximum permissible weight per gripper finger:

- Attach additional throttle screw connections to the module.
- Adjust the opening and closing times depending on the mass moment of inertia of the gripper finger. (See swivel time diagram in the catalog)
- The swivel time can be set optimally by using adjustable throttles.
- Throttle in such a way that the jaw movement is without jerks and bounce.

Throttling is also necessary if the direct connections "a" and "b" are used:

- Attach throttle screw connections (12) to the connections of the adapter plates.
- The direct connections a and b (2) at the bottom are there twice. Only one of them may be pressurized, since otherwise the desired throttling effect is not reached.

4.3 Mounting the sensor

NOTE

Observe the assembly and operating manual of the sensor for mounting and connecting.

The product is prepared for the use of sensors.

- For the exact type designations of suitable sensors, please see catalog datasheet and [Overview of sensors](#) [► 24].
- For technical data for the suitable sensors, see assembly and operating manual and catalog datasheet.
 - The assembly and operating manual and catalog datasheet are included in the scope of delivery for the sensors and are available at schunk.com.
- Information on handling sensors is available at schunk.com or from SCHUNK contact persons.

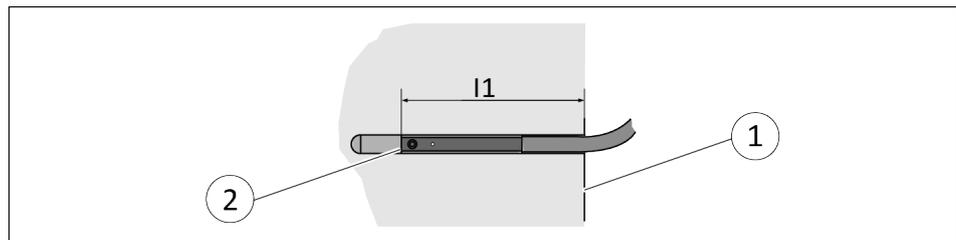
4.3.1 Overview of sensors

Overview of the compatible sensors

Designation	PRG							
	26	34	42	52	64	80	100	125
Inductive proximity switch IN 40	X	X	X	X	X	–	–	–
Inductive proximity switch IN 80	X	X	X	X	X	X	X	X
Magnetic switch MMS 22	X	X	X	X	X	X	X	X
Reed switch RMS 22	X	X	X	X	X	–	–	–
Radio system RSS R1/T2	X	X	X	X	X	–	–	–
Programmable magnetic switch MMS 22-PI1	X	X	X	X	X	X	X	X
Programmable magnetic switch MMS 22-PI2	X	X	X	X	X	–	–	–
Programmable magnetic switch MMS-P 22	X	X	X	X	X	–	–	–

- Exact type designation of the compatible sensors see catalog.
- Information on handling sensors is available at schunk.com or from SCHUNK contact persons.

4.3.2 Setting dimensions for magnetic switches



* Setting dimension l_1 , from product bottom edge (1) to front sensor (2)

The setting dimension applies for the following sensors:

- Programmable magnetic switch MMS 22-PI1
- Programmable magnetic switch MMS 22-PI2
- Programmable magnetic switch MMS-P 22

Size - Opening angle per jaw	l_1^* [mm]	Size - Opening angle per jaw	l_1^* [mm]
26 - 30	22.2	42 - 90	33.7
26 - 60	24.1	52 - 30	30.7
26 - 90	26.4	52 - 60	34.8
34 - 30	23.8	52 - 90	39.6
34 - 60	26.3	64 - 30	34.5
34 - 90	29.3	64 - 60	39.4
42 - 30	26.8	64 - 90	45.1
42 - 60	29.9		

NOTE

The magnetic switch MMS 22-PI1 can be adjusted and taught in two ways.

- "Standard mode" allows for quick installation on the T-nut preset by SCHUNK in the groove or the defined setting dimension " l_1 ."
- In "Optimal Mode", the sensor identifies the optimal position in the groove itself.

SCHUNK recommends "Optimal Mode" for setting the sensors.

Further information on the installation of the sensor, [Mounting MMS 22-PI1 programmable magnetic switch](#) [► 32]

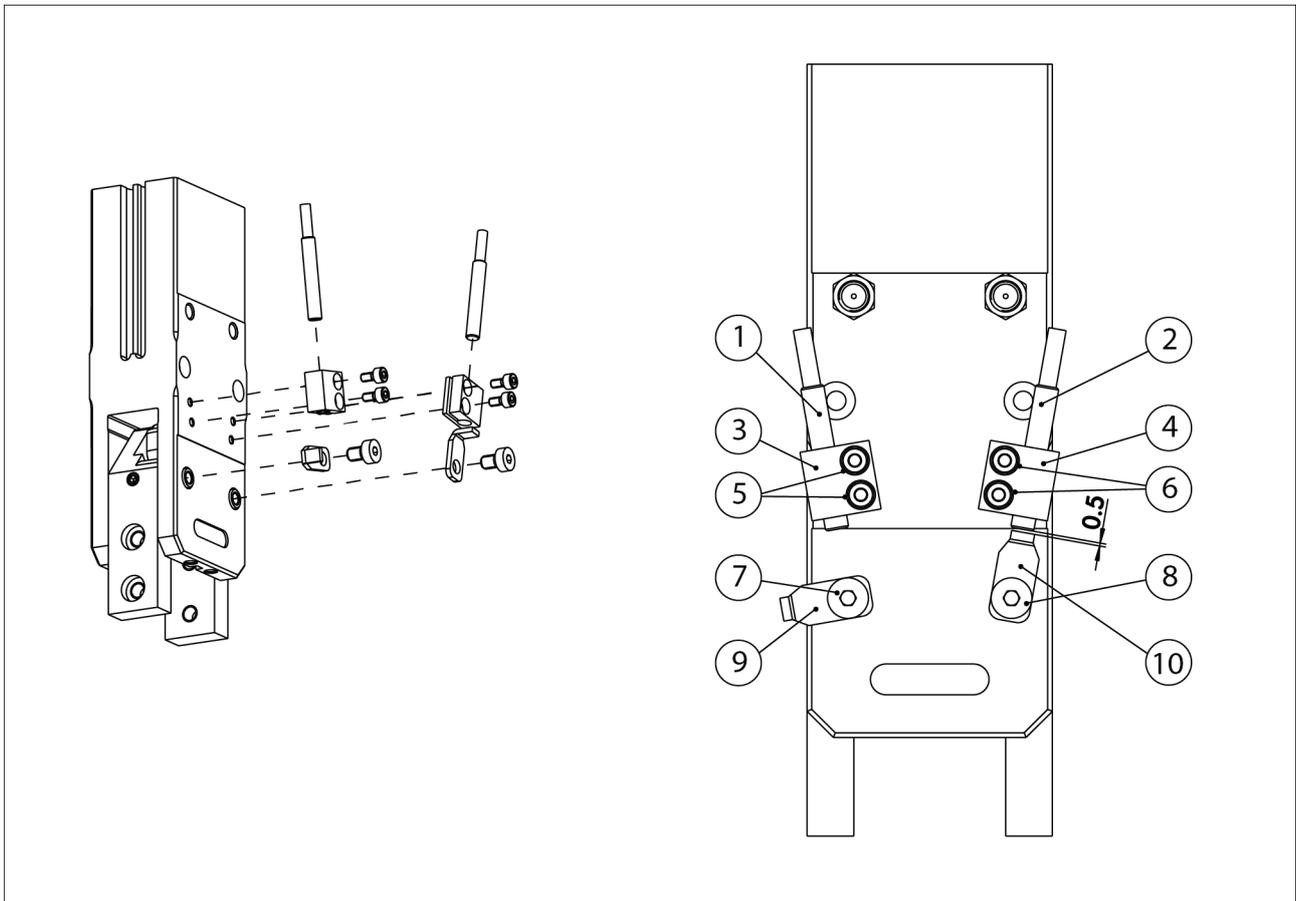
4.3.3 Inductive proximity switch IN 40

NOTE

The sensor can be used only for sizes 26–64

Mounting kit

To use the inductive sensor, the gripper has to be retrofitted with a special mounting kit. This mounting kit is available from SCHUNK for the models below.



Assembly IN 40

Assembly of the mounting kit IN40

- Fasten brackets (3/4) with screws (5/6) to the housing.
- Fasten the switch cams (9/10) with the screws (7/8) to the rotary bolt

Mounting of the proximity switch IN 40

The switching points of the "open" and "closed" positions must be set by the customer himself.

Gripper open:

- Set the gripper to the „Open“ position.
- Carefully push proximity switch (1) into the bracket (3) until it touches the switch cam (9).
- Pull the proximity switch approx 0.5 mm back.
- Fasten the proximity switch by tightening the screws (5).
- Set the gripper to the »Open« position and test the function.

Gripper closed:

- Set the gripper to the „Closed“ position.
- Carefully push proximity switch (2) into the bracket (4) until it touches the switch cam (10).
- Pull the proximity switch approx 0.5 mm back.
- Fasten the proximity switch by tightening the screws (6).
- Set the gripper to the »Closed« position and test the function.

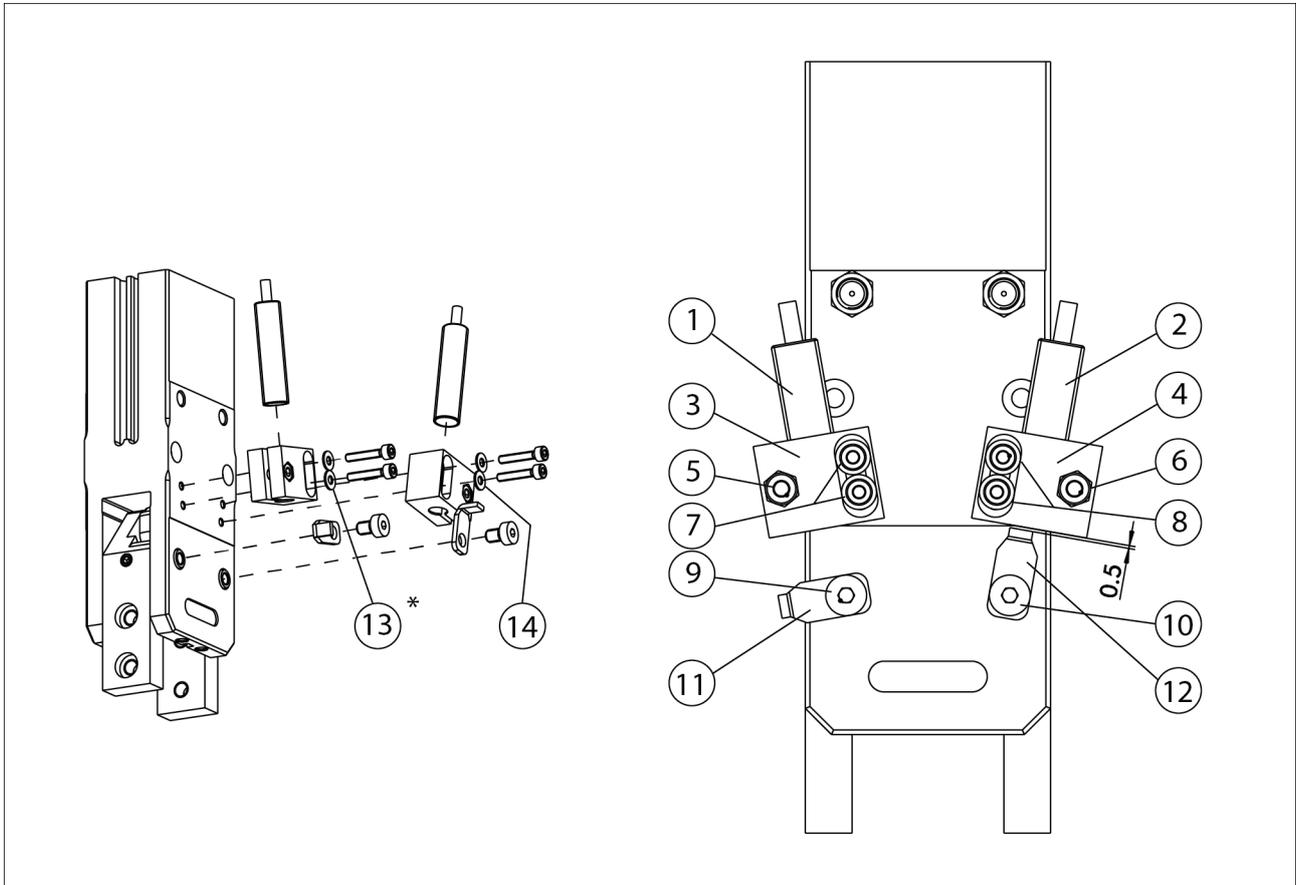
Part gripped (O.D. gripping):

- Clamp the part to be gripped.
- Loosen the screw (8).
- Turn the switch cam (10) so that the lug is parallel to the bracket (4).
- Fasten the switch cam by tightening the screw (8).
- Carefully push proximity switch (2) into the bracket (4) until it touches the switch cam (10).
- Pull the proximity switch approx 0.5 mm back.
- Fasten the proximity switch by tightening the screws (6).
- Test the function by opening the gripper and then closing it again.

4.3.4 Inductive proximity switch IN 40

Mounting kit

To use the inductive sensor, the gripper has to be retrofitted with a special mounting kit. This mounting kit is available from SCHUNK for the models below.



Assembly IN 80

Assembly of the mounting kit IN80 – PRG 26 to 64

- Attach the screw and the nut (5/6) on the bracket (3/4).
- Fasten brackets (3/4) with screws (7/8) and washers (13/14) to the housing.
- Push the brackets down as far as possible (away from the rotary bolt).
- Fasten the switch cams (11/12) with the screws (9/10) to the rotary bolt.

Assembly of the mounting kit IN80 - PRG 80 to 100

- Attach the screw and the nut (5/6) on the bracket (3/4).
- Fasten brackets (3/4) with the screws (7/8) to the housing.
- Push the brackets down as far as possible (away from the rotary bolt).
- Fasten the switch cams (11/12) with the screws (9/10) to the rotary bolt.

Mounting of the proximity switch IN 80

The switching points of the "open" and "closed" positions must be set by the customer himself.

Gripper open:

- Set the gripper to the „Open“ position.
- Push the proximity switch (1) to the stop of the bracket (3).
- Fasten the proximity switch by tightening the screws (5) in the bracket.
- Undo screws (7) and carefully push bracket 1 (3) to the switch cam until it touches the switch cam (11).
- Pull the bracket approx 0.5 mm back.
- Fasten the bracket by tightening the screw (7).
- Set the gripper to the »Open« position and test the function.

Gripper closed:

- Set the gripper to the „Closed“ position.
- Push the proximity switch (2) to the stop of the bracket (4).
- Fasten the proximity switch by tightening the screws (6) in the bracket.
- Undo screws (8) and carefully push bracket (4) to the switch cam until it touches the switch cam (12).
- Pull the bracket approx 0.5 mm back.
- Fasten the bracket by tightening the screw (8).
- Set the gripper to the »Closed« position and test the function.

Part gripped (O.D. gripping):

- Clamp the part to be gripped.
- Loosen the screw (9).
- Turn the switch cam (11) so that the lug is parallel to the bracket (3).
- Fasten the switch cam by tightening the screw (9).
- Push the proximity switch (2) to the stop of the bracket (4)
- Fasten the proximity switch by tightening the screws (6) in the bracket.
- Undo screws (8) and carefully push bracket (4) to the switch cam until it touches the switch cam (12).
- Pull the bracket approx 0.5 mm back.
- Fasten the bracket by tightening the screw (8).
- Test the function by opening the gripper and then closing it again.

4.3.5 Magnetic switch MMS 22 / RMS 22

NOTE

The sensor can be used only for sizes 26–64

CAUTION

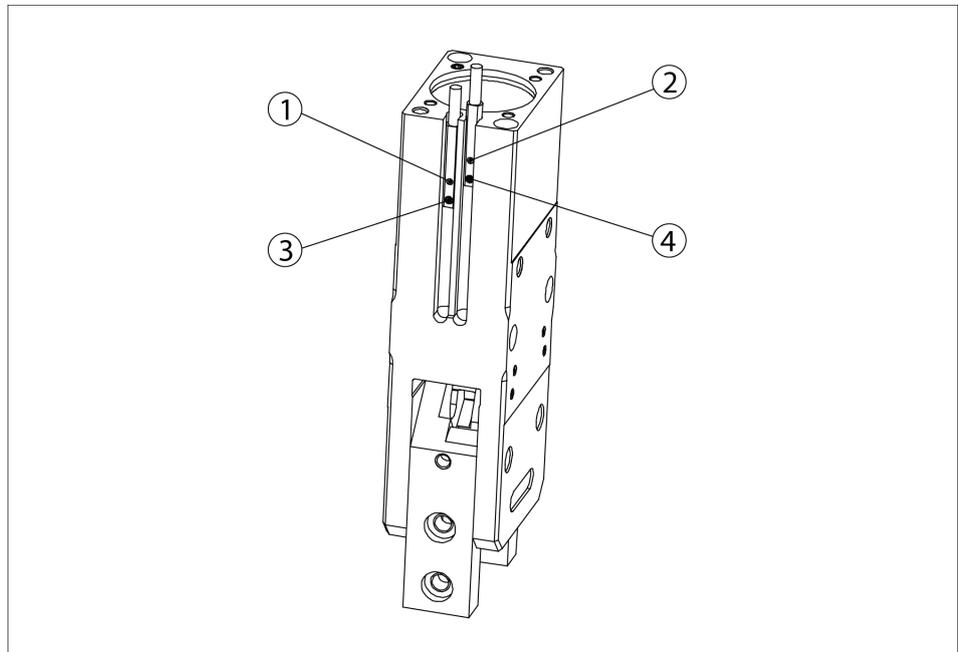
Material damage due to an incorrect tightening torque!

If the threaded pin is tightened with an incorrect tightening torque, the product may be damaged.

- Observe a maximum tightening torque of 10 Ncm for the set-screws.

The RMS sensors have a larger hysteresis than the MMS sensors. This means that short gripper strokes may not be able to be monitored with the RMS sensors.

Positioning the magnetic switch



Positioning of the magnetic switches

Gripper open:

- Set the gripper to the „Open“ position.
- Slide the magnetic switch 1 (1) into the groove (4) until it comes into contact with the housing.
- Slide the magnetic switch 1 (1) slowly back until it switches.
- By tightening the set screw (3), fix the magnetic switch 1 (1) in this position in the groove (4).
- Test the function by closing the gripper and then opening it again.

Gripper closed:

- Set the gripper to the „Closed“ position.
- Slide the magnetic switch 2 (2) into the groove (4) in the direction of the center of the gripper until it switches.
- By tightening the set screw (3), fix the magnetic switch 2 (2) in this position in the groove (4).
- Test the function by opening the gripper and then closing it again.

Part gripped (O.D. gripping):

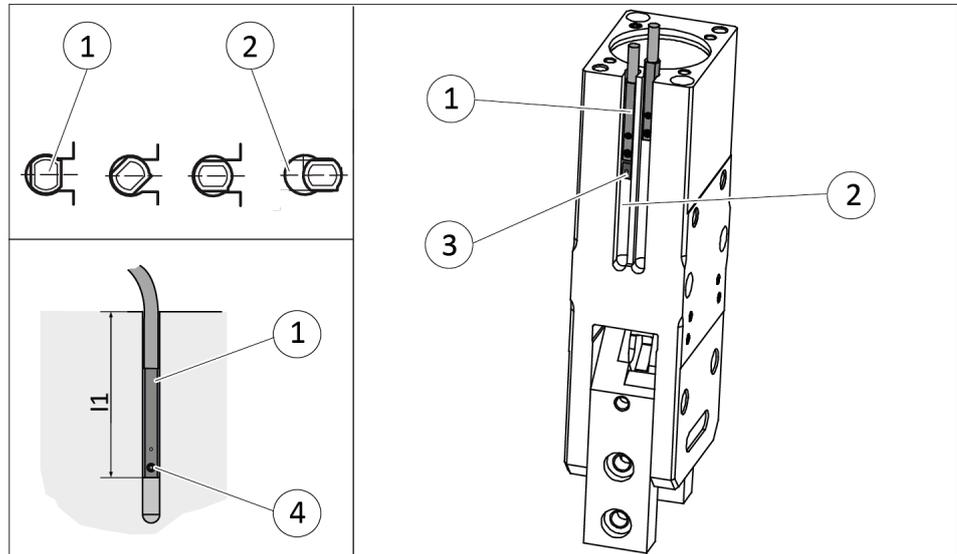
- Clamp the part to be gripped.
- Slide the magnetic switch 2 (2) into the groove (4) in the direction of the center of the gripper until it switches.
- By tightening the set screw (3), fix the magnetic switch 2 (2) in this position in the groove (4).
- Test the function by opening the gripper and then closing it again.

