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Contact Roughness Characterization Parameters for Abrasion-Resistant Epoxy-Coated Surfaces Enhanced with Micro and Nanoparticles

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Abstract

In recent years, numerous studies have been conducted to characterize the physical parameters that define the behavior of surfaces coated with epoxy resins, particularly in terms of hardness and resistance. Many of these surfaces have been doped with micro- and nanoparticles. In this work, we present the internationally defined roughness parameters that are typically of interest for the use of these materials in industrial parts. We analyze the information these parameters provide about the coatings when measured by contact methods, not just optically before and after physical abrasion. The contact profile roughness parameters (R) are highlighted, as they can offer more reliable information regarding the physical wear of these surfaces due to abrasion (typically Ra, Rq, Rz, Rsk, Rku and Rmr). The main advantage is that this approach allows for discerning parameters that, when linked with other functionalities of the parts, provide more comprehensive information without being limited to purely optical or non-contact SEM analysis. The characterization of nanometric particle-doped surfaces with Ra, Rq, and Rz, and of micrometric particle-doped surfaces with Rmr (10–20%) is proposed, in order to clearly characterize the final behavior of the surface before and after wear.

Keywords: contact 2D R roughness parameters; nanoparticles; microparticles; surface performance change

1. Introduction

Epoxy resins are widely recognized for their versatility and superior performance across a range of engineering applications, including adhesives, coatings, encapsulants, casting materials, and as matrices in fiber-reinforced composites [1–3]. Their exceptional thermal, mechanical, and electrical properties enable a broad spectrum of characteristics—from high flexibility to significant strength and hardness—alongside excellent adhesive, chemical, heat, and electrical resistance [4,5]. Despite these advantages, the broader adoption of epoxy resins in high-performance applications is often limited by inherent brittleness, susceptibility to delamination, and restricted fracture toughness [4,5].

To address these limitations, recent research has focused on the incorporation of nano-sized organic and inorganic particles into epoxy matrices [6]. These nanoparticles have demonstrated the potential to significantly enhance material properties, including broader glass transition temperature ranges, increased glassy modulus, and improved

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mechanical performance [1,7,8]. Their molecular dimensions and exceptionally large specific surface areas (exceeding 1000 m^2/g) make them particularly effective as fillers for polymer enhancement [4,5].

Among these, pyrogenic silica (SiO_2) has gained attention due to its established use in adhesives and paints, primarily for rheological modifications [1]. This study specifically investigates the effect of incorporating unmodified pyrogenic nano-silica at concentrations of 3 and 5 wt% into an epoxy resin formulation. The research aims to comprehensively evaluate the impact of these additions on mechanical properties (hardness, bending, and tensile strength), wear resistance (in both bulk and coating applications), cavitation erosion behavior, thermal characteristics (including glass transition temperature, Tg), and the curing kinetics of the epoxy system [1,9].

In parallel, ceramic reinforcements such as silicon carbide (SiC) [10,11] and boron carbide (B_4C) [12–14] are being explored for their exceptional resistance to abrasive wear, high hardness, low density, and durability. These attributes make them ideal candidates for applications requiring enhanced cavitation erosion resistance [8]. Notably, particle size plays a critical role in wear mechanisms [15], with nanometer-scale particles promoting a more ductile material removal process compared to the brittle behavior associated with micrometer-scale particles [8].

Given the limited data available on the wear and cavitation erosion behavior of such engineered nanocomposites, this study also investigates the reinforcement of epoxy matrices with SiC and B_4C particles [16,17] in both nano (30–100 nm) and micro (7–10 μm) scales at 6% and 12% weight ratios. The evaluation includes wear performance on bulk samples and 1 mm thick coatings on aluminum substrates, as well as cavitation-induced mechanical erosion on coated aluminum tips, offering a critical comparison between nano- and microparticle-reinforced epoxy composites [8].

In this paper, we enthusiastically present a detailed measurement into the tribological effects of nanoparticle doping on epoxy resins, with a particular focus on R parameters measurements using a contact roughness meter. This technique enables precise quantification of surface topography changes induced by the incorporation of nano-sized fillers, offering critical insights into wear resistance and frictional behavior. The results reveal how even small concentrations of dopants can dramatically alter the resin's surface morphology, leading to enhanced mechanical interlocking and reduced wear rates. By leveraging high-resolution roughness measurements, we uncover the subtle yet powerful ways in which nanostructuring transforms the tribological performance of epoxy systems—paving the way for smarter, tougher, and more durable composite materials.

This paper presents the measurement procedure applied to doped samples for comparing their final performance. It also proposes the most suitable R parameters for future studies, with the aim of improving effectiveness. The utilization of contact roughness parameters, specifically Ra, Rq, and Rz, provides a robust framework for accurately predicting surface degradation under abrasive conditions. This approach enables the early identification of performance changes that may not be evident through conventional visual inspection, thereby offering a more reliable and quantitative assessment of wear progression.

2. Materials and Methods

2.1. Measured R Parameters

In surface roughness measurements using a contact roughness meter, the traversing length (lt) refers to the total distance traveled by the stylus during profile acquisition, in accordance with EN ISO 21920-1 [18] and EN ISO 21920-2 [19]. This length comprises three segments: pre-travel, evaluation length (ln), and post-travel. The evaluation length

is the portion over which surface parameters are calculated and typically consists of five consecutive sampling lengths. These sampling lengths (lr) are defined by the cut-off wavelength (λc), which serves as a filter to distinguish between roughness and waviness. Additionally, specific reference lengths are used for evaluating the P-profile (lp) and W-profile (lw). Both pre-travel and post-travel are essential for phase-correct filtering, ensuring accurate and reliable surface characterization.

The roughness average (R_a) is a fundamental parameter in surface metrology, representing the arithmetic mean of the absolute values of the roughness profile ordinates over a defined evaluation length. Mathematically, it is expressed as follows:

$$R_a = \frac{1}{l}\int_0^l |Z(x)|dx \quad (1)$$

where Z(x) denotes the vertical deviation in the surface profile from the mean line, and l is the evaluation length. This parameter provides a quantitative measure of surface texture, widely used to assess the quality and functionality of machined or coated surfaces.

The root mean square roughness (R_s or R_q) is a key parameter in surface texture analysis, representing the square root of the mean of the squared values of the roughness profile ordinates over a defined evaluation length. It is mathematically expressed as follows:

$$R_q = \sqrt{\frac{1}{l}\int_0^l Z^2(x)dx} \quad (2)$$

where Z(x) denotes the vertical deviations in the surface profile from the mean line, and l*l* is the evaluation length. Unlike the arithmetic average roughness (R_a), R_q gives greater weight to larger deviations, making it particularly useful for detecting peaks and valleys that significantly influence surface functionality.

The single roughness depth (R_{zi}) represents the vertical distance between the highest peak and the deepest valley within a single sampling length. Building on this, the mean roughness depth (R_z) is defined as the arithmetic mean of the individual R_{zi} values measured across consecutive sampling lengths, which is expressed as follows:

$$R_z = \frac{1}{n}(R_{z1} + R_{z2} + \cdots + R_{zn}) \quad (3)$$

Rz remains a widely used parameter for characterizing surface texture, particularly in applications requiring precise control of peak-to-valley variations.

Skewness (R_{sk}) is a statistical parameter used in surface metrology to describe the asymmetry of the amplitude density curve of a roughness profile. It provides insight into the distribution of peaks and valleys on a surface. A negative skewness value ($R_{sk} < 0$) typically indicates a surface with good bearing properties, as it suggests the presence of deeper valleys that can retain lubricants. Conversely, a positive skewness ($R_{sk} > 0$) implies a surface dominated by peaks, which may lead to increased wear. A skewness of zero ($R_{sk} = 0$) reflects a symmetric distribution of surface features. Mathematically, skewness is defined as follows:

$$R_{sk} = \frac{1}{R_q^3}\frac{1}{l}\int_0^l \left|Z^3(x)\right|dx \quad (4)$$

where Z(x) represents the profile ordinates, R_q is the root mean square roughness, and l*l* is the evaluation length.

Kurtosis (R_{ku}) is a statistical parameter used in surface texture analysis to quantify the peakedness of the amplitude density curve of a roughness profile. It provides insight into the sharpness or flatness of surface features. For a surface with a Gaussian amplitude

distribution, the kurtosis value is typically R_{ku} = 3. The parameter is mathematically defined as follows:

$$R_{ku} = \frac{1}{R_q^4}\frac{1}{l}\int_0^l \left|Z^4(x)\right|dx \quad (5)$$

where Z(x) represents the profile ordinates, R_q is the root mean square roughness, and l*l* is the evaluation length. Both skewness and kurtosis are highly sensitive to isolated peaks and valleys, which can limit their practical relevance in certain surface characterization contexts.

The roughness profile is generated using a specialized filtering technique designed to minimize distortions caused by deep valleys in plateau-like surfaces. This approach ensures a more accurate representation of functional surface characteristics. The resulting profile is analyzed using the Abbott–Firestone curve, which is divided by a straight line into three distinct regions. From these regions, surface parameters are calculated, providing a robust framework for evaluating surfaces with complex topographies, especially those subjected to wear or lubrication.

In surface texture analysis, the core roughness depth (R_k) represents the depth of the central portion of the roughness profile, excluding extreme peaks and valleys. The reduced peak height (R_{pk}) quantifies the average height of the peaks that extend above this core region, while the reduced valley depth (R_{vk}) measures the average depth of the valleys that lie below it. Together, these parameters provide a functional characterization of the surface, which is particularly relevant for tribological applications. Additionally, Mr1 and Mr2 denote the lowest and highest material ratios within the roughness core profile, offering insight into the bearing and lubrication properties of the surface.

