Simulation Modelling Practice and Theory 99 (2020) 102035

Contents lists available at ScienceDirect

Simulation Modelling Practice and Theory

journal homepage: www.elsevier.com/locate/simpat

Determination of optimum numerical parameters in a 3D model of finish turning operation applied to Inconel 718

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ARTICLE INFO

Keywords:
3d numerical model
Finish turning operation
Inconel® 718
Shear deletion elements

ABSTRACT

Finish turning operation consists in a three-dimensional cutting process carried out to accurate size removing a very thin chip section from the work-piece. In this paper, we propose a numerical model of finish turning operation applied to Inconel® 718. The work is focused on the determination of optimum numerical parameters (mesh size and deletion element criterion) for the modeling of chip removing process: 1/ at least 10 elements in the feed direction are needed to predict the cutting forces with accuracy; 2/ the calibration of shear element deletion is a fundamental key: its value affects drastically the temperature distribution in the machined piece. A numerical study on global variables (cutting forces and chip morphology) and local variables (strain, strain rates and temperature) in the chip is presented and discussed. Finally a comparison with experimental measurements in term of forces shows a good accuracy with numerical predictions (the average relative error between numerical and experimental forces is around 2% considering a cutting speed V_c = 300 m/min).

1. Introduction

Nickel based alloys are widely used in aerospace and energy applications due to their excellent mechanical behavior and high corrosion resistance at elevated temperatures [1]. Nevertheless, its mechanical resistance turns out to be problematic for its shaping; industrial processes such as machining are thus complex to perform and may induce extreme conditions of strain, strain rates and temperatures affecting the machined work-piece and a premature tool wear [2]. The low machinability of Inconel 718 has limited its use for a few decades. However experimental [3–11] and numerical studies [12–25] have been carried out to define optimum cutting parameters, to understand the mechanisms of chip formation and the segmentation process and to predict the cutting forces, the residual stresses, the surface integrity or the tool wear. Most of these numerical works have been performed under orthogonal cutting conditions and considering a relatively large chip section [14-18].

Finish turning operation processes consist in a three-dimensional cutting process carried out to accurate size and producing a smooth finish removing a very small chip section from the work-piece. These two characteristics (non-orthogonal process and reduced chip section) lead to significant challenges for the numerical modeling of the finish turning process. Indeed, the tool geometry as well as the cutting conditions (feed and depth of cut) requires a relatively small mesh size inducing high computational time. In recent years, with the improvement of the calculation machines, numerical works on three-dimensional turning process of Inconel 718 have been published [12, 19–25]. In 2007, Uhlmann et al. [19] studied the chip formation process during machining of Inconel

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https://doi.org/10.1016/j.simpat.2019.102035
Received 23 April 2019; Received in revised form 6 November 2019; Accepted 29 November 2019
Available online 30 November 2019
1569-190X/