4.3.6 Mounting MMS 22-PI1 programmable magnetic switch

CAUTION

Risk of damage to the sensor during assembly!

- Observe the maximal tightening torque.



NOTE

The magnetic switch MMS 22-PI1 can be adjusted and taught in two ways.

- "Standard mode" allows for quick installation on the T-nut preset by SCHUNK in the groove or the defined setting dimension "l1."
- In "Optimal Mode", the sensor identifies the optimal position in the groove itself.
SCHUNK recommends "Optimal Mode" for setting the sensors.

Setting the sensor in "Optimum mode"

- Put product in the position in which it is to be set.
- Hold teaching tool to the sensor 1 (1) until the sensor flashes.
- Slide sensor 1 (1) into the groove (2), until the sensor 1 flashes rapidly.
 - ✓ The optimum position is displayed.
- Secure the sensor 1 (1) using the set-screw (4).
Tightening torque: 10 Ncm
- Hold teaching tool to the sensor 1 (1) to confirm the position.
 - ✓ The sensor 1 (1) has been taught in.
- Repeat steps for sensor 2.

Alternatively for size 26 – 64, Setting the sensor in "Standard mode"

- Turn the sensor 1 (1) into the groove (2).
OR: Slide the sensor 1 (1) into the groove (2) until the sensor 1 (1) stops at the T-nut (3).
 - Secure the sensor 1 (1) using the set-screw (4).
Tightening torque: 10 Ncm
 - Adjust sensor 1 (1), see sensor assembly and operating manual.
 - Repeat steps for sensor 2.
-

NOTE

If there is no T-nut available, slide the sensor according to dimension l1 into the groove (2),
[Setting dimensions for magnetic switches](#) [▶ 25].

4.3.7 Mounting programmable MMS 22-PI2 magnetic switch

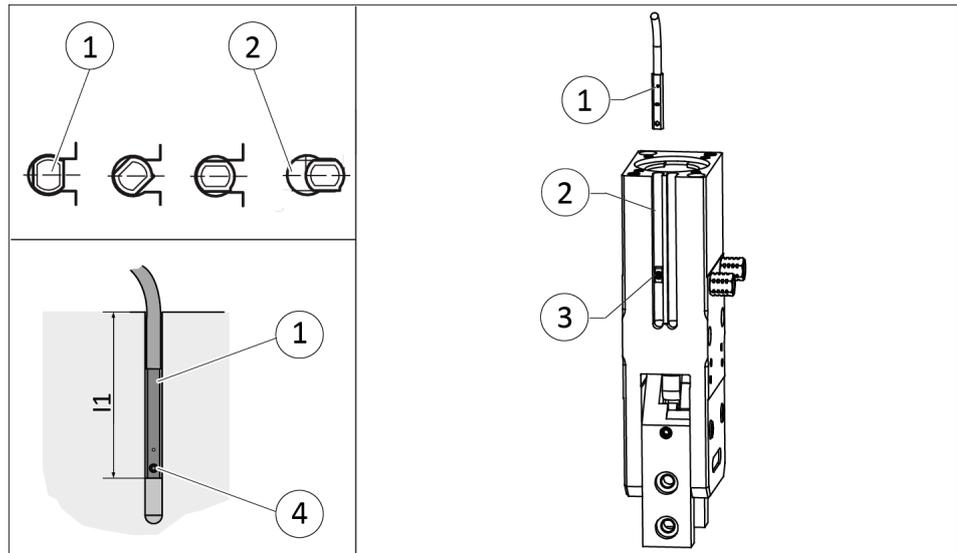
NOTE

The sensor can be used only for sizes 26–64

CAUTION

Risk of damage to the sensor during assembly!

- Observe the maximal tightening torque.



NOTE

If there is no T-nut available, slide the sensor according to dimension l1 into the groove (2), [Setting dimensions for magnetic switches](#) [▶ 25].

- Turn the sensor (1) into the groove (2).
OR: Slide the sensor (1) into the groove (2) until the sensor (1) stops at the T-nut (3).
- Secure the sensor (1) using the set-screw (4).
Tightening torque: 10 Ncm
- Adjust sensor (1), see sensor assembly and operating manual.

4.3.8 Programmable magnetic switch (MMS-P)

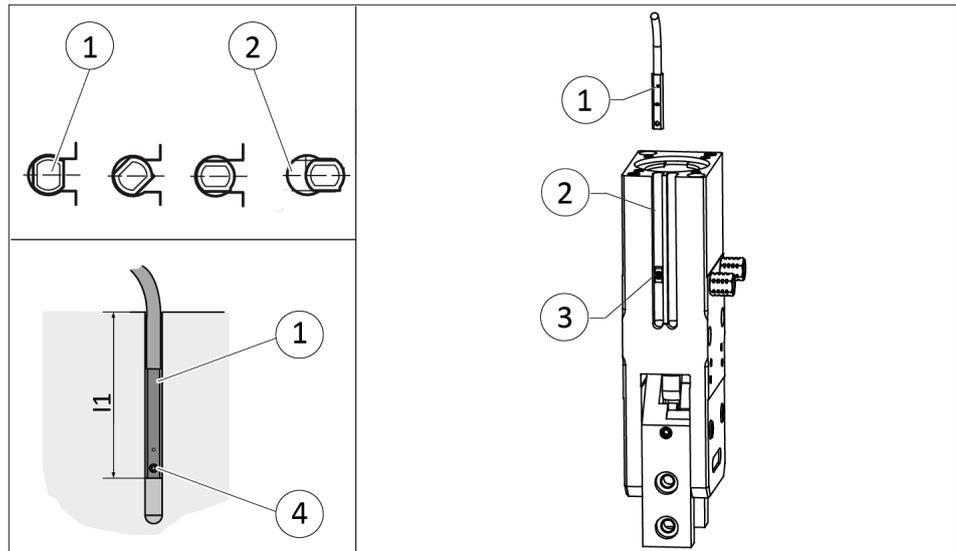
CAUTION

Risk of damage to the sensor during assembly!

- Observe the maximal tightening torque.

NOTE

The sensor can be used only for sizes 26–64



- Turn the sensor (1) into the groove (2).
OR: Slide the sensor (1) into the groove (2) until the sensor (1) stops at the T-nut (3).
- Secure the sensor (1) using the set-screw (4).
Tightening torque: 10 Ncm
- Adjust sensor (1), see sensor assembly and operating manual.

5 Troubleshooting

5.1 Product is not moving

Possible cause	Corrective action
Base jaws jam in housing, e.g. mounting surface is not sufficiently even.	Check the evenness of the mounting surface. Mechanical connection [▶ 19]
	Loosen the mounting screws of the product and actuate the product again.
Pressure drops below minimum.	Check air supply. Air connection [▶ 22]
Compressed air lines switched.	Check compressed air lines. Air connection [▶ 22]
Proximity switch defective or set incorrect.	Readjust or change sensor.
Unused air connections open.	Close unused air connections.
Flow control valve closed.	Open the flow control valve.
Component part defective.	Replace component or send it to SCHUNK for repair.

5.2 Product does not travel the entire stroke

Possible cause	Corrective action
Dirt deposits between cover and piston.	Clean and if necessary re-lubricate. Maintenance [▶ 38]
Pressure drops below minimum.	Check air supply., Air connection [▶ 22]
Mounting surface is not sufficiently flat.	Check the evenness of the mounting surface. Mechanical connection [▶ 19]
Component part defective.	Send product with a SCHUNK repair order or dismantle product.

5.3 Product opens or closes abruptly

Possible cause	Corrective action
Too little grease in the mechanical guiding areas.	Clean and lubricate product. Maintenance [▶ 38]
Compressed air lines blocked.	Check compressed air lines of damage.
Mounting surface is not sufficiently flat.	Check the evenness of the mounting surface.
Loading too large.	Check permissible weight and length of the gripper fingers. Mechanical connection [▶ 19]

5.4 Product opens with heavy impacts in the end position

Possible cause	Corrective action
Mass moment of inertia of the top jaw too great.	Use lighter gripper finger and attach the flow control couplings.

5.5 Gripping force is dropping

Possible cause	Corrective action
Compressed air can escape.	Check seals, if necessary, disassemble the product and replace seals.
Too much grease in the mechanical movement space.	Clean and lubricate product.
Pressure drops below minimum.	Check air supply. Air connection [▶ 22]
Component part defective.	Replace component or send it to SCHUNK for repair.

5.6 Product does not achieve the opening and closing times

Possible cause	Corrective action
Compressed air lines are not installed optimally.	If present: Open the flow control couplings on the product to the maximum that the movement of the jaws occurs without bouncing and hitting.
	Check compressed air lines.
	Inner diameters of compressed air lines are of sufficient size in relation to compressed air consumption.
	Keep compressed air lines between the product and directional control valve as short as possible.
	Flow rate of valve is sufficiently large relative to the compressed air consumption.
	IMPORTANT! The throttle check valve must not be removed, even if the product has not reached the opening and closing times.
	If, despite optimum air connections, the opening and closing times specified in the catalogue are not achieved, SCHUNK recommends the use of quick-air-vent-valves directly at the product.
Loading too large.	Check permissible weight and length of the gripper fingers.

6 Maintenance

6.1 Notes

Original spare parts

Use only original spare parts of SCHUNK when replacing spare and wear parts.

Exchange of housing and base jaws

The base jaws and the guidance in the housing are matched. To exchange these parts, send the product with a repair order to SCHUNK or order the housing with the base jaws as a set.

6.2 Maintenance interval

CAUTION

Material damage due to hardening lubricants!

Lubricants harden more quickly at temperatures above 60°C, leading to possible product damage.

- Reduce the lubricant intervals accordingly.

Interval [Mio. cycles]	2
------------------------	---

6.3 Lubricants/Lubrication points

SCHUNK recommends the lubricants listed.

During maintenance, treat all greased areas with lubricant. Thinly apply lubricant with a lint-free cloth.

Lubricant point	Lubricant
Metallic sliding surfaces	PRG 26-34: microGLEIT GSV 790 PRG 42-125: Toothgood 1
All seals	Sealgood 1
Bore hole at the piston	Sealgood 1

6.4 Disassembly of PRG 26 - 64

6.4.1 Version without gripping force maintenance

Position of the item numbers [Drawings](#) [▶ 43]



⚠ WARNING

Risk of injury due to unexpected movements!

If the power supply is switched on or residual energy remains in the system, components can move unexpectedly and cause serious injuries.

- Before starting any work on the product: Switch off the power supply and secure against restarting.
- Make sure, that no residual energy remains in the system.

- Remove the compressed air hoses.
- Remove circlip (18) for cover (4).
- Pull the cover (4) out of the housing.
- Unscrew and remove the screws (6).
- Pull cylinder piston (5) out of the housing.
- Loosen set-screw (20) in the base jaws (2x).
- Remove rotary bolt (6) (2x).
- Remove base jaws (2) (2x).
- Pull piston rod (3) out of the housing.

6.4.2 Variant with gripping force maintenance “O.D. gripping”

Position of the item numbers [Drawings](#) [▶ 43]



⚠ WARNING

Risk of injury due to unexpected movements!

If the power supply is switched on or residual energy remains in the system, components can move unexpectedly and cause serious injuries.

- Before starting any work on the product: Switch off the power supply and secure against restarting.
- Make sure, that no residual energy remains in the system.



⚠ WARNING

Risk of injury due to spring forces!

The cylinder piston is under spring tension.

- Carefully disassemble the product.



- Remove the compressed air hoses.

⚠ WARNING

Risk of injury due to spring forces!

In case of defect, the screws (18) and the cover (4) can be under spring tension.

- **Carefully** disassemble the module.

- Secure the cover by suitable means.
- Remove circlip (18) for cover (4).
- Carefully remove the cover safety.
- Pull the cover (4) out of the housing.
- Secure the cylinder piston by suitable means.
- Unscrew and remove the screws (6).
- Carefully remove the cylinder piston safety.
- Pull cylinder piston (5) out of the housing.
- Loosen set-screw (20) in the base jaws (2x).
- Remove rotary bolt (6) (2x).
- Remove base jaws (2) (2x).
- Pull piston rod (3) out of the housing.

6.5 Disassembly of PRG 80-125

6.5.1 Version without gripping force maintenance

Position of the item numbers [Drawings](#) [▶ 43]



⚠ WARNING

Risk of injury due to unexpected movements!

If the power supply is switched on or residual energy remains in the system, components can move unexpectedly and cause serious injuries.

- Before starting any work on the product: Switch off the power supply and secure against restarting.
- Make sure, that no residual energy remains in the system.

- Remove the compressed air hoses.
- Remove screws (18) for cover (4).
- Remove the cover (4).
- Unscrew and remove the screws (6).
- Pull cylinder piston (5) out of the housing.
- Loosen set-screw (20) in the base jaws (2x).
- Remove rotary bolt (6) (2x).

- Remove base jaws (2) (2x).
- Pull piston rod (3) out of the housing.

6.5.2 Variant with gripping force maintenance “O.D. gripping”

Position of the item numbers [Drawings](#) [▶ 43]



⚠ WARNING

Risk of injury due to unexpected movements!

If the power supply is switched on or residual energy remains in the system, components can move unexpectedly and cause serious injuries.

- Before starting any work on the product: Switch off the power supply and secure against restarting.
- Make sure, that no residual energy remains in the system.



⚠ WARNING

Risk of injury due to spring forces!

The cylinder piston is under spring tension.

- Carefully disassemble the product.

- Remove the compressed air hoses.



⚠ WARNING

Risk of injury due to spring forces!

In case of defect, the screws (18) and the cover (4) can be under spring tension.

- **Carefully** disassemble the module.

- Secure the cover by suitable means.
- Remove screws (18) for cover (4) (4x).
- Carefully remove the cover safety.
- Pull the cover (4) out of the housing.
- Secure the cylinder piston by suitable means.
- Unscrew and remove the screws (6).
- Carefully remove the cylinder piston safety.
- Pull cylinder piston (5) out of the housing.
- Loosen set-screw (20) in the base jaws (2x).
- Remove rotary bolt (6) (2x).

6.6 Servicing and assembling the product

Maintenance

- Clean all parts thoroughly and check for damage and wear.
- Treat all greased areas with lubricant.
[Lubricants/Lubrication points](#) [▶ 38]
- Oil or grease bare external steel parts.
- Replace all wear parts / seals.
 - Position of the wearing parts [Drawings](#) [▶ 43]
 - Seal kit [Seal kit](#) [▶ 8]

Assembly

Assembly takes place in the opposite order to disassembly.
Observe the following:

- Unless otherwise specified, secure all screws and nuts with Loctite no. 243 and tighten with the appropriate tightening torque.

6.6.1 Screw tightening torques

Position of the item numbers [Drawings](#) [▶ 43]

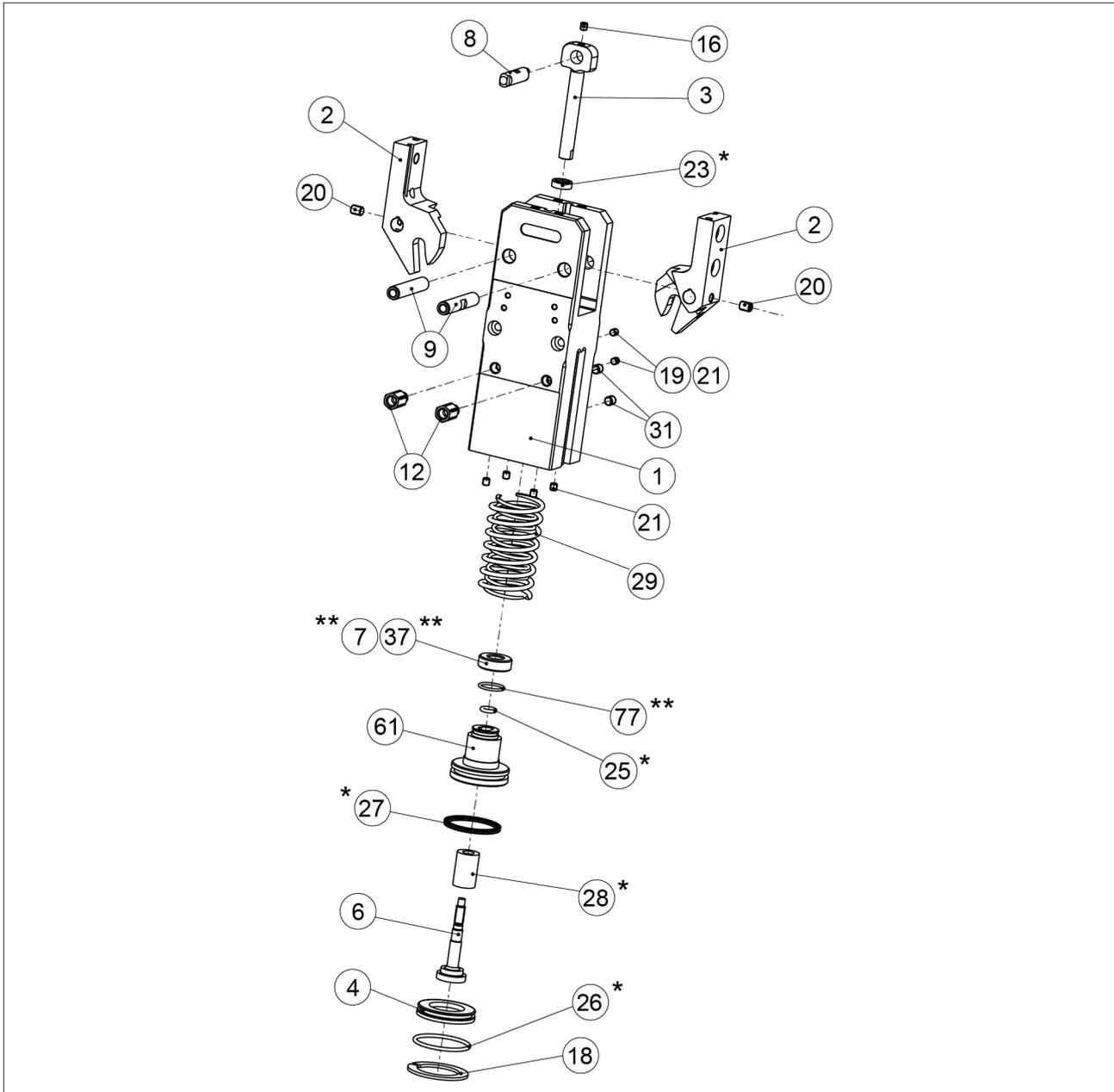
Dimensions in Nm

Item	PRG 26	PRG 34	PRG 42	PRG 52	PRG 64	PRG 80	PRG 100	PRG 125
6	1.3	1.3	3.0	5.9	1.01	10.1	20.0	24.6
16	0.25	0.4	0.7	2.0	4.0	-		
17	0.3					0.5		
18	-					3.0	6.1	6.1
20	0.8	0.8	2.4	7.5	7.5	7.5	10.0	25.0
22	0.8	1.3	3.0	5.9	10.1	10.1	24.6	24.6
83	0.75					-		
13.1 13.2	0.3							

6.7 Drawings

The following figures are example images.
They serve for illustration and assignment of the spare parts.
Variations are possible depending on size and variant.