2.2. Measurands

The samples consisted of circular specimens approximately 13 mm in diameter, with the following coding scheme:

- Pure epoxy resin (corresponding to E1, E2):
  The epoxy resin used is EPOFER Ex 401, with hardener EPOFER E432, referred to simply as EPOFER (E).
- Micron-sized silicon carbide particles (corresponding to 1M6, 2M6, 1M12, 3M12):
  The matrix is EPOFER resin. The silicon carbide (SiC) particles are micrometric in size, specifically 10 μm.
  a. A total of 6% (1M6, 2M6): Contain 6% by weight of these SiC microparticles.
  b. A total of 12% (1M12, 3M12): Contain 12% by weight of these SiC microparticles.
- Nano-sized silicon carbide particles (corresponding to 1N6, 3N6, 1N12, 2N12):
  The matrix is EPOFER resin. The silicon carbide (SiC) particles are nanometric in size, with an average size between 80 and 100 nm.
  a. A total of 6% (1N6, 3N6): Contain 6% by weight of these SiC nanoparticles.
  b. A total of 12% (1N12, 2N12): Contain 12% by weight of these SiC nanoparticles.
- Nano-sized boron carbide particles (corresponding to 1B12, 2B12):
  The matrix is EPOFER resin. The boron carbide (B_4C) particles are nanometric in size, with an average size between 30 and 60 nm.
  A total of 12% (1B12, 2B12): Contain 12% by weight of these B_4C nanoparticles.

Three profiles were measured on each sample, see Figure 1, approximately 60° apart from each other.

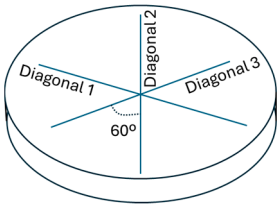

Figure 1. Profile designation.

Wear was developed and measured using a pin-on-disk tribometer, where a stationary alumina pin was pressed against the rotating specimen under a 15 N normal force.

The results will show the change in the contact measured parameters before and after wear, on some of the following samples set up as in Figures 2 and 3:

Figure 2. Sample holder.

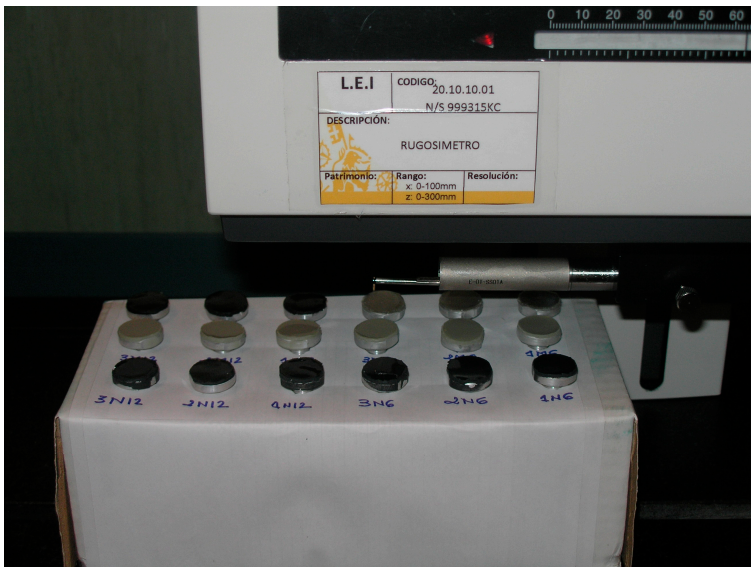

Figure 3. Sample holder in roughness meter.

2.3. Measuring Equipment

Following the specifications outlined in UNE-EN ISO 21920-3 [20] (Tables 1–3), the Surfcom 1500 roughness meter (Carl Zeiss, Tres Cantos, Spain), see Figure 4, was programmed with the following settings:

- Traversing length: 100 mm;
- Straightness: (0.05 + 1.0 L/1000) µm;
- Cut-off range: 0.008 to 25 mm;
- Vertical range: 1000 µm;
- Speed: 0.03 to 3 mm/s (return speed: 20 mm/s);
- Parameters: All roughness and waviness parameters;
- Resolution: Range/64,000;
- Operating principle: Linear motor with glass scale;
- Stylus tip radius: 2 µm (60° conical diamond);
- Stylus measuring force: 0.75 mN.

Table 1. Samples under measurement.

Sample Type	Composition	Particle Type	Particle Size	% by Weight	Codification
Pure epoxy resin	EPOFER Ex 401 + EPOFER E432	—	—	—	E1 E2
Micron-sized SiC particles	EPOFER resin + SiC	Microparticles	10 µm	6%	1M6 2M6
Micron-sized SiC particles	EPOFER resin + SiC	Microparticles	10 µm	12%	1M12 3M12
Nano-sized SiC particles	EPOFER resin + SiC	Nanoparticles	80–100 nm	6%	1N6 3N6
Nano-sized SiC particles	EPOFER resin + SiC	Nanoparticles	80–100 nm	12%	1N12 2N12
Nano-sized B_4C particles	EPOFER resin + B_4C	Nanoparticles	30–60 nm	12%	1B12 2B12

Table 2. Measuring conditions.

Parameter	Value
Output unit	mm, µm
Polarity	Positive
Detector	Standard detector
Measurement type	Roughness
Measurement length	12.5 mm
Sampling length	2.5 mm
Cut-off wavelength	2.5 mm
Measurement range	±500.0 µm
Measurement speed	0.3 mm/s
Cut-off type	Gaussian
Inclination correction method	Least squares (r)
Move speed	3.0 mm/s
Return configuration	Normal
Pre/post travel distance ratio	Cut/3 × 2
Cut-off ratio (Ls)	300
Cut-off wavelength length	8.33 µm
Evaluation length	12.5 mm

Table 3. Environmental measurement conditions.

Parameter	Value
Temperature	(20 ± 1) °C
Relative humidity	(60 ± 10)%

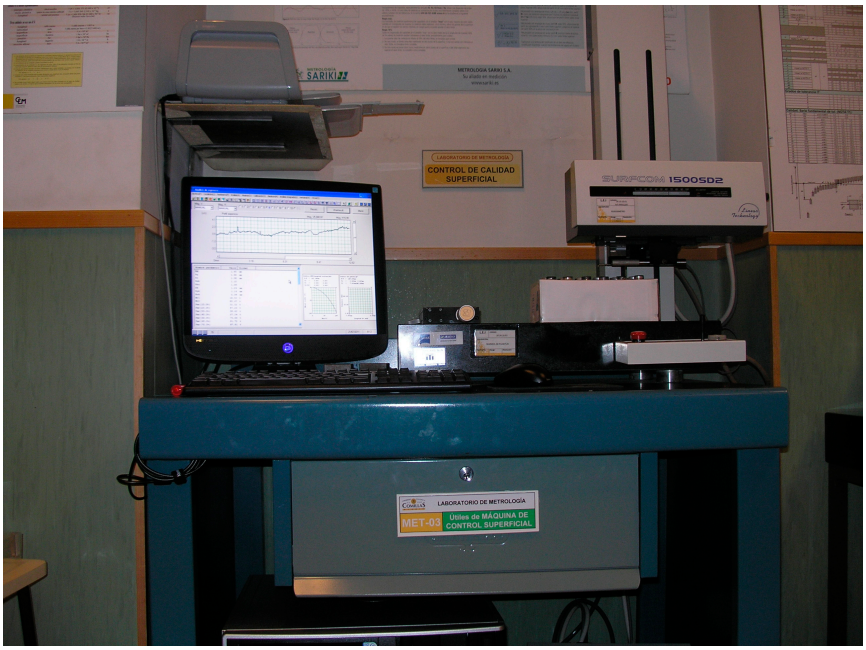

Figure 4. Surfcom 1500.

In Figure 5 it is shown an example of a measurement on a sample.

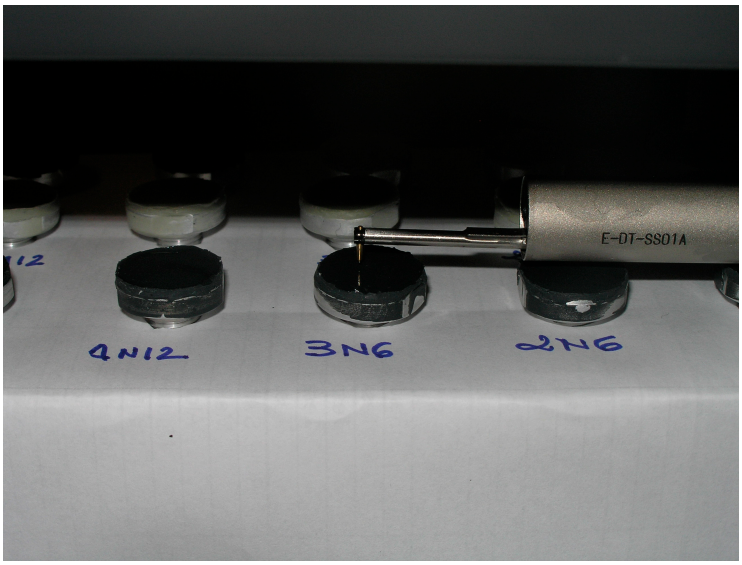

Figure 5. Measurement on a sample.

2.4. Measurement Procedure

The equipment was programmed to measure each profile under the following conditions:

3. Results

This section presents detailed photographs of the samples along with the measured values for each and some graphs containing all the info. The experimental measurements are collected in the following appendices:

- Appendix A for graphical profiles on diagonals before wearing;
- Appendix B for graphical profiles on diagonals after wearing;
- Appendix C for tabulated data.

In the following, the visual change in the tribology of the surface is demonstrated and quantified in Appendix C. The differences will be discussed in the subsequent section.

3.1. Measured Values in Pure Expoxy Resin

3.1.1. Measured Values in E1

It is shown in Figure 6 the apparence of the sample before wear and in Figure 7 after wear for sample E1.

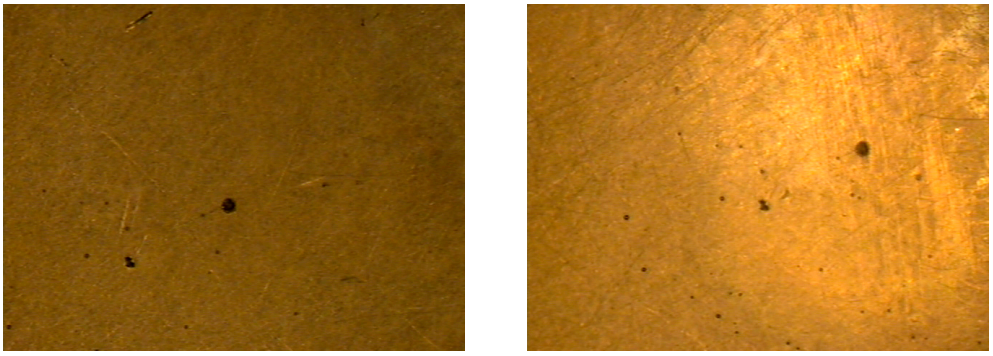

Figure 6. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample E1 (only for information, no measurement).

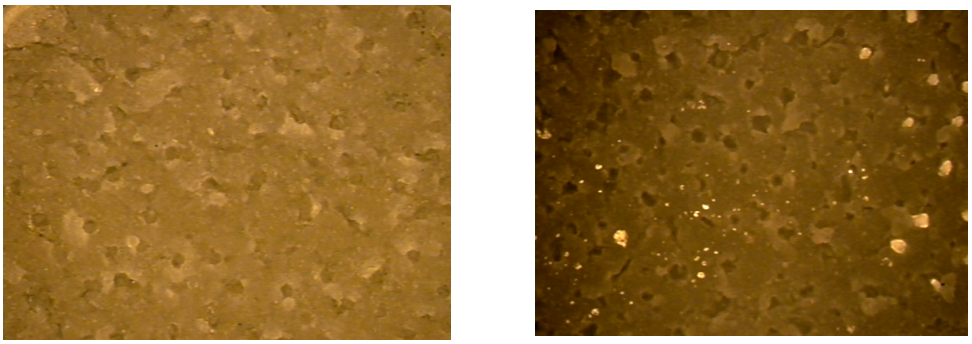

Figure 7. Appearance of the sample after wear under ring and coaxial illumination (respectively) for sample E1 (only for information, no measurement).

3.1.2. Measured Values in E2

It is shown in Figure 8 the apparence of the sample before wear and in Figure 9 after wear for sample E2.

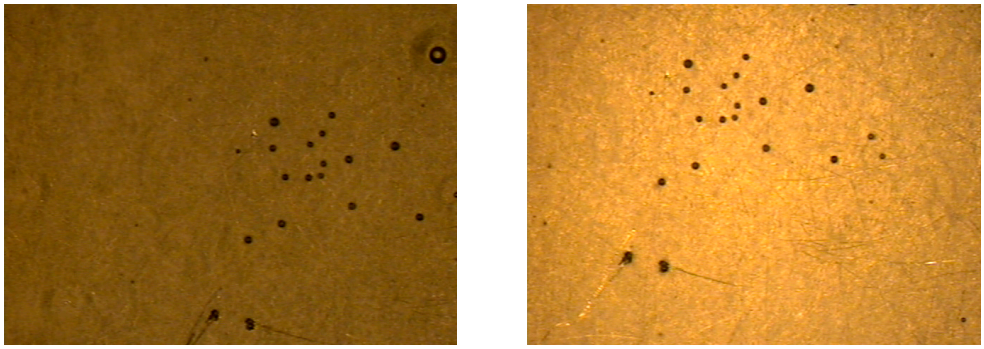

Figure 8. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample E2 (only for information, no measurement).

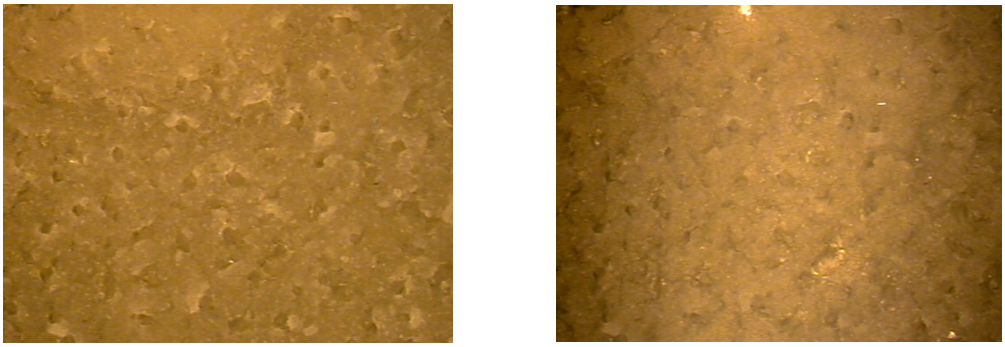

Figure 9. Appearance of the sample after wear under ring and coaxial illumination (respectively) for sample E2 (only for information, no measurement).

3.2. Measured Values in Micron-Sized SiC Particles

3.2.1. Measured Values in 1M6

It is shown in Figure 10 the apparence of the sample before wear and in Figure 11 after wear for sample 1M6.

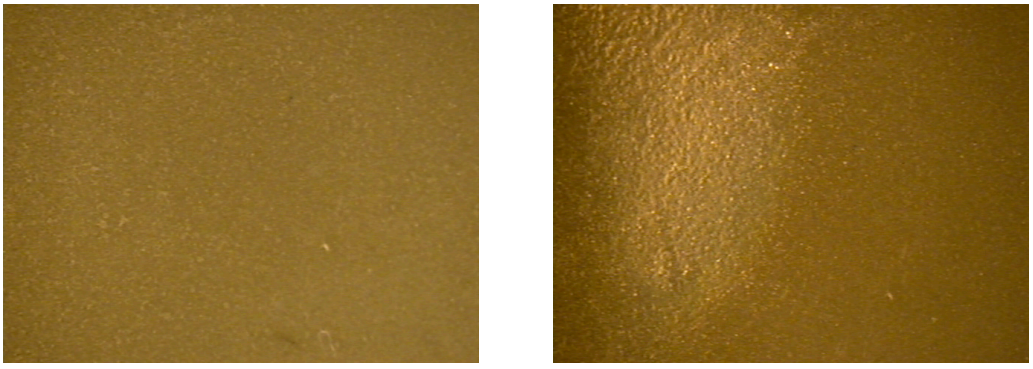

Figure 10. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample 1M6 (only for information, no measurement).

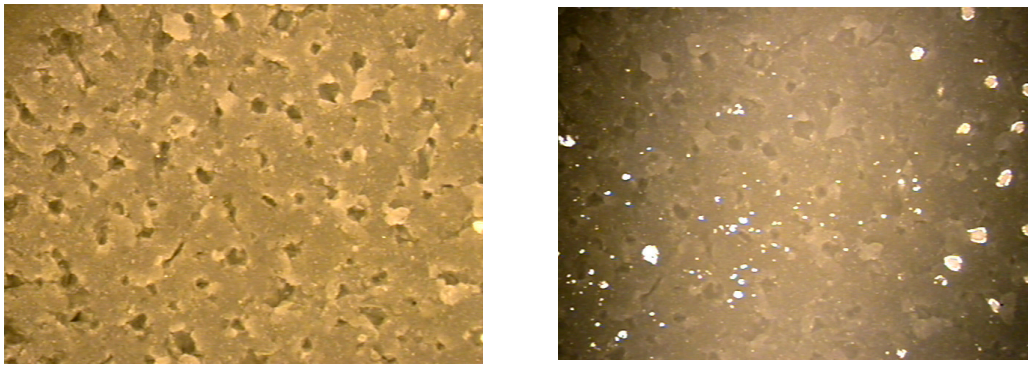

Figure 11. Appearance of the sample after wear under ring and coaxial illumination (respectively) for sample 1M6 (only for information, no measurement).

3.2.2. Measured Values in 2M6

It is shown in Figure 12 the apparence of the sample before wear and in Figure 13 after wear for sample 2M6.