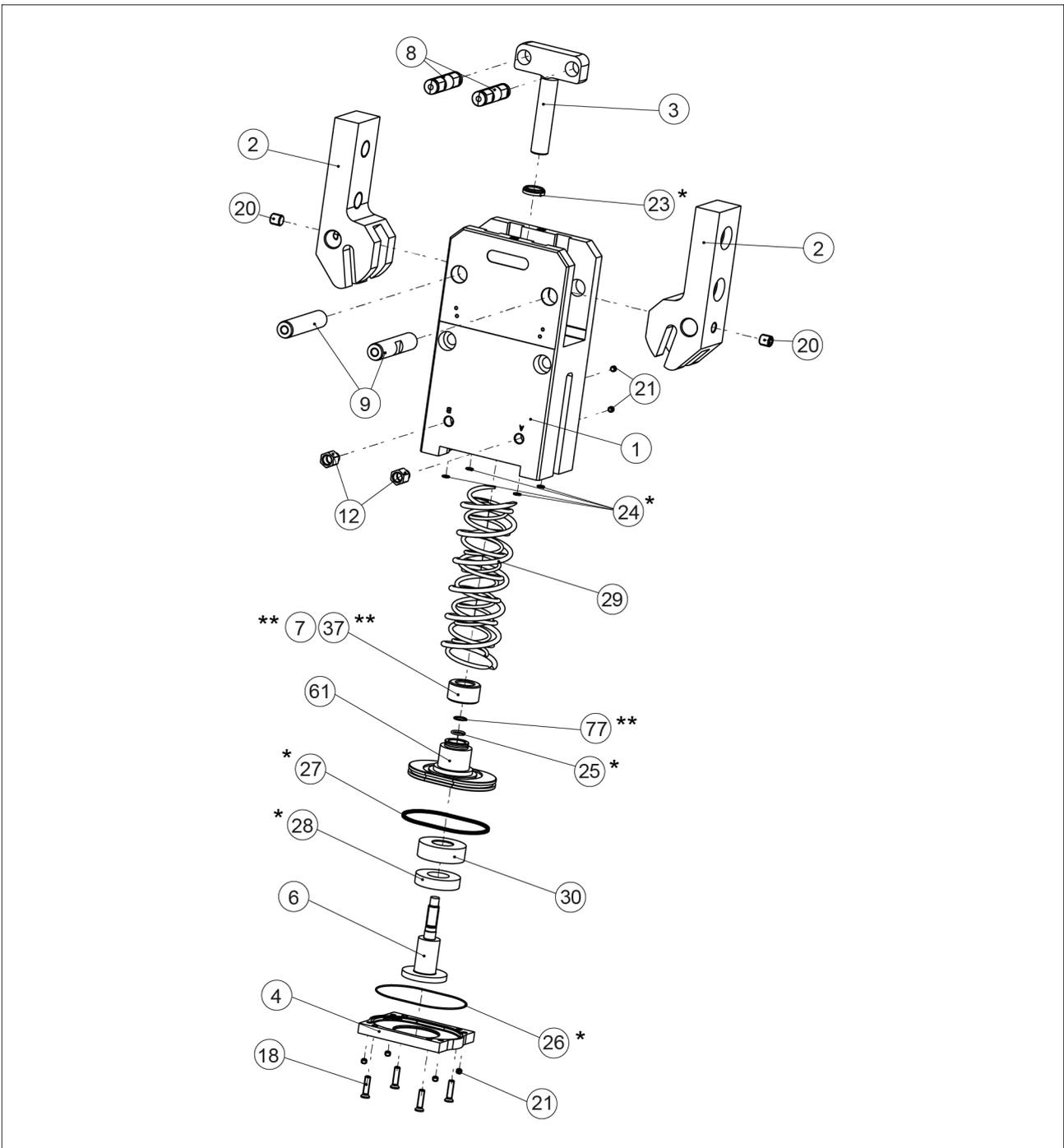
6.7.1 Assembly drawing PRG 26-64



Assembly of the Types O.D.gripping / I.D. gripping / without gripping force maintenance

- * Wearing part, replace during maintenance.
Included in the seal kit. Seal kit can only be ordered completely.
- ** Only for units with 30° or 60° opening angle

6.7.2 Assembly drawing PRG 80-125



Assembly of the Types O.D.gripping / I.D. gripping / without gripping force maintenance

- * Wearing part, replace during maintenance.
Included in the seal kit. Seal kit can only be ordered completely.
- ** Only for units with 30° or 60° opening angle

7.1 Annex to Declaration of Incorporation

according 2006/42/EG, Annex II, No. 1 B

1. Description of the essential health and safety requirements pursuant to 2006/42/EC, Annex I that are applicable and that have been fulfilled with:

Product designation	Pneumatic Radial gripper
Type designation	PRG
ID number	0303651 ... 0303658, 0303661 ... 0303668, 0303671 ... 0303678, 0303681 ... 0303688, 0303691 ... 0303698, 0303701 ... 0303708, 39303651 ... 39303658, 39303661 ... 39303668, 39303671 ... 39303678, 39303681 ... 39303688, 39303691 ... 39303698, 39303701 ... 39303708

To be provided by the System Integrator for the overall machine	↓
Fulfilled for the scope of the partly completed machine	↓
Not relevant	↓

1.1	Essential Requirements			
1.1.1	Definitions		X	
1.1.2	Principles of safety integration		X	
1.1.3	Materials and products		X	
1.1.4	Lighting		X	
1.1.5	Design of machinery to facilitate its handling		X	
1.1.6	Ergonomics		X	
1.1.7	Operating positions			X
1.1.8	Seating			X

1.2	Control Systems			
1.2.1	Safety and reliability of control systems		X	
1.2.2	Control devices		X	
1.2.3	Starting		X	
1.2.4	Stopping		X	
1.2.4.1	Normal stop		X	
1.2.4.2	Operational stop		X	
1.2.4.3	Emergency stop		X	
1.2.4.4	Assembly of machinery		X	
1.2.5	Selection of control or operating modes		X	
1.2.6	Failure of the power supply			X

1.3	Protection against mechanical hazards			
1.3.1	Risk of loss of stability			X

1.3	Protection against mechanical hazards			
1.3.2	Risk of break-up during operation			X
1.3.3	Risks due to falling or ejected objects			X
1.3.4	Risks due to surfaces, edges or angles		X	
1.3.5	Risks related to combined machinery			X
1.3.6	Risks related to variations in operating conditions			X
1.3.7	Risks related to moving parts		X	
1.3.8	Choice of protection against risks arising from moving parts			X
1.3.8.1	Moving transmission parts		X	
1.3.8.2	Moving parts involved in the process			X
1.3.9	Risks of uncontrolled movements			X
1.4	Required characteristics of guards and protective devices			
1.4.1	General requirements			X
1.4.2	Special requirements for guards			X
1.4.2.1	Fixed guards			X
1.4.2.2	Interlocking movable guards			X
1.4.2.3	Adjustable guards restricting access			X
1.4.3	Special requirements for protective devices			X
1.5	Risks due to other hazards			
1.5.1	Electricity supply		X	
1.5.2	Static electricity		X	
1.5.3	Energy supply other than electricity		X	
1.5.4	Errors of fitting		X	
1.5.5	Extreme temperatures			X
1.5.6	Fire			X
1.5.7	Explosion			X
1.5.8	Noise			X
1.5.9	Vibrations			X
1.5.10	Radiation	X		
1.5.11	External radiation	X		
1.5.12	Laser radiation	X		
1.5.13	Emissions of hazardous materials and substances			X
1.5.14	Risk of being trapped in a machine	X		
1.5.15	Risk of slipping, tripping or falling	X		
1.5.16	Lightning			X
1.6	Maintenance			
1.6.1	Machinery maintenance		X	
1.6.2	Access to operating positions and servicing points		X	

Translation of original declaration of incorporation

1.6	Maintenance			
1.6.3	Isolation of energy sources		X	
1.6.4	Operator intervention		X	
1.6.5	Cleaning of internal parts		X	
1.7	Information			
1.7.1	Information and warnings on the machinery		X	
1.7.1.1	Information and information devices		X	
1.7.1.2	Warning devices		X	
1.7.2	Warning of residual risks		X	
1.7.3	Marking of machinery	X		
1.7.4	Instructions	X		
1.7.4.1	General principles for the drafting of instructions	X		
1.7.4.2	Contents of the instructions	X		
1.7.4.3	Sales literature	X		
	The classification from Annex 1 is to be supplemented from here forward.			
2	Supplementary essential health and safety requirements for certain categories of machinery			X
2.1	Foodstuffs machinery and machinery for cosmetics or pharmaceutical products			X
2.2	Portable hand-held and/or guided machinery			X
2.2.1	Portable fixing and other impact machinery			X
2.3	Machinery for working wood and material with similar physical characteristics			X
3	Supplementary essential health and safety requirements to offset hazards due to the mobility of machinery		X	
4	Supplementary essential health and safety requirements to offset hazards due to lifting operations		X	
5	Supplementary essential health and safety requirements for machinery intended for underground work			X
6	Supplementary essential health and safety requirements for machinery presenting particular hazards due to the lifting of persons		X	

RESINAS PARA INGENIERÍA

Flexible 80A Resin

Flexible 80A Resin, para prototipos duros y flexibles

La Flexible 80A Resin es el material más rígido de tacto blando en nuestro catálogo de resinas Flexible y Elastic, con una dureza Shore de 80A que simula la flexibilidad del caucho o del poliuretano termoplástico.

Al combinar blandura con resistencia, la Flexible 80A Resin puede soportar esfuerzos de flexión y compresión, incluso a lo largo de ciclos repetidos. Se trata de un material adecuado para la amortiguación y absorción de impactos.

Mangos, empuñaduras y sobremoldes

Anatomía de cartílagos y ligamentos

Juntas, anillos y máscaras



V1 FLFL8001

formlabs 

Redactado 29/ 05/ 2020
Rev 01 29/ 05/ 2020

A nuestro saber y entender, la información contenida en este documento es precisa. No obstante, Formlabs Inc. no ofrece ninguna garantía, expresa o implícita, con respecto a la exactitud de los resultados derivados del uso de este producto.

Datos de las propiedades de la Flexible 80A Resin

	MÉTRICO ¹		IMPERIAL ¹		MÉTODO
	No poscurada	Poscurada ²	No poscurada	Poscurada ²	
Propiedades mecánicas					
Resistencia a la rotura por tracción ³	3,7 MPa	8,9 MPa	539 psi	1290 psi	ASTM D 412-06 (A)
Esfuerzo de alargamiento al 50 %	1,5 MPa	3,1 MPa	218 psi	433 psi	ASTM D 412-06 (A)
Esfuerzo de alargamiento al 100 %	3,5 MPa	6,3 MPa	510 psi	909 psi	ASTM D 412-06 (A)
Alargamiento de rotura	100 %	120 %	100 %	120 %	ASTM D 412-06 (A)
Dureza Shore	70A	80A	70A	80A	ASTM 2240
Deformación permanente por compresión (23 °C durante 22 horas)	No sometida a ensayo	3 %	No sometida a ensayo	3 %	ASTM D 624-00
Deformación permanente por compresión (70 °C durante 22 horas)	No sometida a ensayo	5 %	No sometida a ensayo	5 %	ASTM D 395-03 (B)
Resistencia al desgarro ⁴	11 kN/m	24 kN/m	61 lbf/in	137 lbf/in	ASTM D 395-03 (B)
Fatiga de flexión Ross a 23 °C	No sometida a ensayo	>200 000 ciclos	No sometida a ensayo	>200 000 ciclos	ASTM D1052, (IZOD), flexión de 60°, 100 ciclos/minuto
Fatiga de flexión Ross a -10 °C	No sometida a ensayo	>50 000 ciclos	No sometida a ensayo	>50 000 ciclos	ASTM D1052, (IZOD), flexión de 60°, 100 ciclos/minuto
Resiliencia Bayshore	No sometida a ensayo	28 %	No sometida a ensayo	28 %	ASTM D2632
Propiedades térmicas					
Temperatura de transición vítrea	No sometida a ensayo	27 °C	No sometida a ensayo	27 °C	Análisis mecánico dinámico (DMA)

¹ Las propiedades del material pueden variar en función de la geometría de la pieza, la orientación y ajustes de impresión y la temperatura.

² Datos obtenidos de piezas impresas con la Form 3, a 100 µm y con ajustes para la Flexible Resin. Las piezas se han lavado en la Form Wash durante 10 minutos y se han sometido a poscurado en una Form Cure a 60 °C durante 10 minutos.

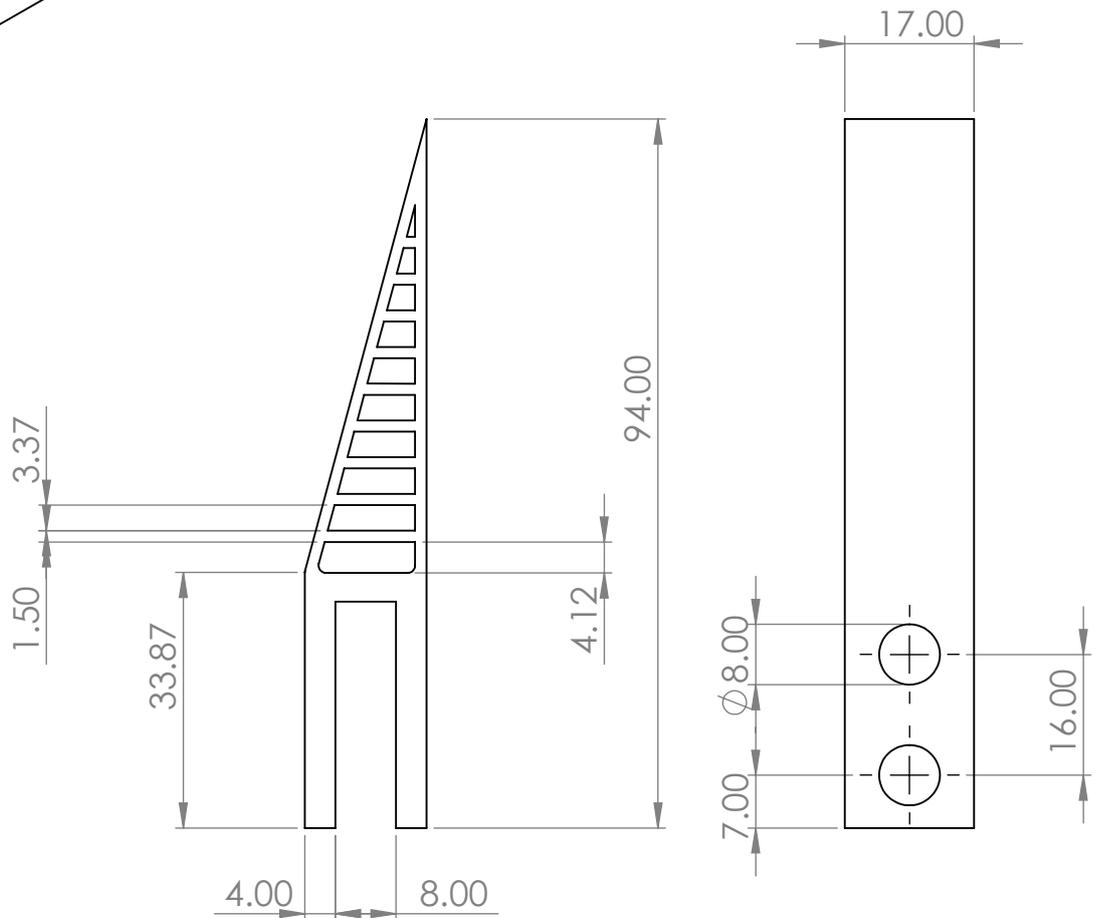
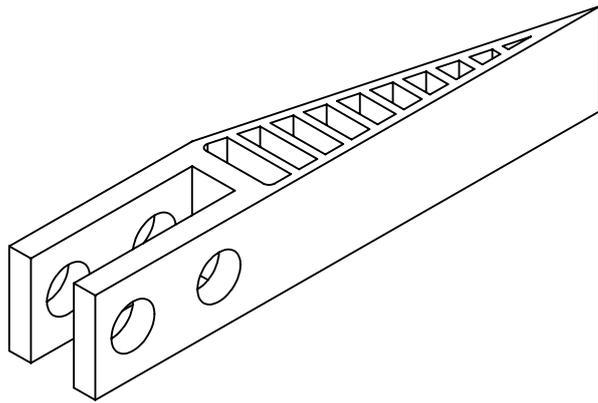
³ El ensayo de tracción se realizó tras más de tres horas a 23 °C, usando un espécimen con troquel C cortado a partir de láminas.

⁴ El ensayo de desgarro se realizó tras más de tres horas a 23 °C, usando un espécimen de desgarro con troquel C impreso directamente.

Compatibilidad de los disolventes

Incremento de peso porcentual a lo largo de 24 horas de un cubo impreso de 1 x 1 x 1 cm, poscurado y sumergido en el disolvente respectivo:

Disolvente	Incremento de peso en 24 h (%)	Disolvente	Incremento de peso en 24 h (%)
Ácido acético, 5 %	0,9	Peróxido de hidrógeno (3 %)	0,7
Acetona	37,4	Isoctano (gasolina)	1,6
Alcohol isopropílico	11,7	Aceite mineral ligero	0,1
Lejía, ~5 % NaOCl	0,6	Aceite mineral pesado	<0,1
Acetato de butilo	51,4	Agua salada (3,5 % NaCl)	0,5
Diésel	2,3	Hidróxido de sodio (0,025 %, pH = 10)	0,6
Éter monometílico de dietilenglicol	19,3	Agua	0,7
Aceite hidráulico	1,0	Xileno	64,1
Skydrol 5	10,7	Ácido fuerte (HCl concentrado)	28,6
Éter monometílico de tripropilenglicol	13,6		



UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN MILLIMETERS
 SURFACE FINISH:
 TOLERANCES:
 LINEAR:
 ANGULAR:

FINISH:

DEBURR AND
 BREAK SHARP
 EDGES

DO NOT SCALE DRAWING

REVISION

NAME	SIGNATURE	DATE
DRAWN AQC		
CHK'D		
APP'VD AQC		
MFG		
Q.A		

TITLE:
Finger: Horizontal

MATERIAL:
 FormLabs 80A Resin

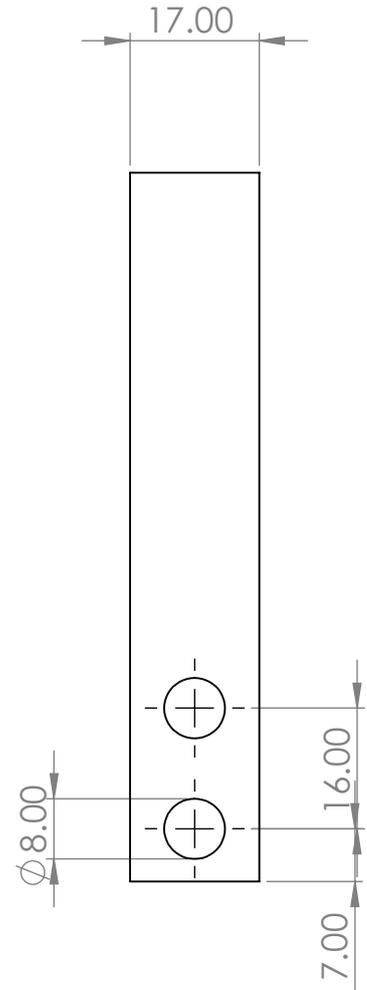
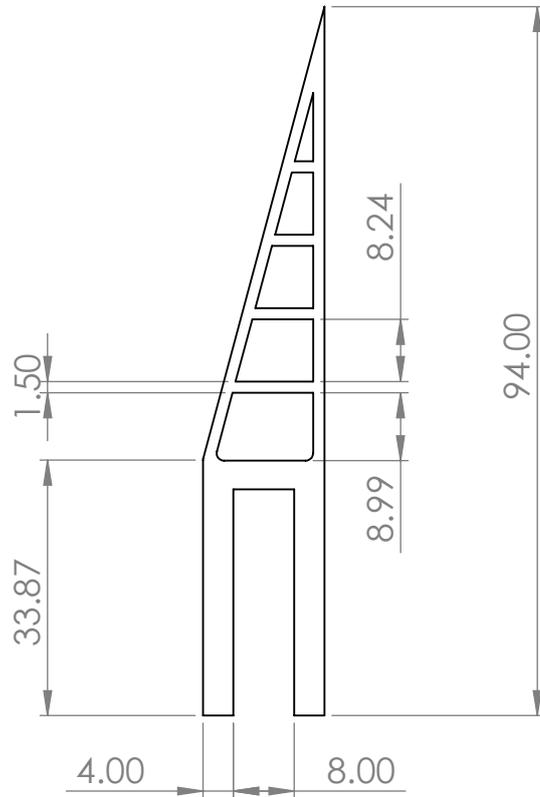
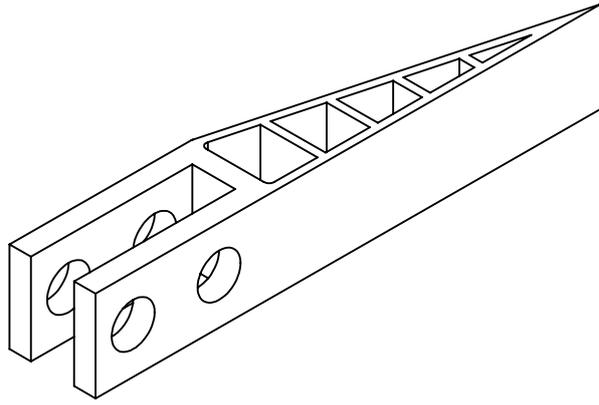
DWG NO.
 FinRay_2claw_horizontal

A4

WEIGHT:

SCALE:1:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN MILLIMETERS
 SURFACE FINISH:
 TOLERANCES:
 LINEAR:
 ANGULAR:

FINISH:

DEBURR AND
 BREAK SHARP
 EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	AQC		
CHK'D			
APPV'D	AQC		
MFG			
Q.A			

TITLE:

Finger:
 horizontal_4v

MATERIAL:

FormLabs 80A Resin

DWG NO.