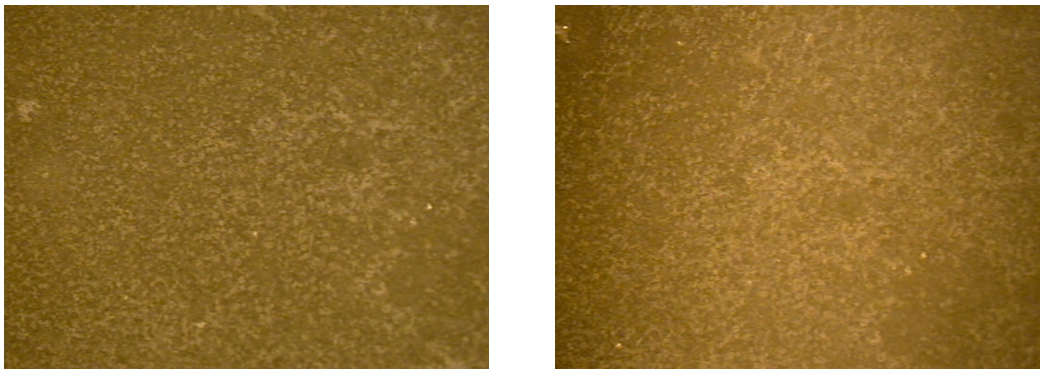

Figure 12. Appearance of the sample before under ring and coaxial illumination (respectively) for sample 2M6 (only for information, no measurement).

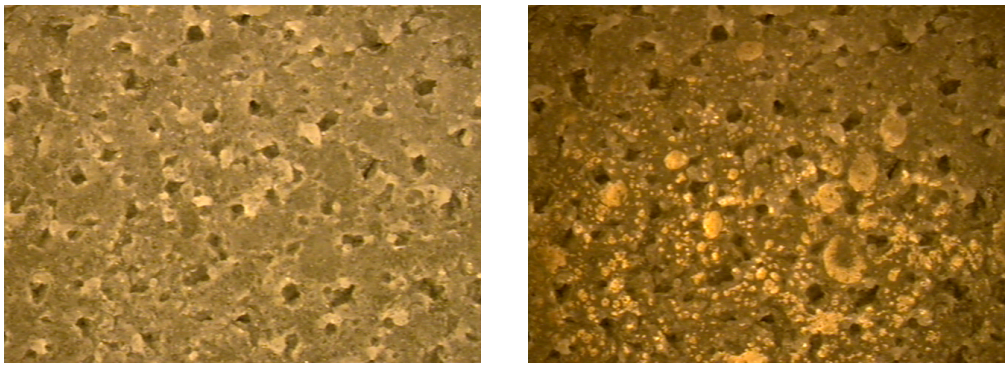

Figure 13. Appearance of the sample after wear under ring and coaxial illumination (respectively) for sample 2M6 (only for information, no measurement).

3.2.3. Measured Values in 1M12

It is shown in Figure 14 the apparence of the sample before wear and in Figure 15 after wear for sample 1M12.

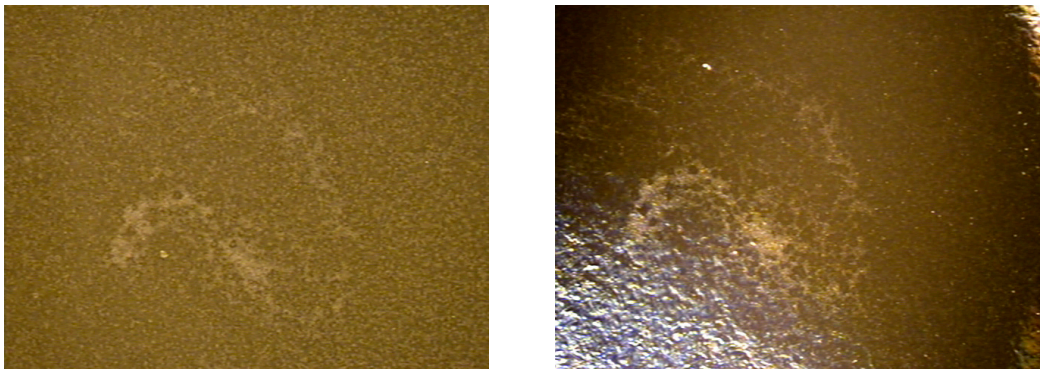

Figure 14. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample 1M12 (only for information, no measurement).

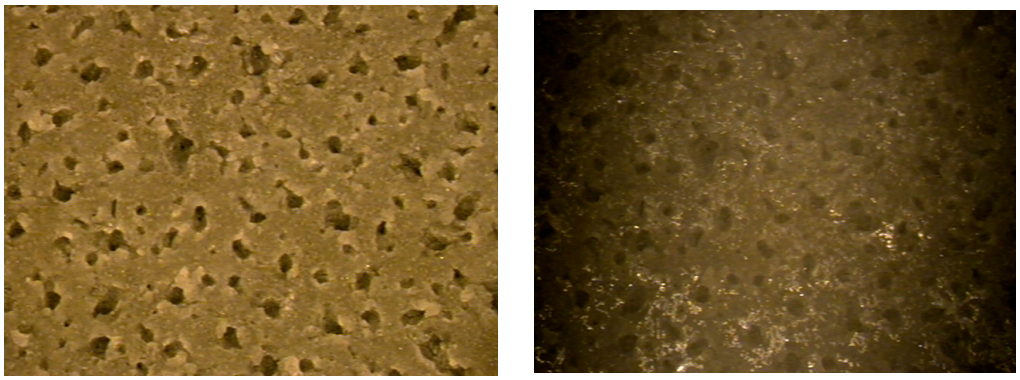

Figure 15. Appearance of the sample after wear under ring and coaxial illumination (respectively) for sample 1M12 (only for information, no measurement).

3.2.4. Measured Values in 3M12

It is shown in Figure 16 the apparence of the sample before wear and in Figure 17 after wear for sample 3M12.

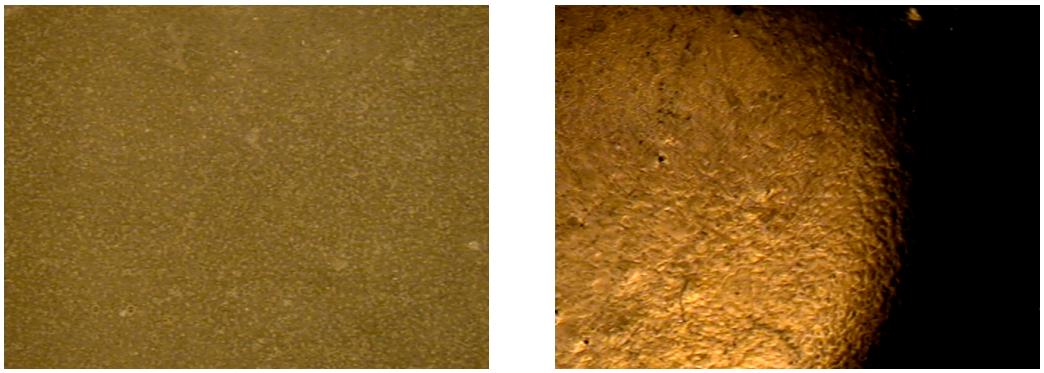

Figure 16. Appearance of the sample before wear for sample 3M12 (only for information, no measurement).

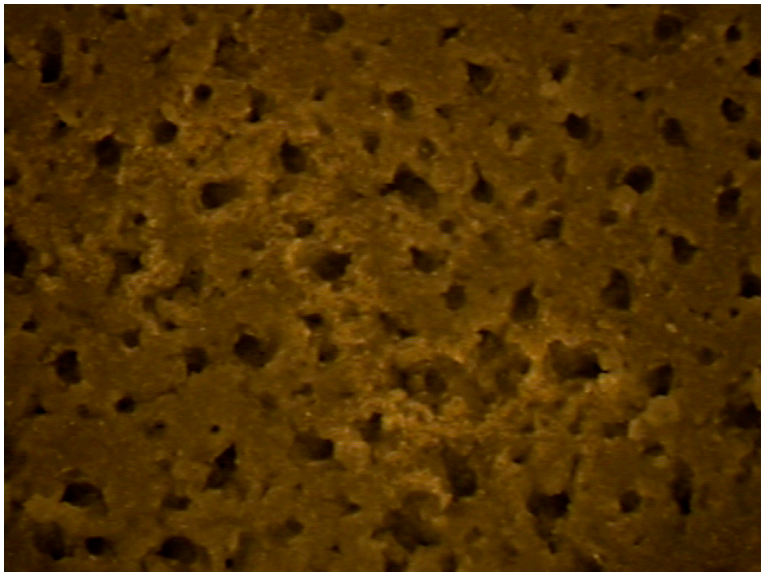

Figure 17. Appearance of the sample after wear for sample 3M12 (only for information, no measurement).

3.3. Measured Values in Nano-Sized SiC Particles

3.3.1. Measured Values in 1N6

It is shown in Figure 18 the apparence of the sample before wear and in Figure 19 after wear for sample 1N6.

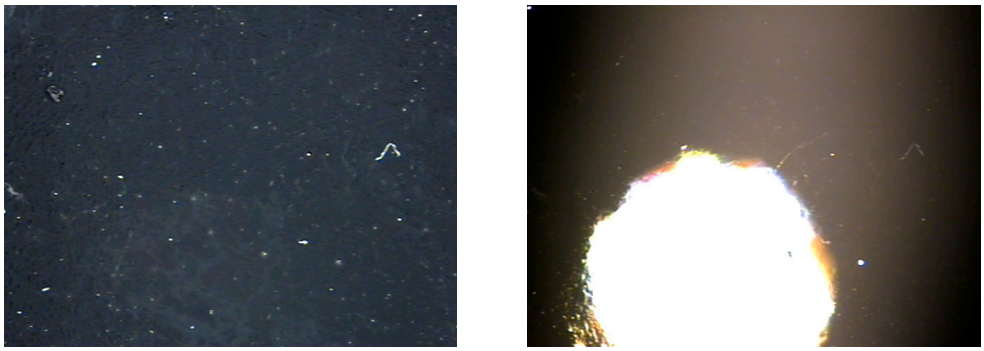

Figure 18. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample 1N6 (only for information, no measurement).