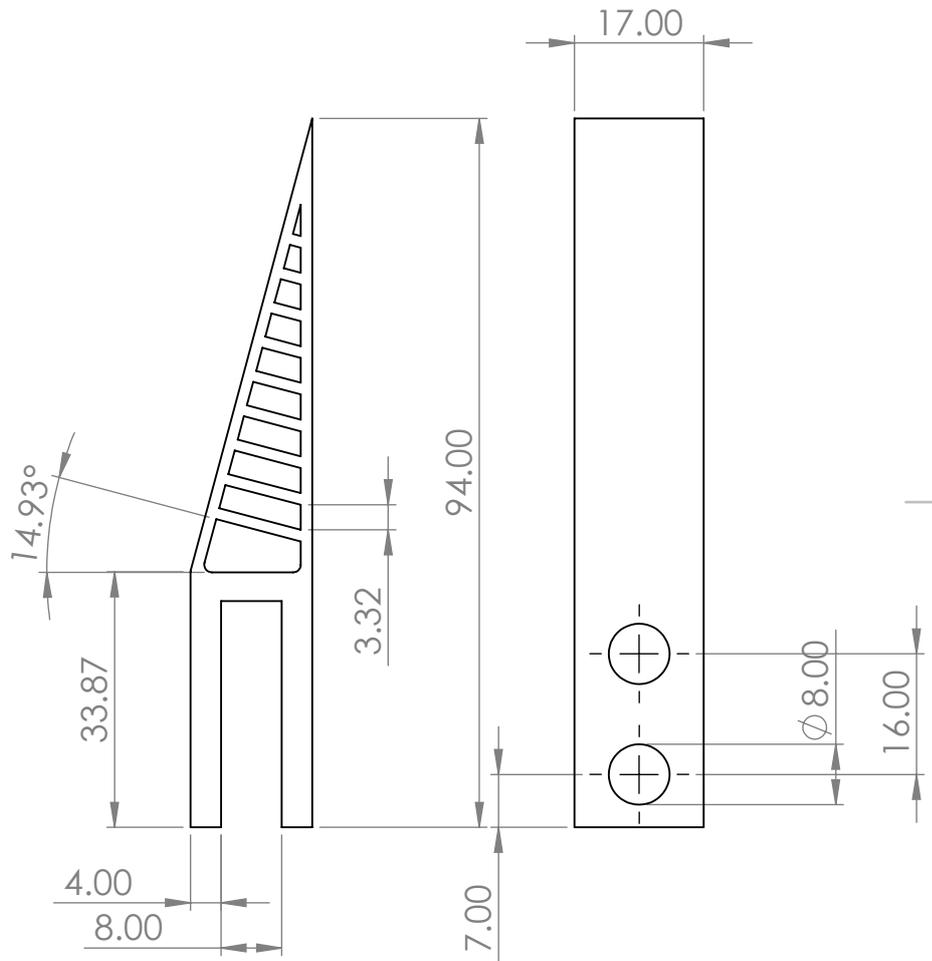
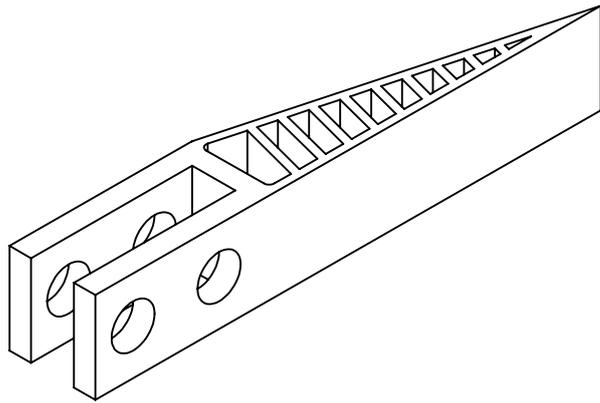
FinRay_2claw_horizontal_4v

A4

WEIGHT:

SCALE:1:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN MILLIMETERS
 SURFACE FINISH:
 TOLERANCES:
 LINEAR:
 ANGULAR:

FINISH:

DEBURR AND
 BREAK SHARP
 EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	AQC		
CHK'D			
APPV'D	AQC		
MFG			
Q.A			

TITLE:

Finger: angular

MATERIAL:

FormLabs 80A Resin

DWG NO.

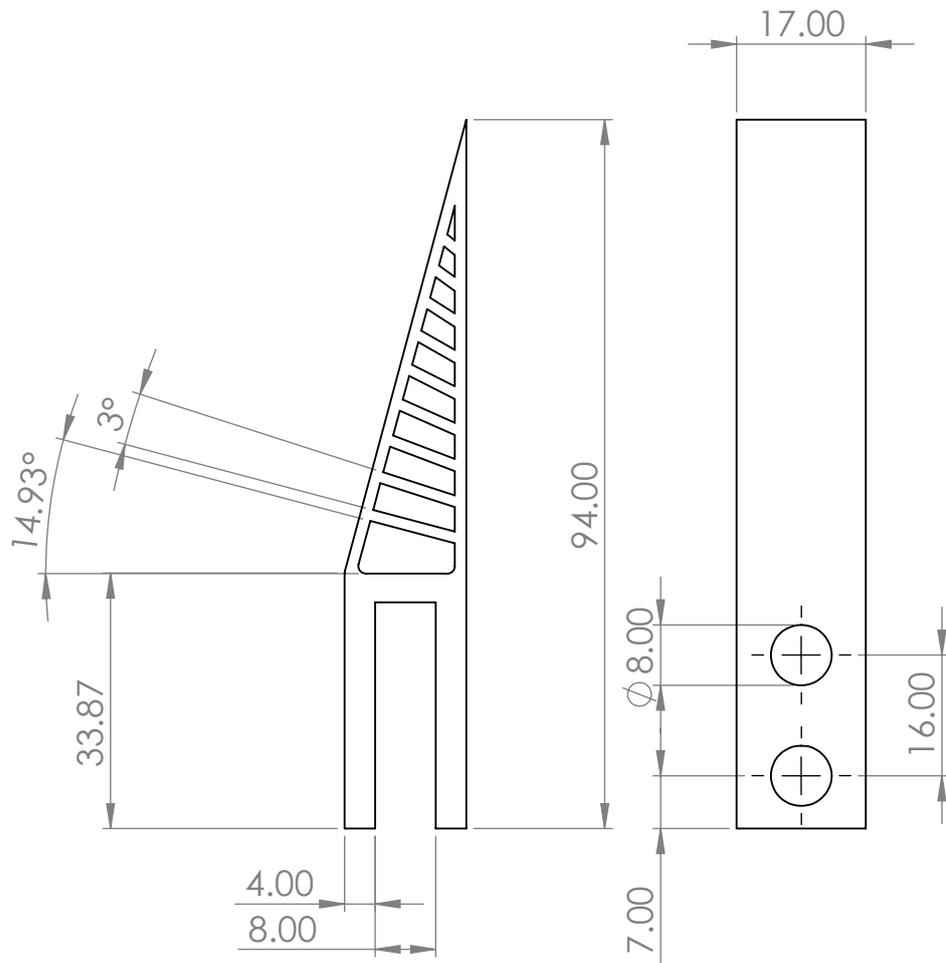
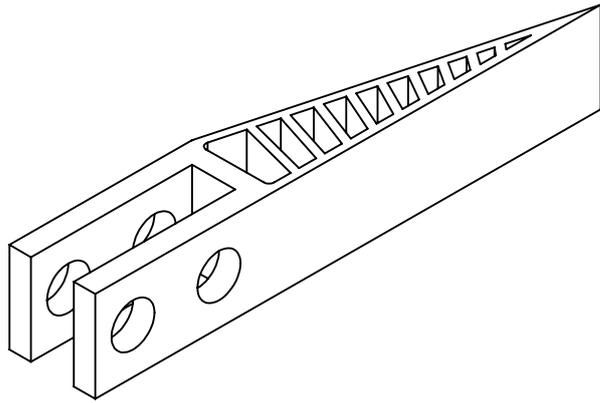
FinRay_2claw_angular

A4

WEIGHT:

SCALE:1:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN MILLIMETERS
 SURFACE FINISH:
 TOLERANCES:
 LINEAR:
 ANGULAR:

FINISH:

DEBURR AND
 BREAK SHARP
 EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	AQC		
CHK'D			
APPV'D	AQC		
MFG			
Q.A			

TITLE:

Finger: progressive

MATERIAL:

FormLabs 80A Resin

DWG NO.

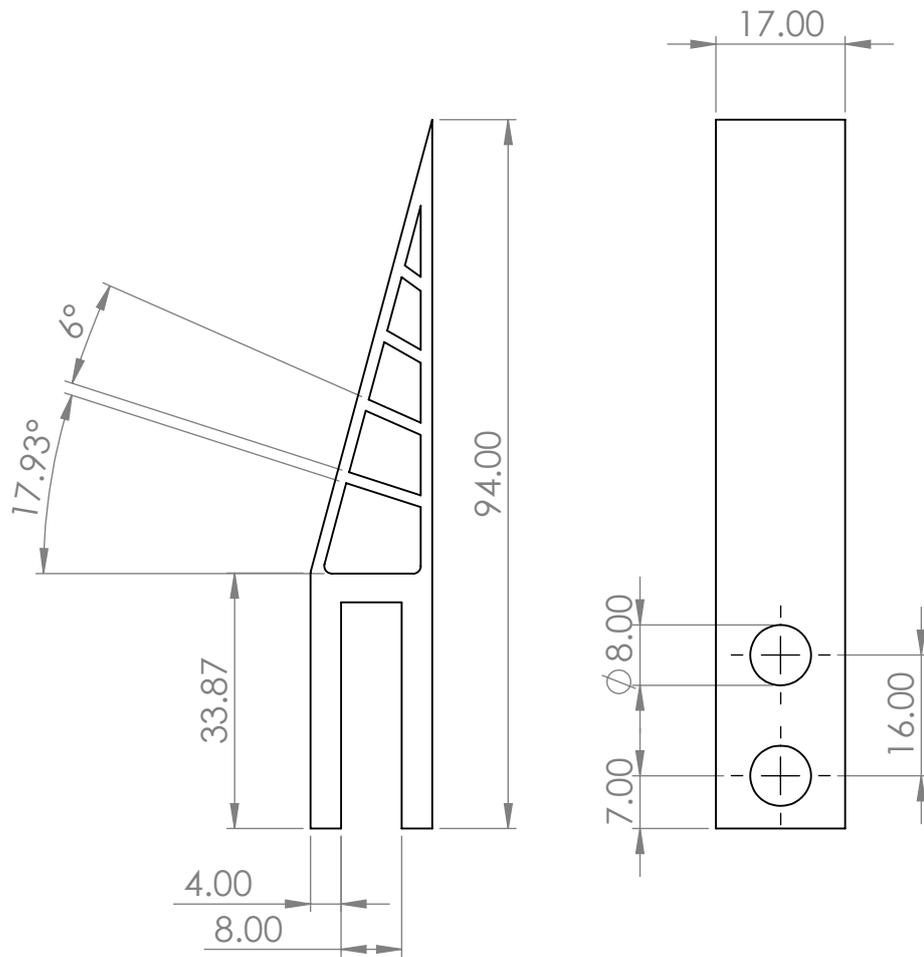
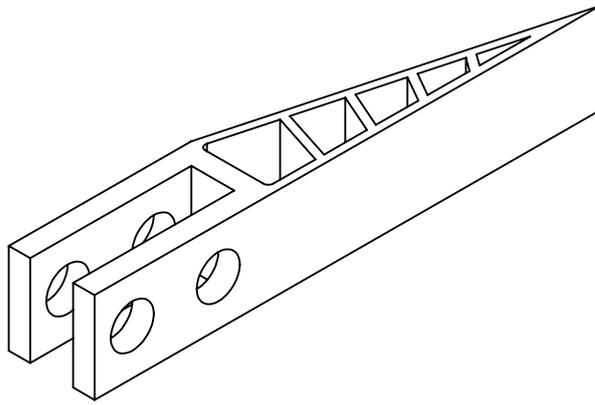
FinRay_2claw_progressive

A4

WEIGHT:

SCALE:1:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN MILLIMETERS
 SURFACE FINISH:
 TOLERANCES:
 LINEAR:
 ANGULAR:

FINISH:

DEBURR AND
 BREAK SHARP
 EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	AQC		
CHK'D			
APPV'D	AQC		
MFG			
Q.A			

TITLE:

Finger:
 progressive_4v

MATERIAL:

FromLabs 80A Resin

DWG NO.

FinRay_2claw_progressive_4v A4

WEIGHT:

SCALE:1:1

SHEET 1 OF 1

Solver Output

Ansys Mechanical Enterprise Academic Student

```
-----  
| WELCOME TO THE ANSYS (R) PROGRAM |  
-----
```

```
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```

2022 R1

Point Releases and Patches installed:

```
Ansys, Inc. Products 2022 R1  
Autodyn 2022 R1  
SpaceClaim 2022 R1  
CFX (includes CFD-Post) 2022 R1  
Chemkin 2022 R1  
EnSight 2022 R1  
FEMAP-ICE 2022 R1  
Fluent (includes CFD-Post) 2022 R1  
Polyflow (includes CFD-Post) 2022 R1  
Forte (includes EnSight) 2022 R1  
TurboGrid 2022 R1  
Aqaa 2022 R1  
Mechanical Products 2022 R1  
Actix Geometry Interface 2022 R1  
AutoCAD Geometry Interface 2022 R1  
Catia, Version 4 Geometry Interface 2022 R1  
Catia, Version 5 Geometry Interface 2022 R1  
Catia, Version 6 Geometry Interface 2022 R1  
Creo Elements/Direct Modeling Geometry Interface 2022 R1  
Creo Parametric Geometry Interface 2022 R1  
Inventor Geometry Interface 2022 R1  
JTopas Geometry Interface 2022 R1  
NX Geometry Interface 2022 R1  
Parasolid Geometry Interface 2022 R1  
Solid Edge Geometry Interface 2022 R1  
SOLIDWORKS Geometry Interface 2022 R1  
Academic Student 2022 R1
```

***** ANSYS COMMAND LINE ARGUMENTS *****

```
BATCH MODE REQUESTED (-b) = NOLIST  
INPUT FILE COPY MODE (-c) = COPY  
DISTRIBUTED MEMORY PARALLEL REQUESTED  
 2 PARALLEL PROCESSES REQUESTED WITH SINGLE THREAD PER PROCESS  
TOTAL OF 2 CORES REQUESTED  
INPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys\_ProjectScratch\scrA33B\dummy.dat  
OUTPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys\_ProjectScratch\scrA33B\solve.out  
START-UP FILE MODE = NOREAD  
STOP FILE MODE = NOREAD  
RELEASE= 2022 R1 BUILID= 22.1 UP2021129 VERSION=WINDOWS x64  
CURRENT JOBNAME=f11e0 13:37:03 JUN 25, 2022 CP= 0.141
```

```
PARAMETER_DS_PROGRESS = 999.000000  
/INPUT FILE= ds.dat LINE= 0
```

```
*** NOTE *** CP = 0.234 TIME= 13:37:03  
The /CONFIG,NOELOB command is not valid in a Distributed ANSYS  
solution. Command is ignored.
```

```
*GET_WALLSTRT FROM ACT1 ITEM=TIME WALL VALUE= 13.6175000
```

```
TITLE=
```

```
Workbench3_probe--Static Structural (B5)
```

```
ACT Extensions:  
LSDYNA, 2021.1  
5f463412-bd3e-484b-87e7-cbcba665e474, wbx
```

```
SET PARAMETER DIMENSIONS ON WB_PROJECTSCRATCH_DIR
```

```
TYPE=STR DIMENSIONS= Z48 1 1
```

```
PARAMETER_WB_PROJECTSCRATCH_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys\_ProjectScratch\scrA33B\
```

```
SET PARAMETER DIMENSIONS ON WB_SOLVERFILES_DIR
```

```
TYPE=STR DIMENSIONS= Z48 1 1
```

```
PARAMETER_WB_SOLVERFILES_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys\Workbench3_probe_files\4p0\878\WBCH3\
```

```

--- Number of total elements = 2597
*GET WALLSOL FROM ACT1 ITEM=TIME WALL VALUE= 13.6175000
***** SOLUTION *****
***** ANSYS SOLUTION ROUTINE *****

PERFORM A STATIC ANALYSIS
THIS WILL BE A NEW ANALYSIS
PARAMETER_THICKRATIO = 0.5000000000
USE SPARSE MATRIX DIRECT SOLVER
CONTACT INFORMATION PRINTOUT LEVEL 1
DO NOT COMBINE ELEMENT MATRIX FILES (.emat) AFTER DISTRIBUTED PARALLEL SOLUTION
DO NOT COMBINE ELEMENT SAVE DATA FILES (.esav) AFTER DISTRIBUTED PARALLEL SOLUTION
NLDIAG: Nonlinear diagnostics CONT option is set to ON.
Writing frequency : each ITERATION.

DO NOT SAVE ANY RESTART FILES AT ALL
***** SOLVE FOR LS 1 OF 1 *****
*** Set Displacements ***
CMELOCK read of NODE component_CM48UX_XP completed
SELECT COMPONENT_CM48UX_XP
SPECIFIED CONSTRAINT UX FOR SELECTED NODES 1 TO 6857 BY
REAL=1,00000000E+02 DPGC= 0.00000000
ALL SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 1 TO 6857 STEP 1
6857 NODES (OF 6857 DEFINED) SELECTED BY MSEL COMMAND.
*** Component For All Non-Zero UX Displacements ***
SELECT COMPONENT_CM48UX_XP
DEFINITION OF COMPONENT = DISPMONEROOX ENTITY=NODE
ALL SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 1 TO 6857 STEP 1
6857 NODES (OF 6857 DEFINED) SELECTED BY MSEL COMMAND.

PRINTOUT RESUMED BY /GOP
USE 1 SUBSTEPS INITIALLY THIS LOAD STEP FOR ALL DEGREES OF FREEDOM
FOR AUTOMATIC TIME STEPPING
USE 1 SUBSTEPS AS A MAXIMUM
USE 1 SUBSTEPS AS A MINIMUM
TIME= 1.0000
ERASE THE CURRENT DATABASE OUTPUT CONTROL TABLE.

WRITE ALL ITEMS TO THE DATABASE WITH A FREQUENCY OF NONE
FOR ALL APPLICABLE ENTITIES
WRITE NSOL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE RSOL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EANG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE ESHD ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE VENG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE STRS ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPEL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPLI ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE CONT ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
*GET ANSINTER FROM ACT1 ITEM=INT VALUE= 0.0000000
*IF ANSINTER_ (= 0.00000 ) NE
0 (= 0.00000 ) THEN
*ENDIF
*** NOTE *** CP = 0.391 TIME= 13:37:03
The automatic domain decomposition logic has selected the MESH domain
decomposition method with 2 processes per solution.
***** ANSYS SOLVE COMMAND *****
*** WARNING *** CP = 0.391 TIME= 13:37:03
Element shape checking is currently inactive. Issue SHPP,ON or
SHPP,WARN to reactivate, if desired.
*** NOTE *** CP = 0.391 TIME= 13:37:03
The model data was checked and warning messages were found.
Please review output or errors file (
C:\Users\quint\OneDrive\Documents\1\CAI\AlbertoQuintanaTFG\Design\Assemb
ly\Ansys\Project\Scratch\ScrA3B\file0.err ) for these warning
messages.
*** SELECTION OF ELEMENT TECHNOLOGIES FOR APPLICABLE ELEMENTS ***
--- GIVE SUGGESTIONS AND RESET THE KEY OPTIONS ---
ELEMENT TYPE 1 IS SOLID186. KEYOPT(1)=0 IS SUGGESTED AND HAS BEEN RESET.
KEYOPT(1-12)= 0 0 0 0 0 0 0 0 0 0 0 0
ELEMENT TYPE 2 IS SOLID187. IT IS NOT ASSOCIATED WITH FULLY INCOMPRESSIBLE
HYPERELASTIC MATERIALS. NO SUGGESTION IS AVAILABLE AND NO RESETTING IS NEEDED.

*** ANSYS - ENGINEERING ANALYSIS SYSTEM RELEASE 2022 R1 22.1 ***
DISTRIBUTED Ansys Mechanical Enterprise Academic Student
00000000 VERSION=WINDOWS x64 13:37:03 JUN 25, 2022 CP= 0.391
Workbench_probe--Static Structural (B5)

```

SOLUTION OPTIONS

```

PROBLEM DIMENSIONALITY. . . . . 3-D
DEGREES OF FREEDOM. . . . . UX UY UZ
ANALYSIS TYPE . . . . . STATIC (STEADY-STATE)
OFFSET TEMPERATURE FROM ABSOLUTE ZERO . . . . . 273.15
EQUATION SOLVER OPTION. . . . . SPARSE
GLOBALLY ASSEMBLED MATRIX . . . . . SYMMETRIC

```

Use constant contact stiffness
 Default Max. friction stress TRMAX 0.1000E+21
 Average contact surface length 0.57199E-02
 Average contact pair depth 0.17615E-02
 Average target surface length 0.58675E-02
 Default pinball region factor FINE 0.25000
 *WARNING: The default pinball radius may be too small to capture
 contacting zones under small sliding assumption. Redefine the pinball
 radius if necessary.
 The resulting pinball region 0.44039E-03
 Initial penetration/gap is excluded.
 Bonded contact (always) is defined.

*** NOTE *** CP = 0.422 TIME= 13:37:03
 Min. Initial gap 4.76475791E-07 was detected between contact element
 4319 and target element 4284.
 Contact is detected due to initial settings.

Max. Geometric gap 4.37059348E-04 has been detected between contact
 element 4308 and target element 4282.
 *WARNING: The geometric gap/penetration may be too large. Increase
 pinball radius if it is a true geometric gap/penetration. Decrease
 pinball if it is a false one.

DISTRIBUTED DOMAIN DECOMPOSER

...Number of elements: 2357
 ...Number of nodes: 8507
 ...Decompose to 2 CPU domains
 ...Element load balance ratio = 1.014

LOAD STEP OPTIONS

LOAD STEP NUMBER 1
 TIME AT END OF THE LOAD STEP 1.0000
 NUMBER OF SUBSTEPS 1
 STEP CHANGE BOUNDARY CONDITIONS NO
 PRINT OUTPUT CONTROLS NO PRINTOUT
 DATABASE OUTPUT CONTROLS NO PRINTOUT

ITEM	FREQUENCY	COMPONENT
ALL	NONE	
NSOL	ALL	
RSOL	ALL	
ENSG	ALL	
ETMP	ALL	
VENG	ALL	
STRES	ALL	
EPEL	ALL	
EPFL	ALL	
CONT	ALL	

SOLUTION MONITORING INFO IS WRITTEN TO FILE=
 file.mstr

***** PRECISE MASS SUMMARY *****

TOTAL RIGID BODY MASS MATRIX ABOUT ORIGIN

Translational mass			Coupled translational/rotational mass		
0.55486	0.0000	0.0000	0.0000	-0.13996E-01	-0.27743E-01
0.0000	0.55486	0.0000	0.13996E-01	0.0000	0.12762E-01
0.0000	0.0000	0.55486	0.27743E-01	-0.12762E-01	0.0000

Rotational mass (inertia)

0.23338E-02	-0.63808E-03	0.32191E-03
-0.63808E-03	0.70899E-03	0.69981E-03
0.32191E-03	0.69981E-03	0.21742E-02

TOTAL MASS = 0.55486
 The mass principal axes coincide with the global Cartesian axes
 CENTER OF MASS (X,Y,Z)= 0.23000E-01 0.50000E-01 -0.25225E-01

TOTAL INERTIA ABOUT CENTER OF MASS

0.49195E-03	0.69977E-04	-0.31231E-12
0.69977E-04	0.62418E-04	0.19055E-17
-0.31231E-12	0.19055E-17	0.49359E-03

The inertia principal axes coincide with the global Cartesian axes

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE	MASS
1	0.554856

Range of element maximum matrix coefficients in global coordinates
 Maximum = 1.30579394E+20 at element 435.
 Minimum = 22845.683 at element 2266.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	544	SOLID186	0.109	0.000201
2	1993	SOLID187	0.266	0.000133
3	30	CONTA174	0.000	0.000000
4	30	TARGE170	0.000	0.000000

Time at end of element matrix formulation CP = 0.879.

DISTRIBUTED SPARSE MATRIX DIRECT SOLVER.
 Number of equations = 18841, Maximum wavefront = 267

Process memory allocated for solver = 47.614 MB
 Process memory required for in-core solution = 45.875 MB
 Process memory required for out-of-core solution = 26.968 MB

Total memory allocated for solver = 87.911 MB
 Total memory required for in-core solution = 84.465 MB
 Total memory required for out-of-core solution = 44.291 MB

*** NOTE *** CP = 1.125 TIME= 13:37:04
 The Distributed Sparse Matrix Solver is currently running in the
 in-core memory mode. This memory mode uses the most amount of memory
 in order to avoid using the hard drive as much as possible, which most
 often results in the fastest solution time. This mode is recommended
 if enough physical memory is present to accommodate all of the solver
 data.
 CPUReq= 8285 totEgn= 8285 Job CP sec= 1.328
 Factor Doses 1001 Factor Wall sec= 0.119 rates 10.2 Gflops
 Distributed sparse solver maximum pivots 4.1164003E+09 at node 1707
 UZ.
 Distributed sparse solver minimum pivots 1176.44593 at node 3175 UZ.
 Distributed sparse solver minimum pivot in absolute value= 1176.44593
 at node 3175 UZ.

*** WARNING *** CP = 1.375 TIME= 13:37:04
 Contact element 4315 (real ID 4) status changes abruptly from
 no-contact -> contact (with target element 4284).

*** ELEMENT RESULT CALCULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	544	SOLID186	0.031	0.000057
2	1993	SOLID187	0.109	0.000055
3	30	CONTA174	0.000	0.000000

*** NODAL LOAD CALCULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
------	--------	-------	----------	--------

EXIT THE ANSYS POSTI DATABASE PROCESSOR

***** ROUTINE COMPLETED ***** CP = 1.609

PRINTOUT RESUMED BY /GOP

*GET _WALLOK FROM ACTI ITEM=TIME WALL VALUE= 13.6177778

PARAMETER _PRETIME = 0.00000000

PARAMETER _SOLTIME = 1.00000000

PARAMETER _POSTIME = 0.00000000

PARAMETER _TOTALTIM = 1.00000000

*GET _DESRATIO FROM ACTI ITEM=SOLU DLRR VALUE= 1.01401869

*GET _COMBTIME FROM ACTI ITEM=SOLU COMB VALUE= 0.205484000E-01

*GET _SEMODE FROM ACTI ITEM=SOLU SSMR VALUE= 2.00000000

*GET _NDDFS FROM ACTI ITEM=SOLU NDOF VALUE= 18841.0000

*GET _SOL_END TIME FROM ACTI ITEM=SET TIME VALUE= 1.00000000

*IF _sol_end time (= 1.00000) EQ

1.000000 (= 1.00000) THEN

/FCLEAN COMMAND REMOVING ALL LOCAL FILES

*ENDIF

--- Total number of nodes = 6897

--- Total number of elements = 2997

--- Element load balance ratio = 1.01401869

--- Time to combine distributed files = 2.05484E-02

--- Sparse memory mode = 2

--- Number of DOF = 18841

EXIT ANSYS WITHOUT SAVING DATABASE

NUMBER OF WARNING MESSAGES ENCOUNTERED= 2

NUMBER OF ERROR MESSAGES ENCOUNTERED= 0

----- D I S T R I B U T E D A N S Y S S T A T I S T I C S -----

Release: 2022 R1 Build: 22.1 Update: UP20211129 Platform: WINNDSWS x64

Date Run: 06/23/2022 Time: 13:37 Process ID: 23284

Operating System: Windows 10 (Build: 22000)

Processor Model: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz

Compiler: Intel(R) Fortran Compiler Version 19.0.5 (Build: 20190815)

Intel(R) C/C++ Compiler Version 19.0.5 (Build: 20190815)

Intel(R) Math Kernel Library Version 2020.0.0 Product Build 20191125

BLAS Library supplied by Intel(R) MKL

Number of machines requested : 1

Total number of cores available : 12

Number of physical cores available : 6

Number of processes requested : 2

Number of threads per process requested : 1

Total number of cores requested : 2 (Distributed Memory Parallel)

MPI Type: INTEL MPI

MPI Version: Intel(R) MPI Library 2019 Update 10 for Windows* OS

GPU Acceleration: Not Requested

Job Name: file0

Input File: dummy.dat

Core Machine Name Working Directory

0 HP-A C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\Scra33B

1 HP-A C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\Scra33B

Latency time from master to core 1 = 2.471 microseconds

Communication speed from master to core 1 = 3760.85 MB/sec

Total CPU time for main thread : 1.7 seconds

Total CPU time summed for all threads : 2.0 seconds

Elapsed time spent obtaining a license : 0.4 seconds

Elapsed time spent pre-processing model (/PREP7) : 0.0 seconds

Elapsed time spent solution - preprocessing : 0.1 seconds

Elapsed time spent computing solution : 0.8 seconds

Elapsed time spent solution - postprocessing : 0.0 seconds

Elapsed time spent post-processing model (/POST1) : 0.0 seconds

Equation solver used : Sparse (symmetric)

Equation solver computational rate : 17.0 Gflops

Sum of memory used on all processes : 288.0 MB

Sum of memory allocated on all processes : 3136.0 MB

Physical memory available : 16 GB

Total amount of I/O written to disk : 0.0 GB

Total amount of I/O read from disk : 0.0 GB

----- E N D D I S T R I B U T E D A N S Y S S T A T I S T I C S -----

| DISTRIBUTED ANSYS RUN COMPLETED |

| Ansys 2022 R1 Build 22.1 UP20211129 WINNDSWS x64 |

| Database Requested(-db) 1024 MB Scratch Memory Requested 1024 MB |

| Maximum Database Used 3 MB Maximum Scratch Memory Used 146 MB |

| CP Time (sec) = 1.969 Time = 13:37:05 |

| Elapsed Time (sec) = 3.000 Date = 06/23/2022 |

Solver Output

Ansys Mechanical Enterprise Academic Student

```
-----  
| WELCOME TO THE ANSYS (R) PROGRAM |  
-----
```

```
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*****
```

```
2022 R1  
Point Releases and Patches installed:  
Ansys, Inc. Products 2022 R1  
Autodyn 2022 R1  
SpaceClaim 2022 R1  
CFX (includes CFD-Post) 2022 R1  
Chemkin 2022 R1  
EnSight 2022 R1  
FEMAP-ICE 2022 R1  
Fluent (includes CFD-Post) 2022 R1  
Polyflow (includes CFD-Post) 2022 R1  
Forte (includes EnSight) 2022 R1  
TurboGrid 2022 R1  
Aqaa 2022 R1  
Mechanical Products 2022 R1  
Actix Geometry Interface 2022 R1  
AutoCAD Geometry Interface 2022 R1  
Catia, Version 4 Geometry Interface 2022 R1  
Catia, Version 5 Geometry Interface 2022 R1  
Catia, Version 6 Geometry Interface 2022 R1  
Creo Elements/Direct Modeling Geometry Interface 2022 R1  
Creo Parametric Geometry Interface 2022 R1  
Inventor Geometry Interface 2022 R1  
J/Open Geometry Interface 2022 R1  
NX Geometry Interface 2022 R1  
Parasolid Geometry Interface 2022 R1  
Solid Edge Geometry Interface 2022 R1  
SOLIDWORKS Geometry Interface 2022 R1  
Academic Student 2022 R1
```

```
***** ANSYS COMMAND LINE ARGUMENTS *****  
BATCH MODE REQUESTED (-b) = NOLIST  
INPUT FILE COPY MODE (-c) = COPY  
DISTRIBUTED MEMORY PARALLEL REQUESTED  
 2 PARALLEL PROCESSES REQUESTED WITH SINGLE THREAD PER PROCESS  
TOTAL OF 2 CORES REQUESTED  
INPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys_ProjectScratch\scrf31b\dummy.dat  
OUTPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys_ProjectScratch\scrf31b\solve.out  
START-UP FILE MODE = NOREAD  
STOP FILE MODE = NOREAD  
RELEASE= 2022 R1 BUILID= 22.1 UP2021129 VERSION=WINDOWS x64  
CURRENT JOBNAME=f11e0 17:38:21 JUN 25, 2022 CP= 0.141
```

```
PARAMETER_DS_PROGRESS = 999.000000  
/INPUT FILE= ds.dat LINE= 0
```

```
*** NOTE *** CP = 0.297 TIME= 17:38:21  
The /CONFIG,NOREAD command is not valid in a Distributed ANSYS  
solution. Command is ignored.
```

```
*GET_WALLSTRT FROM ACT1 ITEM=TIME WALL VALUE= 17.6391667
```

```
TITLE=
```

```
Workbench3_probe--Static Structural (H5)
```

```
ACT Extensions:  
LSDYNA, 2021.1  
5f463412-bd3e-484b-87e7-cbcba65e474, wbx
```

```
SET PARAMETER DIMENSIONS ON WB_PROJECTSCRATCH_DIR
```

```
TYPE=STR DIMENSIONS= 248 1 1
```

```
PARAMETER_WB_PROJECTSCRATCH_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys_ProjectScratch\scrf31b\
```

```
SET PARAMETER DIMENSIONS ON WB_SOLVERFILES_DIR
```

```
TYPE=STR DIMENSIONS= 248 1 1
```

```
PARAMETER_WB_SOLVERFILES_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys\Workbench3_probe_files\4p0\878-1\MECH\
```

```

*GET WALLSOL FROM ACT1 ITEM=TIME WALL VALUE= 17.6391667
*****
***** ANSYS SOLUTION ROUTINE *****

PERFORM A STATIC ANALYSIS
THIS WILL BE A NEW ANALYSIS
PARAMETER_THICKRATIO = 0.500000000
USE SPARSE MATRIX DIRECT SOLVER
CONTACT INFORMATION PRINTOUT LEVEL 1
DO NOT COMBINE ELEMENT MATRIX FILES (.emat) AFTER DISTRIBUTED PARALLEL SOLUTION
DO NOT COMBINE ELEMENT SAVE DATA FILES (.esav) AFTER DISTRIBUTED PARALLEL SOLUTION
NLDIAG: Nonlinear diagnostics CONT option is set to ON.
Scaling frequency: each ITERATION.
DO NOT SAVE ANY RESTART FILES AT ALL
*****
***** SOLVE FOR LS 1 OF 1 *****
*** Set Displacement ***
CMBLOCK read of NODE component _CM39UX_XF completed
SELECT COMPONENT_CM39UX_XF
SPECIFIED CONSTRAINT UX FOR SELECTED NODES 1 TO 5979 BY 1
REAL=-1.00000000E-02 IMAG= 0.00000000
ALL SELECT FOR ITEM-NODE COMPONENT=
IN RANGE 1 TO 5979 STEP 1
5979 NODES (OF 5979 DEFINED) SELECTED BY NSEL COMMAND.
*** Component For all Non-zero UX Displacements ***
SELECT COMPONENT_CM39UX_XF
DEFINITION OF COMPONENT = _DISPROMZEROUX ENTITY-NODE
ALL SELECT FOR ITEM-NODE COMPONENT=
IN RANGE 1 TO 5979 STEP 1
5979 NODES (OF 5979 DEFINED) SELECTED BY NSEL COMMAND.
PRINTOUT RESUMED BY /GOP
USE 1 SUBSTEPS INITIALLY THIS LOAD STEP FOR ALL DEGREES OF FREEDOM
FOR AUTOMATIC TIME STEPPING:
USE 1 SUBSTEPS AS A MAXIMUM
USE 1 SUBSTEPS AS A MINIMUM
TIME= 1.0000
ERASE THE CURRENT DATABASE OUTPUT CONTROL TABLE.
WRITE ALL ITEMS TO THE DATABASE WITH A FREQUENCY OF NONE
FOR ALL APPLICABLE ENTITIES
WRITE ESOL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE ESOL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EAMG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE ETMP ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE VENG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE STRS ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPEL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPFL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE CONT ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
*GET ANSINTER FROM ACT1 ITEM=INT VALUE= 0.00000000
*IF ANSINTER (= 0.00000 ) NE
0 (= 0.00000 ) THEN
*ENDIF
*** NOTE *** CP = 0.453 TIME= 17:38:21
The automatic domain decomposition logic has selected the MESH domain
decomposition method with 2 processes per solution.
***** ANSYS SOLVE COMMAND *****
*** WARNING *** CP = 0.453 TIME= 17:38:21
Element shape checking is currently inactive. Issue SHPP,ON or
SHPP,WARN to reactivate, if desired.
*** NOTE *** CP = 0.453 TIME= 17:38:21
The model data was checked and warning messages were found.
Please review output or errors file (
C:\Users\jquint\OneDrive\Documents\JCR\AlbertoQuintana\TP\Design\Assemb
ly\Ansys_Project\Scratch\Scr631B\Zile0.err ) for these warning
messages.
*** SELECTION OF ELEMENT TECHNOLOGIES FOR APPLICABLE ELEMENTS ***
*** GIVE SUGGESTIONS AND RESET THE KEY OPTIONS ***
ELEMENT TYPE 1 IS SOLID187. IT IS NOT ASSOCIATED WITH FULLY INCOMPRESSIBLE
HYPERELASTIC MATERIALS. NO SUGGESTION IS AVAILABLE AND NO RESETTING IS NEEDED.
ELEMENT TYPE 2 IS SOLID186. KEYOPT(2)=0 IS SUGGESTED AND HAS BEEN RESET.
KEYOPT(1-12)= 0 0 0 0 0 0 0 0 0 0 0 0
*** ANSYS - ENGINEERING ANALYSIS SYSTEM RELEASE 2022 R1 22.1 ***
DISTRIBUTED Ansys Mechanical Enterprise Academic Student
00000000 VERSION=WINDOWS x64 17:38:21 JUN 25, 2022 CP= 0.453
Workbench_probe-Static Structural (R5)