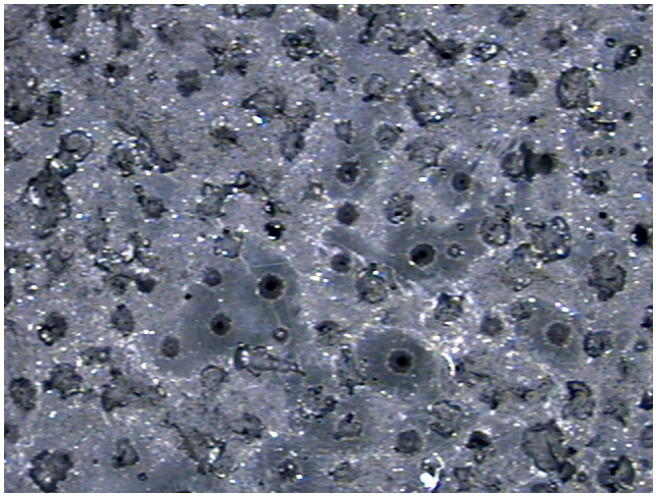

Figure 19. Appearance of the sample after wear for sample 1N6 (only for information, no measurement).

3.3.2. Measured Values in 3N6

It is shown in Figure 20 the apparence of the sample before wear and in Figure 21 after wear for sample 3N6.

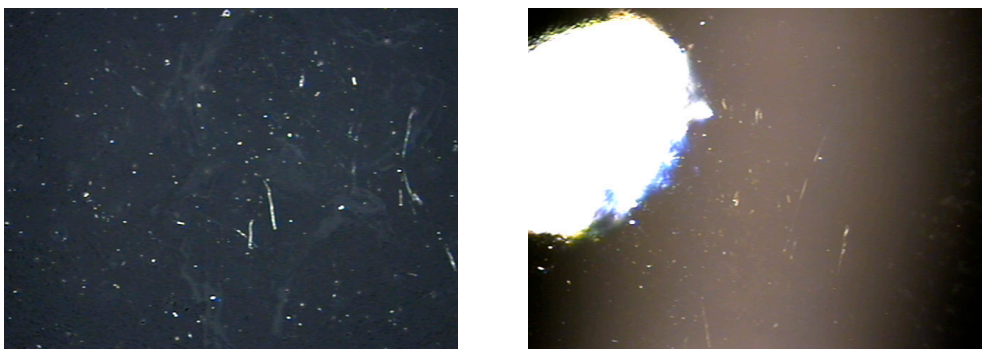

Figure 20. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample 3N6 (only for information, no measurement).

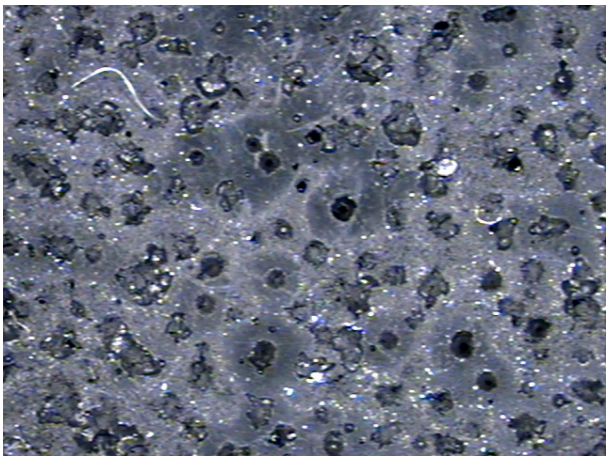

Figure 21. Appearance of the sample after wear for sample 3N6 (only for information, no measurement).

3.3.3. Measured Values in 1N12

It is shown in Figure 22 the apparence of the sample before wear and in Figure 23 after wear for sample 1N12.

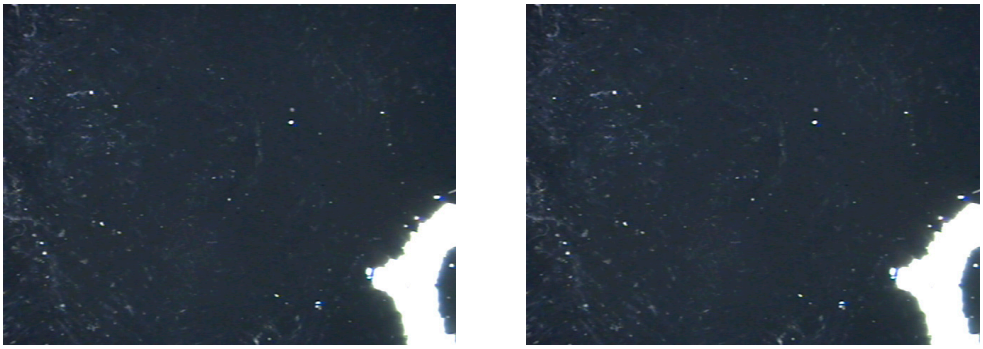

Figure 22. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample 1N12 (only for information, no measurement). There is not significant visual difference.

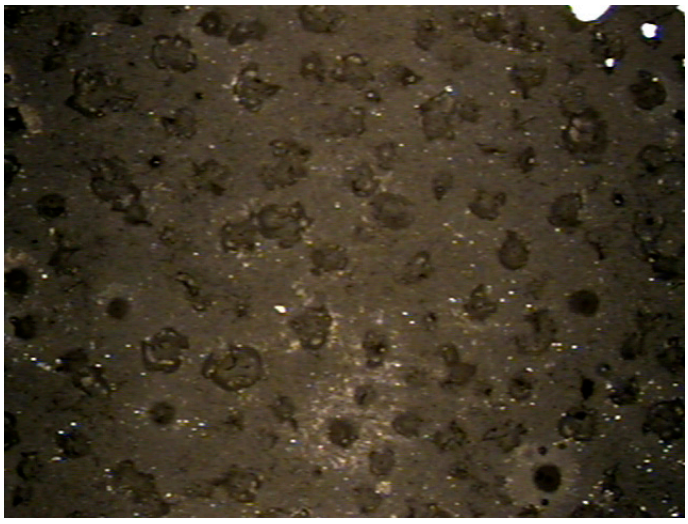

Figure 23. Appearance of the sample after wear for sample 1N12 (only for information, no measurement).

3.3.4. Measured Values in 2N12

It is shown in Figure 24 the apparence of the sample before wear and in Figure 25 after wear for sample 2N12.

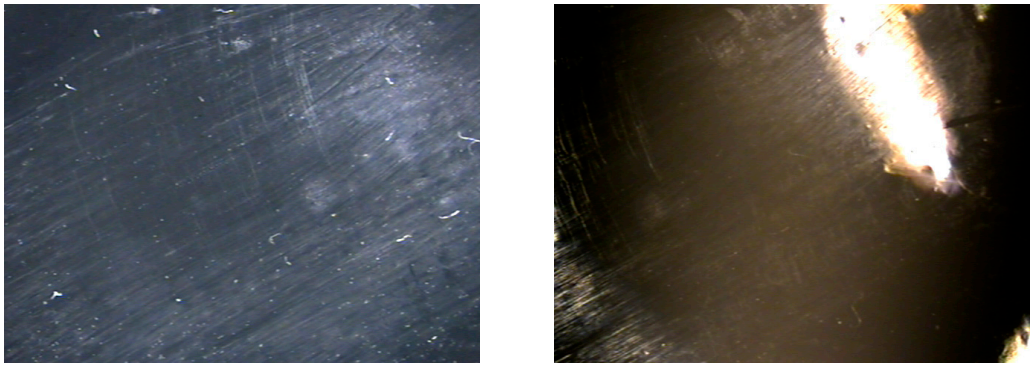

Figure 24. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample 2N12 (only for information, no measurement).

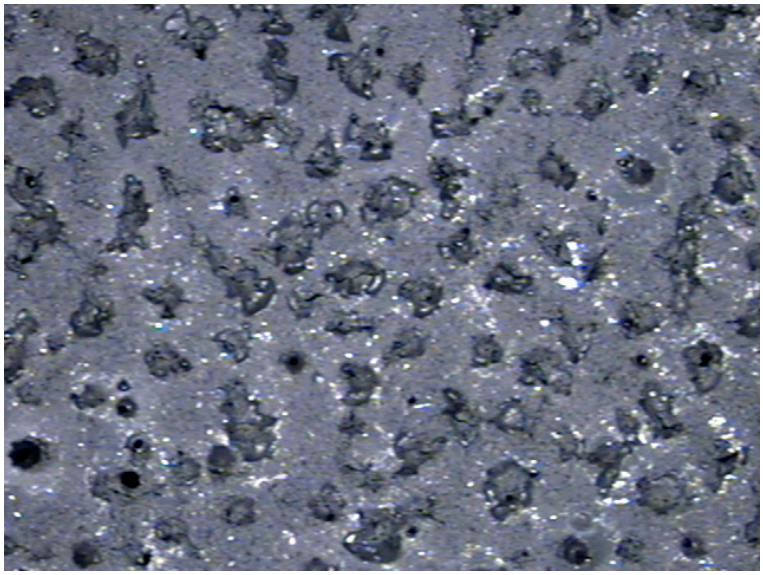

Figure 25. Appearance of the sample after wear for sample 2N12 (only for information, no measurement).