SOLUTION OPTIONS
PROBLEM DIMENSIONALITY . . . . . 3-D
DEGREES OF FREEDOM . . . . . UX UY UZ
ANALYSIS TYPE . . . . . STATIC (STEADY-STATE)
OFFSET TEMPERATURE FROM ABSOLUTE ZERO . . . . . 273.15
EQUATION SOLVER OPTION . . . . . SPARSE
GLOBALLY ASSEMBLED MATRIX . . . . . SYMMETRIC
*** NOTE *** CP = 0.453 TIME= 17:38:21

```

Default opening contact stiffness OPSP will be used.
Default Lagrang stiffness factor FTL 1.0000
Use constant contact stiffness
Default Max. friction stress TMAX 0.1000E+21
Average contact surface length 0.58694E-02
Average contact pair depth 0.51223E-02
Average target surface length 0.56505E-02
Default pinball region factor PINB 0.25000
The resulting pinball region 0.12806E-02
Initial penetration/gap is excluded.
Bonded contact (always) is defined.

*** NOTE *** CP = 0.484 TIME= 17:38:21
Min. Initial gap 5.158391073E-05 was detected between contact element 3614 and target element 3565.
Contact is detected due to initial settings.

Max. Geometric gap 7.533930422E-04 has been detected between contact element 3610 and target element 3578.
WARNING: The geometric gap/penetration may be too large. Increase pinball radius if it is a true geometric gap/penetration. Decrease pinball if it is a false one.

DISTRIBUTED DOMAIN DECOMPOSER

..Number of elements: 2131
..Number of nodes: 5979
..Decompose to 2 CPU domains
..Element load balance ratio = 1.017

LOAD STEP OPTIONS

LOAD STEP NUMBER: 1
TIME AT END OF THE LOAD STEP: 1.0000
NUMBER OF SUBSTEPS: 1
STEP CHANGE BEHAVIOR CONTROLS: NO
PRINT OUTPUT CONTROLS: NO PRINTOUT
DATABASE OUTPUT CONTROLS

ITEM	FREQUENCY	COMPONENT
ALL	NONE	
RSOL	ALL	
RSOL	ALL	
ESNG	ALL	
ETNG	ALL	
VENG	ALL	
STES	ALL	
EFEL	ALL	
EFEL	ALL	
CONV	ALL	

SOLUTION MONITORING INFO IS WRITTEN TO FILE:
file.mnt

***** PRECISE MASS SUMMARY *****

TOTAL RIGID BODY MASS MATRIX ABOUT ORIGIN			Coupled translational/rotational mass		
Translational mass					
0.55486	0.0000	0.0000	0.0000	-0.10418E-01	-0.27743E-01
0.0000	0.55486	0.0000	0.10418E-01	0.0000	0.21545E-01
0.0000	0.0000	0.55486	0.27743E-01	-0.21545E-01	0.0000
Rotational mass (inertia)					
			0.20763E-02	-0.10773E-02	0.40455E-03
			-0.10773E-02	0.10947E-02	0.32093E-03
			0.40455E-03	0.32093E-03	0.27174E-02

TOTAL MASS = 0.55486
The mass principal axes coincide with the global Cartesian axes
CENTER OF MASS (X,Y,Z) = 0.38831E-01 0.50000E-01 -0.18776E-01

TOTAL INERTIA ABOUT CENTER OF MASS
0.49359E-03 -0.86572E-18 0.24364E-12
-0.86572E-18 0.62431E-04 0.33932E-18
0.24364E-12 0.33932E-18 0.49359E-03
The inertia principal axes coincide with the global Cartesian axes

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE	MASS
2	0.554856

Range of element maximum matrix coefficients in global coordinates
Maximum = 1.56047691E+09 at element 523.
Minimum = 24961.2539 at element 1079.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	1544	SOLID187	0.141	0.000091
2	527	SOLID186	0.219	0.000415
3	30	CONV114	0.000	0.000000
4	30	TARGE170	0.000	0.000000

Time at end of element matrix formulation CP = 0.90625.

DISTRIBUTED SPARSE MATRIX DIRECT SOLVER.

Number of equations = 16213, Maximum wavefront = 234
Process memory allocated for solver = 47.870 MB
Process memory required for in-core solution = 45.089 MB
Process memory required for out-of-core solution = 26.024 MB
Total memory allocated for solver = 72.904 MB
Total memory required for in-core solution = 70.082 MB
Total memory required for out-of-core solution = 38.532 MB

*** NOTE *** CP = 1.156 TIME= 17:38:22

The Distributed Sparse Matrix Solver is currently running in the in-core memory mode. This memory mode uses the most amount of memory in order to avoid using the hard drive as much as possible, which most often results in the fastest solution time. This mode is recommended if enough physical memory is present to accommodate all of the solver data.

curEigs= 6879 totEigs= 6879 Job CP sec= 1.155
Factor Done= 100% Factor Wall sec= 0.111 rate= 10.9 GFlops
Distributed sparse solver maximum pivot= 4.792035497E+09 at node 1596 UX
Distributed sparse solver minimum pivot= 402.651594 at node 2760 UX.
Distributed sparse solver minimum pivot in absolute value= 402.651594 at node 2760 UX.

*** ELEMENT RESULT CALCULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	1544	SOLID187	0.125	0.000081
2	527	SOLID186	0.094	0.000178
3	30	CONV114	0.000	0.000000

*** NODAL LOAD CALCULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	1544	SOLID187	0.016	0.000010
2	527	SOLID186	0.000	0.000000
3	30	CONV114	0.000	0.000000

*** LOAD STEP 1 SUBSTEP 1 COMPLETED. CUM ITER = 1

```

PRINTOUT RESUMED BY /GOP
*GET _WALLDOME FROM ACTI ITEM=TIME WALL VALUE= 17.6394444
PARAMETER _PREFTIME = 0.000000000
PARAMETER _SOLVTIME = 1.000000000
PARAMETER _POSTIME = 0.000000000
PARAMETER _TOTALTIM = 1.000000000
*GET _DLBRATIO FROM ACTI ITEM=SOLU DLBR VALUE= 1.01712655
*GET _COMBTIME FROM ACTI ITEM=SOLU COMB VALUE= 0.216151000E-01
*GET _SEMCOE FROM ACTI ITEM=SOLU SEMM VALUE= 2.000000000
*GET _NDOPFS FROM ACTI ITEM=SOLU NDOP VALUE= 16213.00000
*GET _SOL_END_TIME FROM ACTI ITEM=SET TIME VALUE= 1.000000000
*IF _sol_end_time ( = 1.000000 ) EQ
1.000000 ( = 1.000000 ) THEN
/FCLEAN COMMAND REMOVING ALL LOCAL FILES
*ENDIF
--- Total number of nodes = 5979
--- Total number of elements = 2131
--- Element load balance ratio = 1.01712655
--- Time to combine distributed files = 2.16151E-02
--- Sparse memory mode = 2
--- Number of DOF = 16213
EXIT ANSYS WITHOUT SAVING DATABASE

```

```

NUMBER OF WARNING MESSAGES ENCOUNTERED= 1
NUMBER OF ERROR MESSAGES ENCOUNTERED= 0
----- D I S T R I B U T E D   A N S Y S   S T A T I S T I C S -----

```

```

Release: 2022 R1          Build: 22.1          Update: UP20211129 Platform: WINDOWS x64
Date Run: 06/23/2022 Time: 17:38 Process ID: 17648
Operating System: Windows 10 (Build: 22000)
Processor Model: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
Compiler: Intel(R) Fortran Compiler Version 19.0.5 (Build: 20190815)
Intel(R) C/C++ Compiler Version 19.0.5 (Build: 20190815)
Intel(R) Math Kernel Library Version 2020.0.0 Product Build 20191125
MKL Library supplied by Intel(R) MKL
Number of machines requested : 1
Total number of cores available : 12
Number of physical cores available : 6
Number of processes requested : 2
Number of threads per process requested : 1
Total number of cores requested : 2 (Distributed Memory Parallel)
MPI Type: INTEL MPI
MPI Version: Intel(R) MPI Library 2019 Update 10 for Windows* OS

```

```

GPU Acceleration: Not Requested
Job Name: file0
Input File: dummy.dat

```

```

Core Machine Name Working Directory
-----
0 HP-A C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\Scr631B
1 HP-A C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\Scr631B
Latency time from master to core 1 = 4.534 microseconds
Communication speed from master to core 1 = 3294.88 MB/sec
Total CPU time for main thread : 1.8 seconds
Total CPU time summed for all threads : 2.0 seconds
Elapsed time spent obtaining a license : 0.3 seconds
Elapsed time spent pre-processing model (/PREP7) : 0.0 seconds
Elapsed time spent solution = preprocessing : 0.1 seconds
Elapsed time spent computing solution : 0.8 seconds
Elapsed time spent solution = postprocessing : 0.0 seconds
Elapsed time spent post-processing model (/POST1) : 0.0 seconds
Equation solver used : Sparse (symmetric)
Equation solver computational rate : 12.4 Gflops
Sum of memory used on all processes : 283.0 MB
Sum of memory allocated on all processes : 3136.0 MB
Physical memory available : 16 GB
Total amount of I/O written to disk : 0.0 GB
Total amount of I/O read from disk : 0.0 GB

```

```

----- E N D   D I S T R I B U T E D   A N S Y S   S T A T I S T I C S -----

```

```

-----
|
| DISTRIBUTED ANSYS RUN COMPLETED
|
|-----
| Ansys 2022 R1          Build 22.1          UP20211129  WINDOWS x64
|-----
| Database Requested(-db) 1024 MB  Scratch Memory Requested  1024 MB
| Maximum Database Used    4 MB    Maximum Scratch Memory Used  144 MB
|-----
| CP Time (sec) = 1.984   Time = 17:38:23
| Elapsed time (sec) = 3.000   Date = 06/23/2022
|-----

```

Solver Output

Ansys Mechanical Enterprise Academic Student

```
-----  
| WELCOME TO THE ANSYS (R) PROGRAM |  
-----
```

```
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```

2022 R1

Point Releases and Patches installed:

```
Ansys, Inc. Products 2022 R1  
Autodyn 2022 R1  
SpaceClaim 2022 R1  
CFX (includes CFD-Post) 2022 R1  
Chemkin 2022 R1  
EnSight 2022 R1  
FEMAP-ICE 2022 R1  
Fluent (includes CFD-Post) 2022 R1  
Polyflow (includes CFD-Post) 2022 R1  
Forte (includes EnSight) 2022 R1  
TurboGrid 2022 R1  
Aqaa 2022 R1  
Mechanical Products 2022 R1  
Actix Geometry Interface 2022 R1  
AutoCAD Geometry Interface 2022 R1  
Catia, Version 4 Geometry Interface 2022 R1  
Catia, Version 5 Geometry Interface 2022 R1  
Catia, Version 6 Geometry Interface 2022 R1  
Creo Elements/Direct Modeling Geometry Interface 2022 R1  
Creo Parametric Geometry Interface 2022 R1  
Inventor Geometry Interface 2022 R1  
JTopas Geometry Interface 2022 R1  
NX Geometry Interface 2022 R1  
Parasolid Geometry Interface 2022 R1  
Solid Edge Geometry Interface 2022 R1  
SOLIDWORKS Geometry Interface 2022 R1  
Academic Student 2022 R1
```

```
***** ANSYS COMMAND LINE ARGUMENTS *****  
BATCH MODE REQUESTED (-b) = NOLIST  
INPUT FILE COPY MODE (-c) = COPY  
DISTRIBUTED MEMORY PARALLEL REQUESTED  
 2 PARALLEL PROCESSES REQUESTED WITH SINGLE THREAD PER PROCESS  
TOTAL OF 2 CORES REQUESTED  
INPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\alberto\QuintanaTFP\Design\Assembly\Ansys_ProjectScratch\scrA346\dummy.dat  
OUTPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\alberto\QuintanaTFP\Design\Assembly\Ansys_ProjectScratch\scrA346\solve.out  
START-UP FILE MODE = NOREAD  
STOP FILE MODE = NOREAD  
RELEASE= 2022 R1 BUILID= 22.1 UP2021129 VERSION=WINDOWS x64  
CURRENT JOBNAME=f11e0 17:28:08 JUN 25, 2022 CP= 0.125
```

```
PARAMETER_DS_PROGRESS = 999.000000  
/INPUT FILE= ds.dat LINE= 0
```

```
*** NOTE *** CP = 0.297 TIME= 17:28:09  
The /CONFIG,NOREAD command is not valid in a Distributed ANSYS  
solution. Command is ignored.
```

```
*GET_WALLSTRT FROM ACT1 ITEM=TIME WALL VALUE= 17.4691667
```

```
TITLE=
```

```
Workbench3_probe--Static Structural (DS)
```

```
ACT Extensions:  
LSDyna, 2021.1  
5f463412-bd3e-484b-87e7-cbcba665e474, wbx
```

```
SET PARAMETER DIMENSIONS ON WB_PROJECTSCRATCH_DIR
```

```
TYPE=STR DIMENSIONS= Z48 1 1
```

```
PARAMETER_WB_PROJECTSCRATCH_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\alberto\QuintanaTFP\Design\Assembly\Ansys_ProjectScratch\scrA346\
```

```
SET PARAMETER DIMENSIONS ON WB_SOLVERFILES_DIR
```

```
TYPE=STR DIMENSIONS= Z48 1 1
```

```
PARAMETER_WB_SOLVERFILES_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\alberto\QuintanaTFP\Design\Assembly\Ansys\Workbench3_probe_files\4p0\878-2\MECH\
```

```

*GET WALLSOL FROM ACT1 ITEM=TIME WALL VALUE= 17.4691667
*****
***** ANSYS SOLUTION ROUTINE *****

PERFORM A STATIC ANALYSIS
THIS WILL BE A NEW ANALYSIS
PARAMETER_THICKRATIO = 0.500000000
USE SPARSE MATRIX DIRECT SOLVER
CONTACT INFORMATION PRINTOUT LEVEL 1
DO NOT COMBINE ELEMENT MATRIX FILES (.emat) AFTER DISTRIBUTED PARALLEL SOLUTION
DO NOT COMBINE ELEMENT SAVE DATA FILES (.esav) AFTER DISTRIBUTED PARALLEL SOLUTION
NLDIAG: Nonlinear diagnostics CONT option is set to ON.
Scaling frequency: each ITERATION.
DO NOT SAVE ANY RESTART FILES AT ALL
*****
***** SOLVE FOR LS 1 OF 1 *****
*** Set Displacement ***
CMBLOCK read of NODE component _CM40UX_XP completed
SELECT COMPONENT_CM40UX_XP
SPECIFIED CONSTRAINT UX FOR SELECTED NODES 1 TO 6789 BY 1
REAL=-1.00000000E-02 IMAG= 0.00000000
ALL SELECT FOR ITEM-NODE COMPONENT=
IN RANGE 1 TO 6789 STEP 1
6789 NODES (OF 6789 DEFINED) SELECTED BY NSEL COMMAND.
*** Component For All Non-zero UX Displacements ***
SELECT COMPONENT_CM40UX_XP
DEFINITION OF COMPONENT = _DISPROMZEROUX ENTITY-NODE
ALL SELECT FOR ITEM-NODE COMPONENT=
IN RANGE 1 TO 6789 STEP 1
6789 NODES (OF 6789 DEFINED) SELECTED BY NSEL COMMAND.
PRINTOUT RESUMED BY /GOP
USE 1 SUBSTEPS INITIALLY THIS LOAD STEP FOR ALL DEGREES OF FREEDOM
FOR AUTOMATIC TIME STEPPING:
USE 1 SUBSTEPS AS A MAXIMUM
USE 1 SUBSTEPS AS A MINIMUM
TIME= 1.0000
ERASE THE CURRENT DATABASE OUTPUT CONTROL TABLE.
WRITE ALL ITEMS TO THE DATABASE WITH A FREQUENCY OF NONE
FOR ALL APPLICABLE ENTITIES
WRITE ESOL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE ESOL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EAMG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE ETMP ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE VENG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE STRS ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPEL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPFL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE CONT ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
*GET ANSINTER FROM ACT1 ITEM=INT VALUE= 0.00000000
*IF ANSINTER ( = 0.00000 ) NE
0 ( = 0.00000 ) THEN
*ENDIF
*** NOTE *** CP = 0.531 TIME= 17:28:09
The automatic domain decomposition logic has selected the MESH domain
decomposition method with 2 processes per solution.
***** ANSYS SOLVE COMMAND *****
*** WARNING *** CP = 0.531 TIME= 17:28:09
Element shape checking is currently inactive. Issue SHPP,ON or
SHPP,WARN to reactivate, if desired.
*** NOTE *** CP = 0.562 TIME= 17:28:09
The model data was checked and warning messages were found.
Please review output or errors file (
C:\Users\jquin\OneDrive\Documents\JQC\AlbertoQuintana\TP\Design\Assemb
ly\Ansys_Project\Scratch\ScrA546\Z1160.err ) for these warning
messages.
*** SELECTION OF ELEMENT TECHNOLOGIES FOR APPLICABLE ELEMENTS ***
*** GIVE SUGGESTIONS AND RESET THE KEY OPTIONS ***
ELEMENT TYPE 1 IS SOLID184. KEYOPT(2)=0 IS SUGGESTED AND HAS BEEN RESET.
KEYOPT(1-12)= 0 0 0 0 0 0 0 0 0 0 0 0
ELEMENT TYPE 2 IS SOLID187. IT IS NOT ASSOCIATED WITH FULLY INCOMPRESSIBLE
HYPERELASTIC MATERIALS. NO SUGGESTION IS AVAILABLE AND NO RESETTING IS NEEDED.
*** ANSYS - ENGINEERING ANALYSIS SYSTEM RELEASE 2022 R1 22.1 ***
DISTRIBUTED Ansys Mechanical Enterprise Academic Student
00000000 VERSION=WINDOWS x64 17:28:09 JUN 25, 2022 CP= 0.562
Workbench_probe=Static Structural (D5)

SOLUTION OPTIONS
PROBLEM DIMENSIONALITY . . . . .3-D
DEGREES OF FREEDOM . . . . .UX UY UZ
ANALYSIS TYPE . . . . .STATIC (STEADY-STATE)
OFFSET TEMPERATURE FROM ABSOLUTE ZERO . . . . .273.15
EQUATION SOLVER OPTION . . . . .SPARSE
GLOBALLY ASSEMBLED MATRIX . . . . .SYMMETRIC
*** NOTE *** CP = 0.594 TIME= 17:28:09

```

Default Max. friction stress TAUMAX 0.10000E+21
Average contact surface length 0.37848E+02
Average contact pair depth 0.17838E+02
Average target surface length 0.58878E+02
Default pinball region factor PINB 0.25000
WARNING: The default pinball radius may be too small to capture
contacting nodes under small sliding assumption. Redefine the pinball
radius if necessary.
The resulting pinball region 0.44034E+03
Initial penetration/gap is excluded.
Bonded contact (always) is defined.

*** NOTE *** CP = 0.625 TIME= 17:28:09
Min. Initial gap 1.106074492E-07 was detected between contact element
4288 and target element 4272.
Contact is detected due to initial settings.

Max. Geometric gap 4.313721893E-04 has been detected between contact
element 4291 and target element 4271.
WARNING: The geometric gap/penetration may be too large. Increase
pinball radius if it is a true geometric gap/penetration. Decrease
pinball if it is a false one.

DISTRIBUTED DOMAIN DECOMPOSER

...Number of elements: 2584
...Number of nodes: 6789
...Decompose to 2 CPU domains
...Element load balance ratio = 1.013

LOAD STEP OPTIONS

LOAD STEP NUMBER: 1
TIME AT END OF THE LOAD STEP: 1.0000
NUMBER OF SUBSTEPS: 1
STEP CHANGE BEHAVIOR: NO
PRINT OUTPUT CONTROLS: NO PRINTOUT
DATABASE OUTPUT CONTROLS

ITEM FREQUENCY COMPONENT
ALL NONE
RSOL ALL
RSOL ALL
RANG ALL
RANG ALL
VENG ALL
STRES ALL
EPEL ALL
EPEL ALL
COWT ALL

SOLUTION MONITORING INFO IS WRITTEN TO FILE
file.mnt

***** PRECISE MASS SUMMARY *****

TOTAL RIGID BODY MASS MATRIX ABOUT ORIGIN
Translational mass | Coupled translational/rotational mass
0.55486 0.0000 0.0000 | 0.0000 -0.10603E-01 -0.27743E-01
0.0000 0.55486 0.0000 | 0.10603E-01 0.0000 0.28481E-01
0.0000 0.0000 0.55486 | 0.27743E-01 -0.28481E-01 0.0000

Rotational mass (inertia)
0.20834E-02 -0.14240E-02 0.54427E-03
-0.14240E-02 0.17270E-02 0.33017E-03
0.54427E-03 0.33017E-03 0.33426E-02

TOTAL MASS = 0.55486
The mass principal axes coincide with the global Cartesian axes
CENTER OF MASS (X,Y,Z) = 0.51330E-01 0.50000E-01 -0.19110E-01

TOTAL INERTIA ABOUT CENTER OF MASS
0.49359E-03 0.34818E-17 0.24363E-12
0.34818E-17 0.62418E-14 0.11770E-17
0.24363E-12 0.11770E-17 0.49359E-03
The inertia principal axes coincide with the global Cartesian axes

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE MASS
1 0.554856
Range of element maximum matrix coefficients in global coordinates
Maximum = 1.560476915E+09 at element 523.
Minimum = 22671.4319 at element 2005.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE NUMBER ENAME TOTAL CP AVE CP
1 523 SOLID186 0.188 0.000356
2 1997 SOLID187 0.281 0.000141
3 30 CONTA174 0.016 0.000521
4 30 TARGET170 0.000 0.000000
Time at end of element matrix formulation CP = 1.171875.

DISTRIBUTED SPARSE MATRIX DIRECT SOLVER.
Number of equations = 18643, Maximum wavefront = 234
Process memory allocated for solver = 47.981 MB
Process memory required for in-core solution = 45.209 MB
Process memory required for out-of-core solution = 27.124 MB
Total memory allocated for solver = 82.762 MB
Total memory required for in-core solution = 79.548 MB
Total memory required for out-of-core solution = 43.053 MB

*** NOTE *** CP = 1.484 TIME= 17:28:09
The Distributed Sparse Matrix Solver is currently running in the
in-core memory mode. This memory mode uses the most amount of memory
in order to avoid using the hard drive as much as possible, which most
often results in the fastest solution time. This mode is recommended
if enough physical memory is present to accommodate all of the solver
data.
curEigs= 7037 tonEigs= 7037 Job CP sec= 1.703
Factor Done= 100% Factor Wall sec= 0.124 rate= 9.6 GFlops
Distributed sparse solver maximum pivot= 5.083248679E+09 at node 1584
UY.
Distributed sparse solver minimum pivot= 753.224115 at node 3091 UY.
Distributed sparse solver minimum pivot in absolute value= 753.224115
at node 3091 UY.

*** WARNING *** CP = 1.766 TIME= 17:28:10
Contact element 4297 (real ID 4) status changes abruptly from
no-contact => contact (with target element 4270).