3.4. Measured Values Nano-Sized B_4C Particles

3.4.1. Measured Values in 1B12

It is shown in Figure 26 the apparence of the sample before wear and in Figure 27 after wear for sample 1B12.

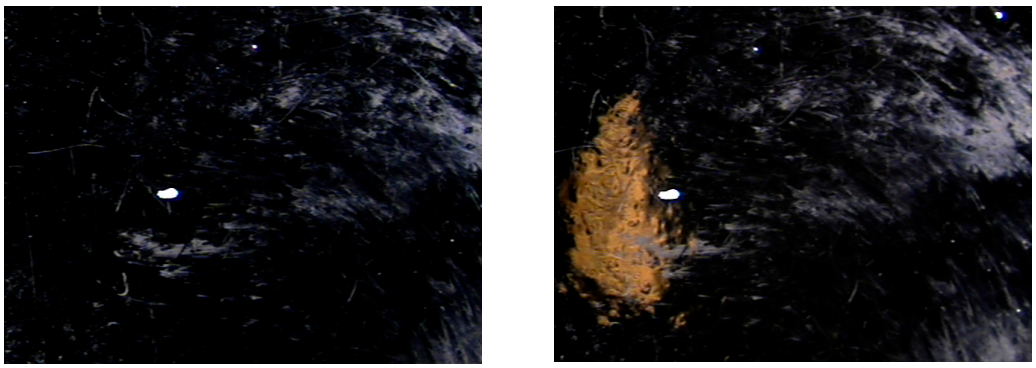

Figure 26. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample 1B12 (only for information, no measurement).

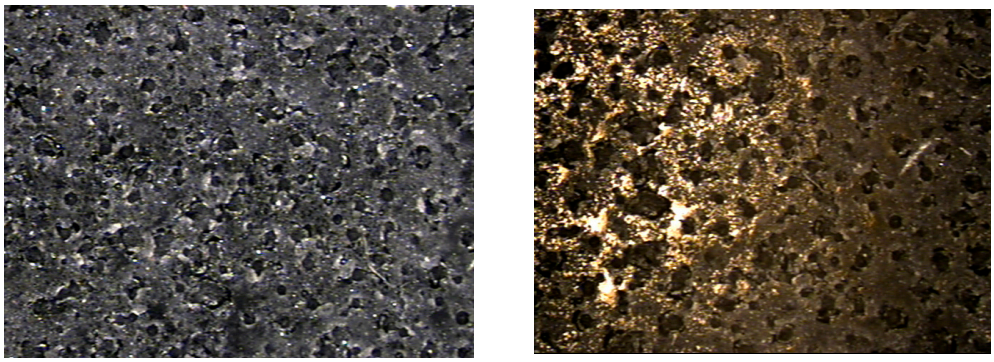

Figure 27. Appearance of the sample after wear under ring and coaxial illumination (respectively) for sample 1B12 (only for information, no measurement).

3.4.2. Measured Values in 2B12

It is shown in Figure 28 the apparence of the sample before wear and in Figure 29 after wear for sample 2B12.

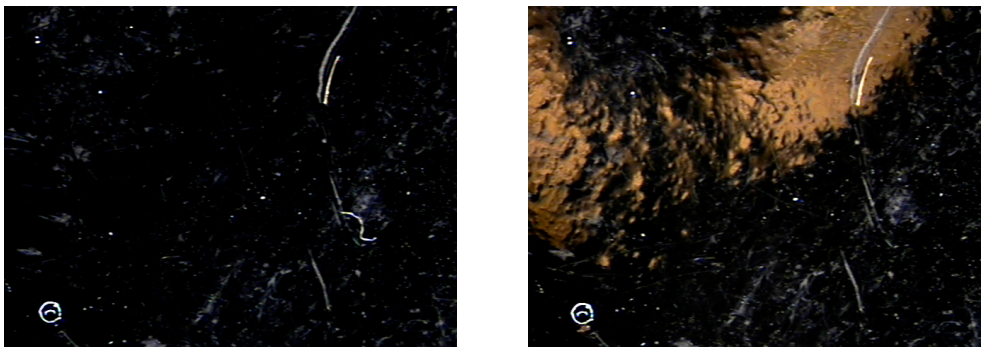

Figure 28. Appearance of the sample before wear under ring and coaxial illumination (respectively) for sample 2B12 (only for information, no measurement).

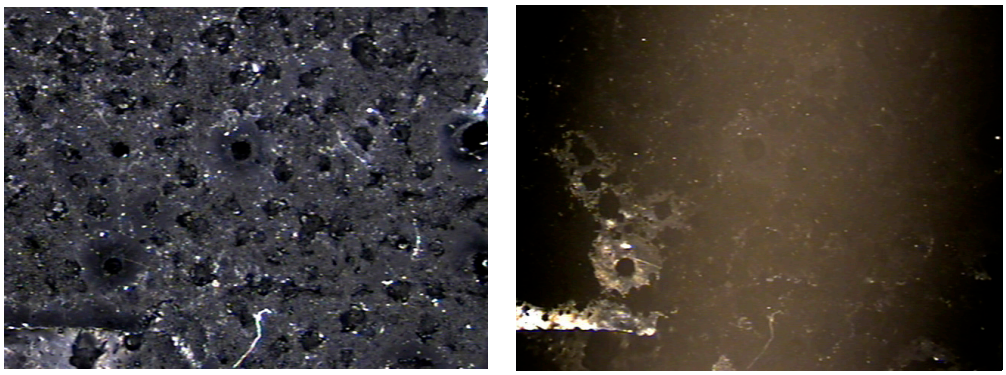

Figure 29. Appearance of the sample after wear under ring and coaxial illumination (respectively) for sample 2B12 (only for information, no measurement).

4. Discussion

There are very clear macroscopic differences between the samples before and after abrasion and wear, and these are directly reflected in the measured roughness parameter values, as it is shown in the following graphs and tables.

In each sample, the following parameters have been measured:

- Ra, Rq, Rz, Rsk, Rku;
- Rmr (10–80%);
- Rmr2 (0%, 10%) to Rmr2 (0%, 70%).

The highest measurement uncertainty for the evaluated parameters was kept at 0.16 µm.

In Annex D, all the data are compiled and plotted. Here we collect the main conclusions from those data:

Ra (average roughness), Rq (root mean square roughness), and Rz (maximum height of profile) generally increase after contact, indicating surface degradation or wear. Samples like E1, E2, and 1M6 show significant increases in Ra and Rz, suggesting material removal or plastic deformation during contact.

Rsk (skewness) values tend to shift from positive to negative, indicating a transition from peaked surfaces to plateaued or valley-dominated surfaces.

Rku (kurtosis) values decrease in many samples, suggesting a flattening of surface features and a reduction in sharp peaks, which is consistent with wear.

In relation with the bearing area curve parameters, Rmr (material ratio) increases significantly at higher percentages (e.g., 50%, 60%, 70%, 80%) after contact, indicating that more surface area is in contact, which is typical of flattened or worn surfaces.

Rmr2, which measures the material ratio between two heights, also shows a marked increase, reinforcing the conclusion of surface smoothing and increased contact area.

From plots, the main conclusions are as follows:

In relation with the wear resistance indicators (Rpk, Rvk, Rk), Rpk (reduced peak height) tends to decrease, indicating peak removal due to wear; Rvk (reduced valley depth) shows mixed behavior, but in many cases decreases, suggesting valley filling or smoothing; Rk (core roughness depth) remains relatively stable, indicating that core material properties are less affected than surface features.

The data supports the hypothesis that contact induces significant changes in surface topography, leading to increased contact area, reduced peak prominence, and more uniform surfaces.

Epoxy coatings enhanced with nanoparticles initially exhibit slightly higher roughness values (Ra, Rq, Rz) compared to pure resin, but this effect is superficial and does not significantly influence structural integrity. After wear, all samples—whether pure resin or particle-doped—show a marked increase in roughness parameters, indicating surface degradation and plastic deformation. Additionally, bearing area curve parameters (Rmr, Rmr2) become highly uniform beyond 40% material ratio after wear, while skewness (Rsk) shifts from positive to negative and kurtosis (Rku) decreases, reflecting a transition to flatter, valley-dominated surfaces.

These findings matter because they reveal how particle size and distribution affect surface behavior under abrasion. Micron-sized particles introduce variability at low material ratios (10–20%), making surfaces more sensitive to initial contact, whereas nanoparticles mainly influence superficial morphology without compromising mechanical integrity. This knowledge enables engineers to select appropriate roughness parameters for future studies—Ra, Rq, and Rz for nanometric particles, and Rmr (10–20%) for micrometric particles—optimizing coating design for durability and performance in industrial applications.

These changes are indicative of plastic deformation, abrasive wear, and possibly adhesive wear mechanisms depending on material pairings.

Understanding how surface topography evolves under wear is essential for designing coatings that meet the demands of high-performance sectors such as aerospace, automotive, and energy, where durability and friction control are critical. Contact roughness measurements provide deeper functional insights than optical or SEM analysis, enabling more accurate predictions of real-world performance. By identifying key roughness parameters, manufacturers can streamline testing, reduce costs, and tailor coatings to specific tribological requirements. Furthermore, linking these parameters to manufacturing processes opens

the door to smarter, tougher, and more sustainable composite materials, driving innovation in industrial applications.