*** ELEMENT RESULT CALCULATION TIMES

TYPE NUMBER ENAME TOTAL CP AVE CP
1 523 SOLID186 0.062 0.000119
2 1997 SOLID187 0.188 0.000094
3 30 CONTA174 0.016 0.000521

*** NODAL LOAD CALCULATION TIMES

TYPE NUMBER ENAME TOTAL CP AVE CP

EXIT THE ANSYS POST1 DATABASE PROCESSOR

***** ROUTINE COMPLETED ***** CP = 2.047

PRINTOUT RESUMED BY /GOP

*GET _KALLDONE FROM ACT1 ITEM=TIME WALL VALUE= 17.4694444
PARAMETER _PREP TIME = 0.000000000
PARAMETER _SOL TIME = 1.000000000
PARAMETER _POST TIME = 0.000000000
PARAMETER _TOTAL TIME = 1.000000000
*GET _DLBRATIO FROM ACT1 ITEM=SOLU DLBR VALUE= 1.01330203
*GET _COMB TIME FROM ACT1 ITEM=SOLU COMB VALUE= 0.307415000E-01
*GET _SMMODE FROM ACT1 ITEM=SOLU SMM VALUE= 2.000000000
*GET _NDOPFS FROM ACT1 ITEM=SOLU NDOP VALUE= 18643.0000
*GET _SOL_END_TIME FROM ACT1 ITEM=SET TIME VALUE= 1.000000000
*IF _sol_end_time (= 1.00000) EQ
1.000000 (= 1.00000) THEN

/PCLEAN COMMAND REMOVING ALL LOCAL FILES

*ENDIF
--- Total number of nodes = 6789
--- Total number of elements = 2584
--- Element load balance ratio = 1.01330203
--- Time to combine distributed files = 3.07415E-02
--- Sparse memory mode = 2
--- Number of dof = 18643

EXIT ANSYS WITHOUT SAVING DATABASE

NUMBER OF WARNING MESSAGES ENCOUNTERED= 2
NUMBER OF ERROR MESSAGES ENCOUNTERED= 0

----- D I S T R I B U T E D A N S Y S S T A T I S T I C S -----

Release: 2022 R1 Build: 22.1 Update: UP20211129 Platform: WINDOWS x64
Date Run: 06/25/2022 Time: 17:28 Process ID: 3356
Operating System: Windows 10 (Build: 22000)

Processor Model: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz
Compiler: Intel(R) Fortran Compiler Version 19.0.5 (Build: 20190815)
Intel(R) C/C++ Compiler Version 19.0.5 (Build: 20190815)
Intel(R) Math Kernel Library Version 2020.0.0 Product Build 20191125
BLAS Library supplied by Intel(R) MKL

Number of machines requested : 1
Total number of cores available : 12
Number of physical cores available : 6
Number of processes requested : 2
Number of threads per process requested : 1
Total number of cores requested : 2 (Distributed Memory Parallel)
MPI Type: INTEL MPI
MPI Version: Intel(R) MPI Library 2019 Update 10 for Windows® OS

GPU Acceleration: Not Requested

Job Name: file0
Input File: dummy.dat

Core	Machine Name	Working Directory
0	HP-A	C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\ScrA546
1	HP-A	C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\ScrA546

Latency time from master to core 1 = 4.690 microseconds

Communication speed from master to core 1 = 2593.71 MB/sec

Total CPU time for main thread : 2.3 seconds
Total CPU time summed for all threads : 2.4 seconds
Elapsed time spent obtaining a license : 0.5 seconds
Elapsed time spent pre-processing model (/PREP7) : 0.1 seconds
Elapsed time spent solution - preprocessing : 0.1 seconds
Elapsed time spent computing solution : 1.1 seconds
Elapsed time spent solution - postprocessing : 0.0 seconds
Elapsed time spent post-processing model (/POST1) : 0.0 seconds
Equation solver used : Sparse (symmetric)
Equation solver computational rate : 12.2 Gflops
Sum of memory used on all processes : 288.0 MB
Sum of memory allocated on all processes : 3136.0 MB
Physical memory available : 16 GB
Total amount of I/O written to disk : 0.0 GB
Total amount of I/O read from disk : 0.0 GB

----- E N D D I S T R I B U T E D A N S Y S S T A T I S T I C S -----

```
-----  
|  
| DISTRIBUTED ANSYS RUN COMPLETED |  
|  
|-----  
| Ansys 2022 R1 Build 22.1 UP20211129 WINDOWS x64 |  
|-----  
| Database Requested(-db) 1024 MB Scratch Memory Requested 1024 MB |  
| Maximum Database Used 3 MB Maximum Scratch Memory Used 146 MB |  
|-----  
| CP Time (sec) = 2.422 Time = 17:28:10 |  
| Elapsed Time (sec) = 3.000 Date = 06/25/2022 |  
|-----
```

Solver Output

Ansys Mechanical Enterprise Academic Student

```
-----  
| WELCOME TO THE ANSYS(R) PROGRAM |  
-----
```

```
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*****
```

2022 R1

Point Releases and Patches installed:

```
Ansys, Inc. Products 2022 R1  
Autodyn 2022 R1  
SpaceClaim 2022 R1  
CFX (includes CFD-Post) 2022 R1  
Chemkin 2022 R1  
Enight 2022 R1  
FEMAP-ICE 2022 R1  
Fluent (includes CFD-Post) 2022 R1  
Polyflow (includes CFD-Post) 2022 R1  
Forte (includes Enight) 2022 R1  
TurboGrid 2022 R1  
Aqaa 2022 R1  
Mechanical Products 2022 R1  
Actix Geometry Interface 2022 R1  
AutoCAD Geometry Interface 2022 R1  
Catia, Version 4 Geometry Interface 2022 R1  
Catia, Version 5 Geometry Interface 2022 R1  
Catia, Version 6 Geometry Interface 2022 R1  
Creo Elements/Direct Modeling Geometry Interface 2022 R1  
Creo Parametric Geometry Interface 2022 R1  
Inventor Geometry Interface 2022 R1  
JTopas Geometry Interface 2022 R1  
NX Geometry Interface 2022 R1  
Parasolid Geometry Interface 2022 R1  
Solid Edge Geometry Interface 2022 R1  
SOLIDWORKS Geometry Interface 2022 R1  
Academic Student 2022 R1
```

***** ANSYS COMMAND LINE ARGUMENTS *****

```
BATCH MODE REQUESTED (-b) = NOLIST  
INPUT FILE COPY MODE (-c) = COPY  
DISTRIBUTED MEMORY PARALLEL REQUESTED  
 2 PARALLEL PROCESSES REQUESTED WITH SINGLE THREAD PER PROCESS  
TOTAL OF 2 CORES REQUESTED  
INPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys_ProjectScratch\ScrE2D2\dummy.dat  
OUTPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys_ProjectScratch\ScrE2D2\save.out  
START-UP FILE MODE = NOREAD  
STOP FILE MODE = NOREAD  
RELEASE= 2022 R1 BUILD= 22.1 UP2021129 VERSION=WINDOWS x64  
CURRENT JOBNAME=f11e0 17:32:23 JUN 25, 2022 CP= 0.172
```

```
PARAMETER_DS_PROGRESS = 999.000000  
/INPUT FILE= ds.dat LINE= 0
```

```
*** NOTE *** CP = 0.312 TIME= 17:32:23  
The /CONFIG,NOREAD command is not valid in a Distributed ANSYS  
solution. Command is ignored.
```

```
*GET_WALLSTRT FROM ACT1 ITEM=TIME WALL VALUE= 17.5397222
```

```
TITLE=
```

```
Workbench3_probe--Static Structural (F5)
```

```
ACT Extensions:
```

```
LSYWA, 2021.1  
5f463412-bd3e-484b-87e7-cbcba665e474, wbx
```

```
SET PARAMETER DIMENSIONS ON WB_PROJECTSCRATCH_DIR
```

```
TYPE=STR DIMENSIONS= Z48 1 1
```

```
PARAMETER_WB_PROJECTSCRATCH_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys_ProjectScratch\ScrE2D2\
```

```
SET PARAMETER DIMENSIONS ON WB_SOLVERFILES_DIR
```

```
TYPE=STR DIMENSIONS= Z48 1 1
```

```
PARAMETER_WB_SOLVERFILES_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFP\Design\Assembly\Ansys\Workbench3_probe_files\4p0\SYD-3\MECH\
```

```

*GET WALLSOL FROM ACT1 ITEM=TIME WALL VALUE= 17.5397222
*****
***** ANSYS SOLUTION ROUTINE *****

PERFORM A STATIC ANALYSIS
THIS WILL BE A NEW ANALYSIS
PARAMETER_THICKRATIO = 0.500000000
USE SPARSE MATRIX DIRECT SOLVER
CONTACT INFORMATION PRINTOUT LEVEL 1
DO NOT COMBINE ELEMENT MATRIX FILES (.emat) AFTER DISTRIBUTED PARALLEL SOLUTION
DO NOT COMBINE ELEMENT SAVE DATA FILES (.esav) AFTER DISTRIBUTED PARALLEL SOLUTION
NLDIAG: Nonlinear diagnostics CONT option is set to ON.
Scaling frequency: each ITERATION.
DO NOT SAVE ANY RESTART FILES AT ALL
*****
***** SOLVE FOR LS 1 OF 1 *****
*** Set Displacement ***
CMBLOCK read of NODE component _CM64UX_XP completed
SELECT COMPONENT_CM64UX_XP
SPECIFIED CONSTRAINT UX FOR SELECTED NODES 1 TO 6756 BY 1
REAL=-1.00000000E-02 IMAG= 0.00000000
ALL SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 1 TO 6756 STEP 1
6756 NODES (OF 6756 DEFINED) SELECTED BY NSEL COMMAND.
*** Component For all Non-zero UX Displacements ***
SELECT COMPONENT_CM64UX_XP
DEFINITION OF COMPONENT = _DISPROMZEROUX ENTITY=NODE
ALL SELECT FOR ITEM=NODE COMPONENT=
IN RANGE 1 TO 6756 STEP 1
6756 NODES (OF 6756 DEFINED) SELECTED BY NSEL COMMAND.
PRINTOUT RESUMED BY /GOP
USE 1 SUBSTEPS INITIALLY THIS LOAD STEP FOR ALL DEGREES OF FREEDOM
FOR AUTOMATIC TIME STEPPING:
USE 1 SUBSTEPS AS A MAXIMUM
USE 1 SUBSTEPS AS A MINIMUM
TIME= 1.0000
ERASE THE CURRENT DATABASE OUTPUT CONTROL TABLE.
WRITE ALL ITEMS TO THE DATABASE WITH A FREQUENCY OF NONE
FOR ALL APPLICABLE ENTITIES
WRITE RESL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE RESL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EAMG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE ETMP ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE VENG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE STRS ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPFL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPPL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE CONT ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
*GET ANSINTER FROM ACT1 ITEM=INT VALUE= 0.00000000
*IF ANSINTER ( = 0.00000 ) NE
0 ( = 0.00000 ) THEN
*ENDIF
*** NOTE *** CP = 0.500 TIME= 17:32:23
The automatic domain decomposition logic has selected the MESH domain
decomposition method with 2 processes per solution.
***** ANSYS SOLVE COMMAND *****
*** WARNING *** CP = 0.500 TIME= 17:32:23
Element shape checking is currently inactive. Issue SHPP,ON or
SHPP,WARN to reactivate, if desired.
*** NOTE *** CP = 0.500 TIME= 17:32:23
The model data was checked and warning messages were found.
Please review output or errors file (
C:\Users\jquin\OneDrive\Documents\JQC\AlbertoQuintana\TP\Design\Assemb
ly\Ansys_Project\Scratch\ScrECCD\Z110.err ) for these warning
messages.
*** SELECTION OF ELEMENT TECHNOLOGIES FOR APPLICABLE ELEMENTS ***
*** GIVE SUGGESTIONS AND RESET THE KEY OPTIONS ***
ELEMENT TYPE 1 IS SOLID184. KEYOPT(2)=0 IS SUGGESTED AND HAS BEEN RESET.
KEYOPT(1-12)= 0 0 0 0 0 0 0 0 0 0 0 0
ELEMENT TYPE 2 IS SOLID187. IT IS NOT ASSOCIATED WITH FULLY INCOMPRESSIBLE
HYPERELASTIC MATERIALS. NO SUGGESTION IS AVAILABLE AND NO RESETTING IS NEEDED.
*** ANSYS - ENGINEERING ANALYSIS SYSTEM RELEASE 2022 R1 22.1 ***
DISTRIBUTED Ansys Mechanical Enterprise Academic Student
00000000 VERSION=WINDOWS x64 17:32:23 JUN 25, 2022 CP= 0.531
Workbench_probe=Static Structural (F5)

SOLUTION OPTIONS
PROBLEM DIMENSIONALITY . . . . . 3-D
DEGREES OF FREEDOM . . . . . UX UY UZ
ANALYSIS TYPE . . . . . STATIC (STEADY-STATE)
OFFSET TEMPERATURE FROM ABSOLUTE ZERO . . . . . 273.15
EQUATION SOLVER OPTION . . . . . SPARSE
GLOBALLY ASSEMBLED MATRIX . . . . . SYMMETRIC
*** NOTE *** CP = 0.531 TIME= 17:32:23

```

Default Max. friction stress TAUMAX 0.10000E+21
Average contact surface length 0.37844E+02
Average contact pair depth 0.17639E+02
Average target surface length 0.58675E+02
Default pinball region factor PINB 0.25000
WARNING: The default pinball radius may be too small to capture
contacting nodes under small sliding assumption. Redefine the pinball
radius if necessary.
The resulting pinball region 0.44034E+03
Initial penetration/gap is excluded.
Bonded contact (always) is defined.

*** NOTE *** CP = 0.562 TIME= 17:32:23
Min. Initial gap 1.25360593E-06 was detected between contact element
4258 and target element 4242.
Contact is detected due to initial settings.

Max. Geometric gap 3.94407047E-04 has been detected between contact
element 4258 and target element 4238.
WARNING: The geometric gap/penetration may be too large. Increase
pinball radius if it is a true geometric gap/penetration. Decrease
pinball if it is a false one.

D I S T R I B U T E D D O M A I N D E C O M P O S E R

...Number of elements: 2560
...Number of nodes: 6756
...Decompose to 2 CPU domains
...Element load balance ratio = 1.013

L O A D S T E P O P T I O N S

LOAD STEP NUMBER 1
TIME AT END OF THE LOAD STEP 1.0000
NUMBER OF SUBSTEPS 1
STEP CHANGE SCHEME/CONTROL NO
PRINT OUTPUT CONTROLS NO PRINTOUT
DATABASE OUTPUT CONTROLS

ITEM FREQUENCY COMPONENT
ALL NONE
RSOL ALL
RSOL ALL
RANG ALL
RNGF ALL
VENG ALL
STKS ALL
EFEL ALL
EPEL ALL
COWT ALL

SOLUTION MONITORING INFO IS WRITTEN TO FILE
file.mnt

***** PRECISE MASS SUMMARY *****

TOTAL RIGID BODY MASS MATRIX ABOUT ORIGIN
Translational mass | Coupled translational/rotational mass
0.55486 0.0000 0.0000 | 0.0000 -0.10542E-01 -0.27743E-01
0.0000 0.55486 0.0000 | 0.10542E-01 0.0000 0.16662E-01
0.0000 0.0000 0.55486 | 0.27743E-01 -0.16662E-01 0.0000

Rotational mass (inertia)
| 0.20810E-02 -0.83312E-03 0.31658E-03
| -0.83312E-03 0.76309E-03 0.52711E-03
| 0.31658E-03 0.52711E-03 0.23811E-02

TOTAL MASS = 0.55486
The mass principal axes coincide with the global Cartesian axes
CENTER OF MASS (X,Y,Z) = 0.30300E-01 0.50000E-01 -0.19000E-01

TOTAL INERTIA ABOUT CENTER OF MASS
0.49359E-03 0.21430E-19 0.24364E-12
0.21430E-19 0.64341E-14 0.12295E-17
0.24364E-12 0.12295E-17 0.49359E-03
The inertia principal axes coincide with the global Cartesian axes

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE MASS
1 0.554856
Range of element maximum matrix coefficients in global coordinates
Maximum = 1.560476915E+09 at element 523.
Minimum = 2.22294133 at element 1996.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE NUMBER ENAME TOTAL CP AVE CP
1 527 SOLID186 0.125 0.000237
2 1973 SOLID187 0.281 0.000143
3 30 CONTA174 0.000 0.000000
4 30 TARGE170 0.000 0.000000
Time at end of element matrix formulation CP = 1.046875.

DISTRIBUTED SPARSE MATRIX DIRECT SOLVER.

Number of equations = 18544, Maximum wavefront = 291
Process memory allocated for solver = 41.681 MB
Process memory required for in-core solution = 29.810 MB
Process memory required for out-of-core solution = 18.484 MB
Total memory allocated for solver = 81.342 MB
Total memory required for in-core solution = 78.191 MB
Total memory required for out-of-core solution = 43.677 MB

*** NOTE *** CP = 1.359 TIME= 17:32:24
The Distributed Sparse Matrix Solver is currently running in the
in-core memory mode. This memory mode uses the most amount of memory
in order to avoid using the hard drive as much as possible, which most
often results in the fastest solution time. This mode is recommended
if enough physical memory is present to accommodate all of the solver
data.

curEigs= 6743 totEigs= 6743 Job CP sec= 1.605
Factor Done= 100% Factor Wall sec= 0.154 rate= 7.5 GFlops
Distributed sparse solver maximum pivot= 5.300252699E+09 at node 1591
UX.
Distributed sparse solver minimum pivot= 261.188466 at node 2952 UX.
Distributed sparse solver minimum pivot in absolute value= 261.188466
at node 2952 UX.

*** WARNING *** CP = 1.688 TIME= 17:32:24
Contact element 4259 (real ID 4) status changes abruptly from
no-contact => contact (with target element 4238).