5. Conclusions

Surfaces doped with nanometric particles exhibit slightly higher roughness values (Ra, Rq, Rz) prior to wear compared to undoped surfaces, as evidenced in the corresponding graphs. This increase is interpreted as a purely superficial effect resulting from the incorporation of nanoparticles into the resin matrix. However, after surface interaction and wear, the bearing area curve parameters become notably homogeneous from 40% material ratio onwards, regardless of the presence or type of subparticles in the resin. This indicates that the mechanical behavior under load stabilizes and that the nanoparticles do not significantly alter the substrate's response to physical abrasion measured by contact roughness.

In contrast, at lower material ratios (Rmr 10–20%), a high variability is observed, particularly in samples containing micrometric particles. This suggests a greater sensitivity of the surface to initial contact conditions. Meanwhile, nanometric particles do not produce significant deviations from the baseline resin substrate, reinforcing the hypothesis that their influence is predominantly superficial and does not compromise the functional integrity of the material under abrasive conditions developed by the type of force of this study.

In this paper, we focus on R measurement parameters that can be applied in future studies to different samples, without addressing other performance aspects of the samples.

Therefore, in this paper, we propose the following parameters for surface characterization:

- For nanometric particle-doped surfaces: Ra, Rq, and Rz;
- For micrometric particle-doped surfaces: Rmr (10–20%).

A future statistical study should be conducted in any study to compare the results obtained from different samples, in order to determine the most appropriate applications.

A potential future application of this work will be to link various manufacturing processes of the samples with their performance, for example, wear, measuring only the R parameters proposed in this paper.

If available, it would be desirable to conduct a study of the samples using areal parameters as specified in EN ISO 25178 [21], in order to develop the most appropriate material for each application. The adoption of internationally recognized roughness parameters ensures full compliance with EN ISO standards, thereby facilitating standardized characterization across diverse industrial applications. This alignment promotes global interoperability in quality control processes, enabling manufacturers to implement consistent evaluation protocols and enhance reliability in surface performance assessments.

It will be desirable to carry out a detailed uncertainty assessment in each particular study.

Linking particle size and type—whether nano- or micro-scale—with roughness metrics offers a strategic pathway for optimizing epoxy composite design to meet specific mechanical and tribological requirements, thereby supporting the development of abrasion-resistant coatings for critical components. Furthermore, advanced parameters such as Rsk and Rku provide valuable insights into lubricant retention and peak-to-valley distribution, which are essential for reducing friction and extending service life. Future research can integrate these findings with manufacturing variables, such as curing conditions and particle dispersion, to establish correlations that enable process optimization for enhanced durability. In addition, contact-based roughness measurements present a cost-effective alternative to expensive optical or SEM techniques, improving reliability while reducing inspection costs. Finally, this approach lays the groundwork for incorporating areal parameters in accordance with EN ISO 25178 and conducting detailed uncertainty analyses, thereby paving the way for next-generation surface engineering and more comprehensive material characterization.

Author Contributions: Conceptualization, M.A.S.-N. and C.P.; Methodology, M.A.S.-N.; Software, M.A.S.-N.; Validation, M.A.S.-N. and C.P.; Formal analysis, M.A.S.-N.; Investigation, M.A.S.-N. and C.P.; Resources, M.A.S.-N.; Data curation, M.A.S.-N. and C.P.; Writing—original draft, M.A.S.-N. and C.P.; Writing—review & editing, M.A.S.-N. and C.P.; Visualization, M.A.S.-N. and C.P.; Supervision, C.P.; Project administration, M.A.S.-N. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Measurements Before Wear

Appendix A.1. Measurements Before Wear in Sample E1

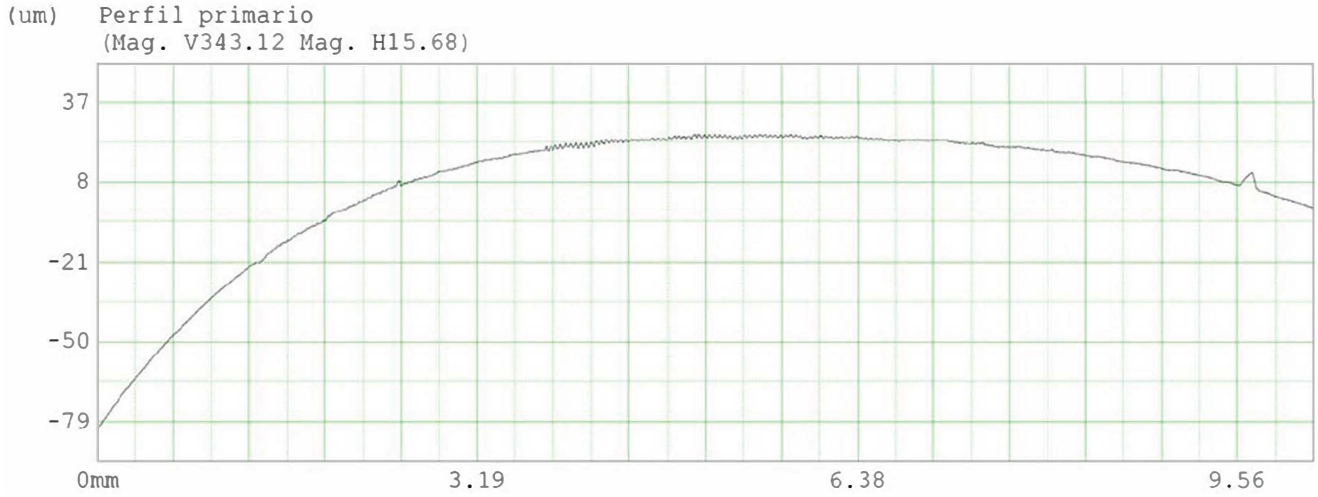

Figure A1. Primary profile; diagonal 1 before wear in sample E1.

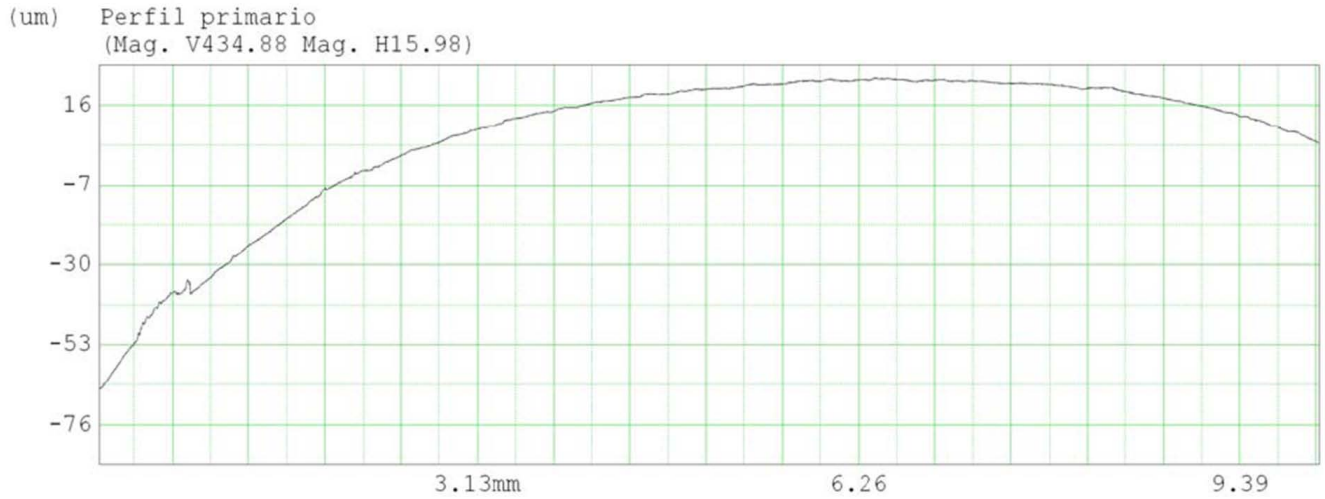

Figure A2. Primary profile; diagonal 2 before wear in sample E1.

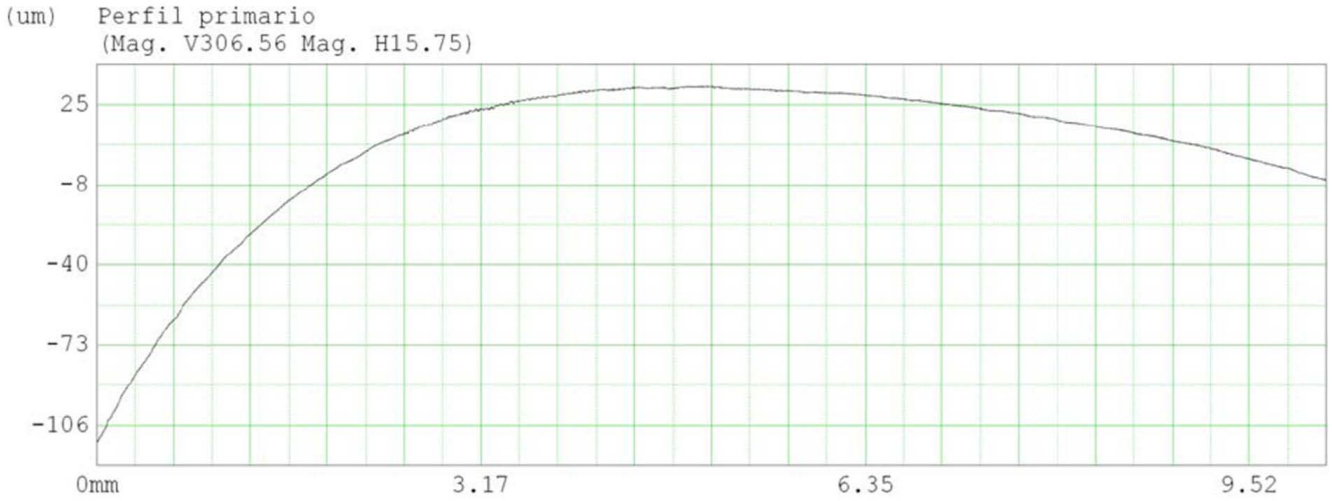

Figure A3. Primary profile; diagonal 3 before wear in sample E1.