*** ELEMENT RESULT CALCULATION TIMES

TYPE NUMBER ENAME TOTAL CP AVE CP
1 527 SOLID186 0.016 0.000030
2 1973 SOLID187 0.203 0.000103
3 30 CONTA174 0.016 0.000521

*** NODAL LOAD CALCULATION TIMES

TYPE NUMBER ENAME TOTAL CP AVE CP

EXIT THE ANSYS POST1 DATABASE PROCESSOR

***** ROUTINE COMPLETED ***** CP = 2.000

PRINTOUT RESUMED BY /GOP

*GET _KALLDONE FROM ACT1 ITEM=TIME WALL VALUE= 17.5402778
PARAMETER _PREP TIME = 0.000000000
PARAMETER _SOL TIME = 1.000000000
PARAMETER _POST TIME = 1.000000000
PARAMETER _TOTAL TIME = 2.000000000
*GET _DLBRATIO FROM ACT1 ITEM=SOLU DLBR VALUE= 1.01263823
*GET _COMB TIME FROM ACT1 ITEM=SOLU COMB VALUE= 0.302824000E-01
*GET _SMMODE FROM ACT1 ITEM=SOLU SMM VALUE= 2.000000000
*GET _NDOPS FROM ACT1 ITEM=SOLU NDOP VALUE= 18544.0000
*GET _SOL_END_TIME FROM ACT1 ITEM=SET TIME VALUE= 1.000000000
*IF _sol_end_time (= 1.000000) EQ
1.000000 (= 1.000000) THEN

/PCLEAN COMMAND REMOVING ALL LOCAL FILES

*ENDIF

--- Total number of nodes = 6756
--- Total number of elements = 2560
--- Element load balance ratio = 1.01263823
--- Time to combine distributed files = 3.02824E-02
--- Sparse memory mode = 2
--- Number of DOF = 18544

EXIT ANSYS WITHOUT SAVING DATABASE

NUMBER OF WARNING MESSAGES ENCOUNTERED= 2
NUMBER OF ERROR MESSAGES ENCOUNTERED= 0

----- D I S T R I B U T E D A N S Y S S T A T I S T I C S -----

Release: 2022 R1 Build: 22.1 Update: UP20211129 Platform: WINDOWS x64
Date Run: 06/25/2022 Time: 17:32 Process ID: 12848
Operating System: Windows 10 (Build: 22000)

Processor Model: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz

Compiler: Intel(R) Fortran Compiler Version 19.0.5 (Build: 20190815)
Intel(R) C/C++ Compiler Version 19.0.5 (Build: 20190813)
Intel(R) Math Kernel Library Version 2020.0.0 Product Build 20191125
BLAS Library supplied by Intel(R) MKL

Number of machines requested : 1
Total number of cores available : 12
Number of physical cores available : 6
Number of processes requested : 2
Number of threads per process requested : 1
Total number of cores requested : 2 (Distributed Memory Parallel)
MPI Type: INTEL MPI
MPI Version: Intel(R) MPI Library 2019 Update 10 for Windows® OS

GPU Acceleration: Not Requested

Job Name: file0
Input File: dummy.dat

Core	Machine Name	Working Directory
0	HP-A	C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\Scratch2
1	HP-A	C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\Scratch2

Latency time from master to core 1 = 3.708 microseconds

Communication speed from master to core 1 = 2792.50 MB/sec

Total CPU time for main thread : 2.0 seconds
Total CPU time summed for all threads : 2.4 seconds
Elapsed time spent obtaining a license : 0.4 seconds
Elapsed time spent pre-processing model (/PREP7) : 0.1 seconds
Elapsed time spent solution - preprocessing : 0.1 seconds
Elapsed time spent computing solution : 1.1 seconds
Elapsed time spent solution - postprocessing : 0.0 seconds
Elapsed time spent post-processing model (/POST1) : 0.0 seconds
Equation solver used : Sparse (symmetric)
Equation solver computational rate : 9.7 GFlops
Equation solver effective I/O rate : 9.0 GB/sec
Sum of memory used on all processes : 288.0 MB
Sum of memory allocated on all processes : 3136.0 MB
Physical memory available : 16 GB
Total amount of I/O written to disk : 0.0 GB
Total amount of I/O read from disk : 0.0 GB

----- E N D D I S T R I B U T E D A N S Y S S T A T I S T I C S -----

```
-----  
|  
| DISTRIBUTED ANSYS RUN COMPLETED |  
|  
|-----  
| Ansys 2022 R1 Build 22.1 UP20211129 WINDOWS x64 |  
|-----  
| Database Requested(-db) 1024 MB Scratch Memory Requested 1024 MB |  
| Maximum Database Used 3 MB Maximum Scratch Memory Used 136 MB |  
|-----  
| CP Time (sec) = 2.359 Time = 17:32:25 |  
| Elapsed Time (sec) = 3.000 Date = 06/25/2022 |  
|-----
```

Solver Output

Ansys Mechanical Enterprise Academic Student

```
-----  
| WELCOME TO THE ANSYS (R) PROGRAM |  
-----
```

```
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```

```
2022 R1  
Point Releases and Patches installed:  
Ansys, Inc. Products 2022 R1  
Autodyn 2022 R1  
SpaceClaim 2022 R1  
CFX (includes CFD-Post) 2022 R1  
Chemkin 2022 R1  
EnSight 2022 R1  
FEMAP-ICE 2022 R1  
Fluent (includes CFD-Post) 2022 R1  
Polyflow (includes CFD-Post) 2022 R1  
Forte (includes EnSight) 2022 R1  
TurboGrid 2022 R1  
Aqaa 2022 R1  
Mechanical Products 2022 R1  
Actix Geometry Interface 2022 R1  
AutoCAD Geometry Interface 2022 R1  
Catia, Version 4 Geometry Interface 2022 R1  
Catia, Version 5 Geometry Interface 2022 R1  
Catia, Version 6 Geometry Interface 2022 R1  
Creo Elements/Direct Modeling Geometry Interface 2022 R1  
Creo Parametric Geometry Interface 2022 R1  
Inventor Geometry Interface 2022 R1  
JOpen Geometry Interface 2022 R1  
NX Geometry Interface 2022 R1  
Parasolid Geometry Interface 2022 R1  
Solid Edge Geometry Interface 2022 R1  
SOLIDWORKS Geometry Interface 2022 R1  
Academic Student 2022 R1
```

```
***** ANSYS COMMAND LINE ARGUMENTS *****  
BATCH MODE REQUESTED (-b) = NOLIST  
INPUT FILE COPY MODE (-c) = COPY  
DISTRIBUTED MEMORY PARALLEL REQUESTED  
 2 PARALLEL PROCESSES REQUESTED WITH SINGLE THREAD PER PROCESS  
TOTAL OF 2 CORES REQUESTED  
INPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\alberto\QuintanaTFP\Design\Assembly\Ansys_ProjectScratch\scr\FIE\dummy.dat  
OUTPUT FILE NAME = C:\Users\quint\OneDrive\Documents\ICAI\alberto\QuintanaTFP\Design\Assembly\Ansys_ProjectScratch\scr\FIE\solve.out  
START-UP FILE MODE = NOREAD  
STOP FILE MODE = NOREAD  
RELEASE= 2022 R1 BUILID= 22.1 UP2021129 VERSION=WINDOWS x64  
CURRENT JOBNAME=f11e0 18:04:26 JUN 25, 2022 CP= 0.141
```

```
PARAMETER_DS_PROGRESS = 999.000000  
/INPUT FILE= ds.dat LINE= 0
```

```
*** NOTE *** CP = 0.297 TIME= 18:04:26  
The /CONFIG,NOREAD command is not valid in a Distributed ANSYS  
solution. Command is ignored.
```

```
*GET_WALLSTRT FROM ACT1 ITEM=TIME WALL VALUE= 18.0738889  
TITLE= Workbench3_probe--Static Structural (J5)  
ACT Extensions:  
LSDYNA, 2021.1  
5f463412-bd3e-484b-87e7-cbcba665e474, wbx
```

```
SET PARAMETER DIMENSIONS ON WB_PROJECTSCRATCH_DIR  
TYPE=STR DIMENSIONS= Z48 1 1  
PARAMETER WB_PROJECTSCRATCH_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\alberto\QuintanaTFP\Design\Assembly\Ansys_ProjectScratch\scr\FIE\  
SET PARAMETER DIMENSIONS ON WB_SOLVERFILES_DIR  
TYPE=STR DIMENSIONS= Z48 1 1  
PARAMETER WB_SOLVERFILES_DIR(1) = C:\Users\quint\OneDrive\Documents\ICAI\alberto\QuintanaTFP\Design\Assembly\Ansys\Workbench3_probe_files\4p0\878-4\MECH\
```

```

*GET WALLSOL FROM ACT1 ITEM=TIME WALL VALUE= 18.0738889
*****
***** ANSYS SOLUTION ROUTINE *****

PERFORM A STATIC ANALYSIS
THIS WILL BE A NEW ANALYSIS
PARAMETER_THICKRATIO = 0.500000000
USE SPARSE MATRIX DIRECT SOLVER
CONTACT INFORMATION PRINTOUT LEVEL 1
DO NOT COMBINE ELEMENT MATRIX FILES (.emat) AFTER DISTRIBUTED PARALLEL SOLUTION
DO NOT COMBINE ELEMENT SAVE DATA FILES (.esav) AFTER DISTRIBUTED PARALLEL SOLUTION
NLDIAG: Nonlinear diagnostics CONT option is set to ON.
Scaling frequency: each ITERATION.
DO NOT SAVE ANY RESTART FILES AT ALL
*****
***** SOLVE FOR LS 1 OF 1 *****
*** Set Displacement ***
CMBLOCK read of NODE component _CM40UX_XP completed
SELECT COMPONENT_CM40UX_XP
SPECIFIED CONSTRAINT UX FOR SELECTED NODES 1 TO 5933 BY 1
REAL=-1.00000000E-02 IMAG= 0.00000000
ALL SELECT FOR ITEM-NODE COMPONENT=
IN RANGE 1 TO 5933 STEP 1
5933 NODES (OF 5933 DEFINED) SELECTED BY NSEL COMMAND.
*** Component For All Non-zero UX Displacements ***
SELECT COMPONENT_CM40UX_XP
DEFINITION OF COMPONENT = _DISPROMZEROUX ENTITY-NODE
ALL SELECT FOR ITEM-NODE COMPONENT=
IN RANGE 1 TO 5933 STEP 1
5933 NODES (OF 5933 DEFINED) SELECTED BY NSEL COMMAND.
PRINTOUT RESUMED BY /GOP
USE 1 SUBSTEPS INITIALLY THIS LOAD STEP FOR ALL DEGREES OF FREEDOM
FOR AUTOMATIC TIME STEPPING:
USE 1 SUBSTEPS AS A MAXIMUM
USE 1 SUBSTEPS AS A MINIMUM
TIME= 1.0000
ERASE THE CURRENT DATABASE OUTPUT CONTROL TABLE.
WRITE ALL ITEMS TO THE DATABASE WITH A FREQUENCY OF NONE
FOR ALL APPLICABLE ENTITIES
WRITE ESOL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE ESOL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EAMG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE ETMP ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE VENG ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE STRS ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPEL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE EPFL ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
WRITE CONT ITEMS TO THE DATABASE WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES
*GET ANSINTER_ FROM ACT1 ITEM=INT VALUE= 0.00000000
*IF ANSINTER_ (= 0.00000 ) NE
0 (= 0.00000 ) THEN
*ENDIF
*** NOTE *** CP = 0.516 TIME= 18:04:26
The automatic domain decomposition logic has selected the MESH domain
decomposition method with 2 processes per solution.
***** ANSYS SOLVE COMMAND *****
*** WARNING *** CP = 0.516 TIME= 18:04:26
Element shape checking is currently inactive. Issue SHPP,ON or
SHPP,WARN to reactivate, if desired.
*** NOTE *** CP = 0.531 TIME= 18:04:26
The model data was checked and warning messages were found.
Please review output or errors file (
C:\Users\jquin\OneDrive\Documents\JQC\AlbertoQuintana\TP\Design\Assemb
ly\Ansys_Project\Scratch\Scr\FIB\FI160.err ) for these warning
messages.
*** SELECTION OF ELEMENT TECHNOLOGIES FOR APPLICABLE ELEMENTS ***
*** GIVE SUGGESTIONS AND RESET THE KEY OPTIONS ***
ELEMENT TYPE 1 IS SOLID184. KEYOPT(2)=0 IS SUGGESTED AND HAS BEEN RESET.
KEYOPT(1-12)= 0 0 0 0 0 0 0 0 0 0 0 0
ELEMENT TYPE 2 IS SOLID187. IT IS NOT ASSOCIATED WITH FULLY INCOMPRESSIBLE
HYPERELASTIC MATERIALS. NO SUGGESTION IS AVAILABLE AND NO RESETTING IS NEEDED.
*** ANSYS - ENGINEERING ANALYSIS SYSTEM RELEASE 2022 R1 22.1 ***
DISTRIBUTED Ansys Mechanical Enterprise Academic Student
00000000 VERSION=WINDOWS x64 18:04:26 JUN 25, 2022 CP= 0.531
Workbench_probe=Static Structural (J5)

SOLUTION OPTIONS
PROBLEM DIMENSIONALITY . . . . . 3-D
DEGREES OF FREEDOM . . . . . UX UY UZ
ANALYSIS TYPE . . . . . STATIC (STEADY-STATE)
OFFSET TEMPERATURE FROM ABSOLUTE ZERO . . . . . 273.15
EQUATION SOLVER OPTION . . . . . SPARSE
GLOBALLY ASSEMBLED MATRIX . . . . . SYMMETRIC
*** NOTE *** CP = 0.531 TIME= 18:04:26

```

Default Max. friction stress TAUMAX 0.10000E+21
Average contact surface length 0.37388E-02
Average contact pair depth 0.17638E-02
Average target surface length 0.56878E-02
Default pinball region factor PINB 0.25000
WARNING: The default pinball radius may be too small to capture
contacting nodes under small sliding assumption. Redefine the pinball
radius if necessary.
The resulting pinball region 0.44034E-03
Initial penetration/gap is excluded.
Bonded contact (always) is defined.

*** NOTE *** CP = 0.562 TIME= 18:04:26
Min. Initial gap 7.181609075E-08 was detected between contact element
3558 and target element 3527.
Contact is detected due to initial settings.

Max. Geometric gap 4.091924713E-04 has been detected between contact
element 1946 and target element 3531.
WARNING: The geometric gap/penetration may be too large. Increase
pinball radius if it is a true geometric gap/penetration. Decrease
pinball if it is a false one

D I S T R I B U T E D D O M A I N D E C O M P O S E R

...Number of elements: 2118
...Number of nodes: 5938
...Decompose to 2 CPU domains
...Element load balance ratio = 1.016

L O A D S T E P O P T I O N S

LOAD STEP NUMBER: 1
TIME AT END OF THE LOAD STEP: 1.0000
NUMBER OF SUBSTEPS: 1
STEP CHANGE BEHAVIOR CONDITIONS: NO
PRINT OUTPUT CONTROLS: NO PRINTOUT
DATABASE OUTPUT CONTROLS

I T E M F R E Q U E N C Y C O M P O N E N T

ITEM	FREQUENCY	COMPONENT
ALL	NONE	
RSOL	ALL	
RSOL	ALL	
ESNG	ALL	
ETNG	ALL	
VENG	ALL	
STES	ALL	
EFEL	ALL	
EFEL	ALL	
CONV	ALL	

SOLUTION MONITORING INFO IS WRITTEN TO FILE:
file.mnt

***** P R E C I S E M A S S S U M M A R Y *****

TOTAL RIGID BODY MASS MATRIX ABOUT ORIGIN

Translational mass			Coupled translational/rotational mass		
0.61617	0.0000	0.0000	0.0000	-0.11932E-01	-0.28264E-01
0.0000	0.61617	0.0000	0.11932E-01	0.0000	0.17169E-01
0.0000	0.0000	0.61617	0.28264E-01	-0.17169E-01	0.0000

Rotational mass (inertia)		
0.21638E-02	-0.83673E-03	0.35189E-03
-0.83673E-03	0.84342E-03	0.57893E-03
0.35189E-03	0.57893E-03	0.23925E-02

TOTAL MASS = 0.61617
The mass principal axes coincide with the global Cartesian axes
CENTER OF MASS (X,Y,Z) = 0.27864E-01 0.45871E-01 -0.19397E-01

TOTAL INERTIA ABOUT CENTER OF MASS

0.63547E-03	-0.49179E-04	0.18860E-04
-0.49179E-04	0.11489E-03	0.30686E-04
0.18860E-04	0.30686E-04	0.61757E-03

PRINCIPAL INERTIAS = 0.64880E-03 0.12797E-03 0.61166E-03
ORIENTATION VECTORS OF THE INERTIA PRINCIPAL AXES IN GLOBAL CARTESIAN
(0.878, -0.056, 0.473) (0.939, 0.399, -0.066) (-0.469, 0.105, 0.871)

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE	MASS
1	0.55485E
2	0.61009E-01

Range of element maximum matrix coefficients in global coordinates
Maximum = 4.88271784E+10 at element 3560.
Minimum = 1.98944096 at element 1559.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	527	SOLID186	0.172	0.000326
2	1531	SOLID187	0.250	0.000163
3	30	CONTA174	0.000	0.000000
4	30	ELEM170	0.000	0.000000

Time at end of element matrix formulation CP = 1.140625.

D I S T R I B U T E D S P A R S E M A T R I X D I R E C T S O L V E R

Number of equations = 16075, Maximum wavefront = 243

Process memory allocated for solver	=	41.226 MB
Process memory required for in-core solution	=	39.466 MB
Process memory required for out-of-core solution	=	18.442 MB
Total memory allocated for solver	=	72.362 MB
Total memory required for in-core solution	=	69.562 MB
Total memory required for out-of-core solution	=	38.339 MB

*** NOTE *** CP = 1.422 TIME= 18:04:27
The Distributed Sparse Matrix Solver is currently running in the
in-core memory mode. This memory mode uses the most amount of memory
in order to avoid using the hard drive as much as possible, which most
often results in the fastest solution time. This mode is recommended
if enough physical memory is present to accommodate all of the solver
data.

curEqs= 12538 totEqs= 12538 Job CP sec= 1.625
Factor Dose= 1004 Factor Wall sec= 0.105 rates 7.7 GFlops
Distributed sparse solver maximum pivot= 2.861798881E+10 at node 5790
UX.
Distributed sparse solver minimum pivot= 5745574.84 at node 2838 UX.
Distributed sparse solver minimum pivot in absolute value= 5745574.84
at node 2838 UX.

*** ELEMENT RESULT CALCULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	527	SOLID186	0.078	0.000148
2	1531	SOLID187	0.078	0.000051
3	30	CONTA174	0.000	0.000000

*** NODAL LOAD CALCULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
------	--------	-------	----------	--------

EXIT THE ANSYS POST1 DATABASE PROCESSOR

***** ROUTINE COMPLETED ***** CP = 1.875

PRINTOUT RESUMED BY /GOP

*GET _KALLDONE FROM ACT1 ITEM=TIME WALL VALUE= 18.0741667
PARAMETER PREP TIME = 0.000000000
PARAMETER SOLV TIME = 1.000000000
PARAMETER POST TIME = 0.000000000
PARAMETER TOTAL TIME = 1.000000000
*GET _DLBRATIO FROM ACT1 ITEM=SOLU DLBR VALUE= 1.01626794
*GET _COMB TIME FROM ACT1 ITEM=SOLU COMB VALUE= 0.202027000E-01
*GET _SMMODE FROM ACT1 ITEM=SOLU SMM VALUE= 2.000000000
*GET _NDOPS FROM ACT1 ITEM=SOLU NDOP VALUE= 16075.0000
*GET _SOL_END_TIME FROM ACT1 ITEM=SET TIME VALUE= 1.000000000
*IF _sol_end_time (= 1.000000) EQ
1.000000 (= 1.000000) THEN

/PCLEAN COMMAND REMOVING ALL LOCAL FILES

*ENDIF

--- Total number of nodes = 5933
--- Total number of elements = 2118
--- Element load balance ratio = 1.01626794
--- Time to combine distributed files = 2.02027E-02
--- Sparse memory mode = 2
--- Number of DOF = 16075

EXIT ANSYS WITHOUT SAVING DATABASE

NUMBER OF WARNING MESSAGES ENCOUNTERED= 1
NUMBER OF ERROR MESSAGES ENCOUNTERED= 0

----- D I S T R I B U T E D A N S Y S S T A T I S T I C S -----

Release: 2022 R1 Build: 22.1 Update: UP20211129 Platform: WINDOWS x64
Date Run: 06/25/2022 Time: 18:04 Process ID: 16628
Operating System: Windows 10 (Build: 22000)

Processor Model: Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz

Compiler: Intel(R) Fortran Compiler Version 19.0.5 (Build: 20190815)
Intel(R) C/C++ Compiler Version 19.0.5 (Build: 20190815)
Intel(R) Math Kernel Library Version 2020.0.0 Product Build 20191125
BLAS Library supplied by Intel(R) MKL

Number of machines requested : 1
Total number of cores available : 12
Number of physical cores available : 6
Number of processes requested : 2
Number of threads per process requested : 1
Total number of cores requested : 2 (Distributed Memory Parallel)
MPI Type: INTEL MPI
MPI Version: Intel(R) MPI Library 2019 Update 10 for Windows® OS

GPU Acceleration: Not Requested

Job Name: file0
Input File: dummy.dat

Core	Machine Name	Working Directory
0	HP-A	C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\ScrBFE
1	HP-A	C:\Users\quint\OneDrive\Documents\ICAI\AlbertoQuintanaTFG\Design\Assembly\Ansys_Project\Scratch\ScrBFE

Latency time from master to core 1 = 4.045 microseconds

Communication speed from master to core 1 = 1964.50 MB/sec

Total CPU time for main thread : 1.9 seconds
Total CPU time summed for all threads : 2.3 seconds
Elapsed time spent obtaining a license : 0.4 seconds
Elapsed time spent pre-processing model (/PREP7) : 0.1 seconds
Elapsed time spent solution - preprocessing : 0.1 seconds
Elapsed time spent computing solution : 0.9 seconds
Elapsed time spent solution - postprocessing : 0.0 seconds
Elapsed time spent post-processing model (/POST1) : 0.0 seconds
Equation solver used : Sparse (symmetric)
Equation solver computational rate : 13.9 Gflops
Equation solver effective I/O rate : 9.5 GB/sec
Sum of memory used on all processes : 284.0 MB
Sum of memory allocated on all processes : 3136.0 MB
Physical memory available : 16 GB
Total amount of I/O written to disk : 0.0 GB
Total amount of I/O read from disk : 0.0 GB

----- E N D D I S T R I B U T E D A N S Y S S T A T I S T I C S -----

```
-----  
|  
| DISTRIBUTED ANSYS RUN COMPLETED |  
|  
|-----|  
| Ansys 2022 R1 Build 22.1 UP20211129 WINDOWS x64 |  
|-----|  
| Database Requested(-db) 1024 MB Scratch Memory Requested 1024 MB |  
| Maximum Database Used 4 MB Maximum Scratch Memory Used 135 MB |  
|-----|  
| CP Time (sec) = 2.266 Time = 18:04:28 |  
| Elapsed Time (sec) = 4.000 Date = 06/25/2022 |  
|-----|
```