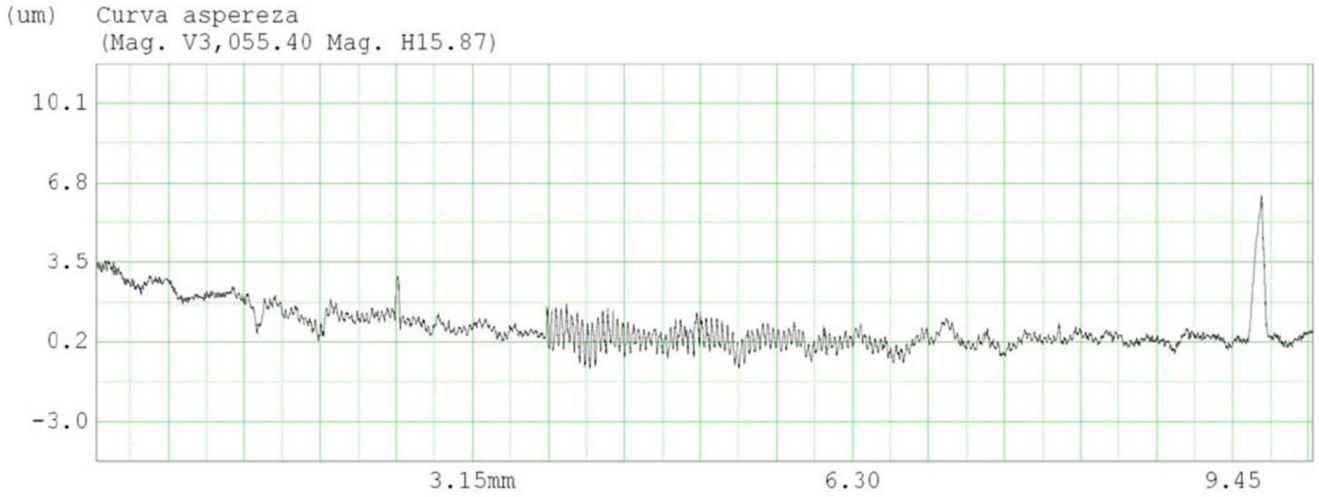

Figure A4. Roughness profile; diagonal 1 before wear in sample E1.

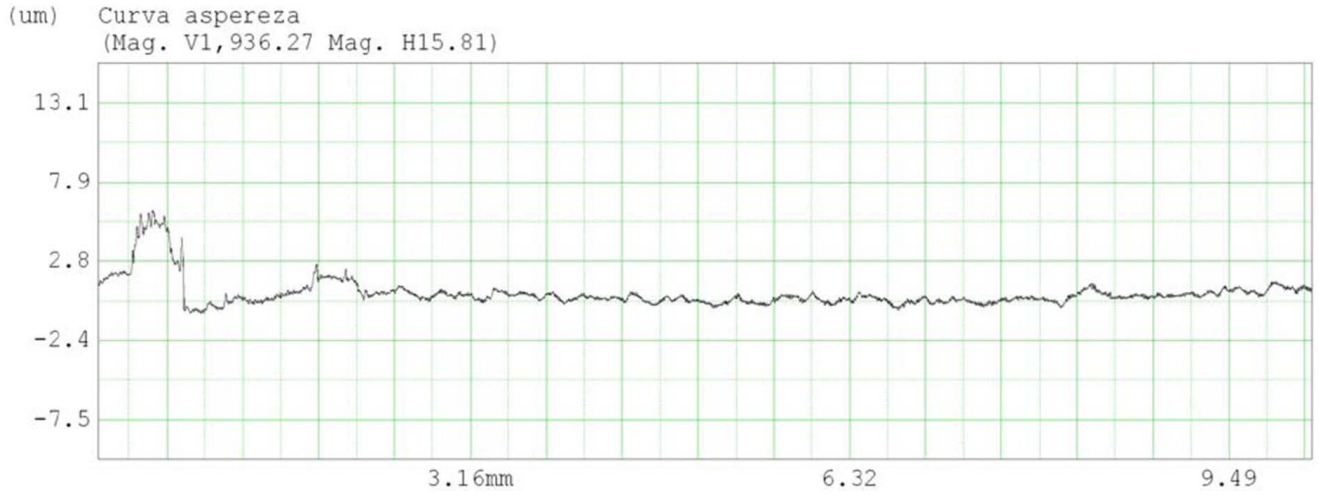

Figure A5. Roughness profile; diagonal 2 before wear in sample E1.

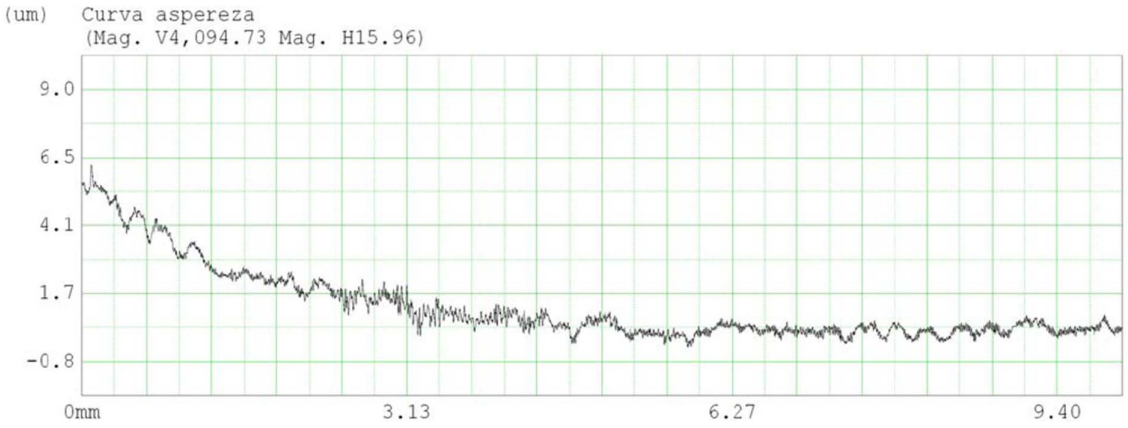

Figure A6. Roughness profile; diagonal 3 before wear in sample E1.

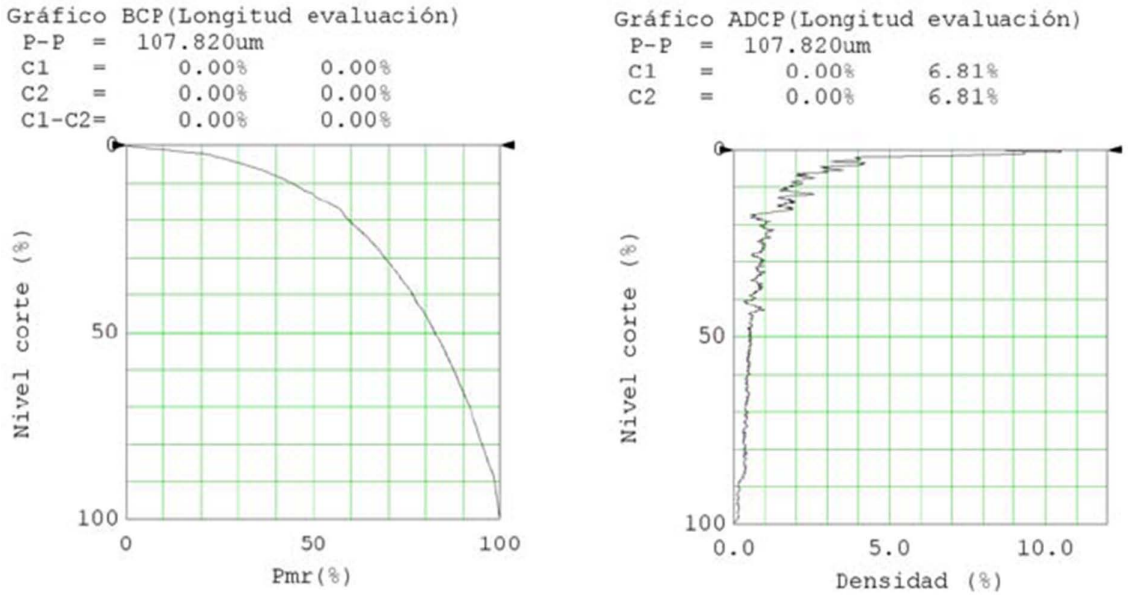

Figure A7. Roughness profile; diagonal 1 before wear in sample E1.

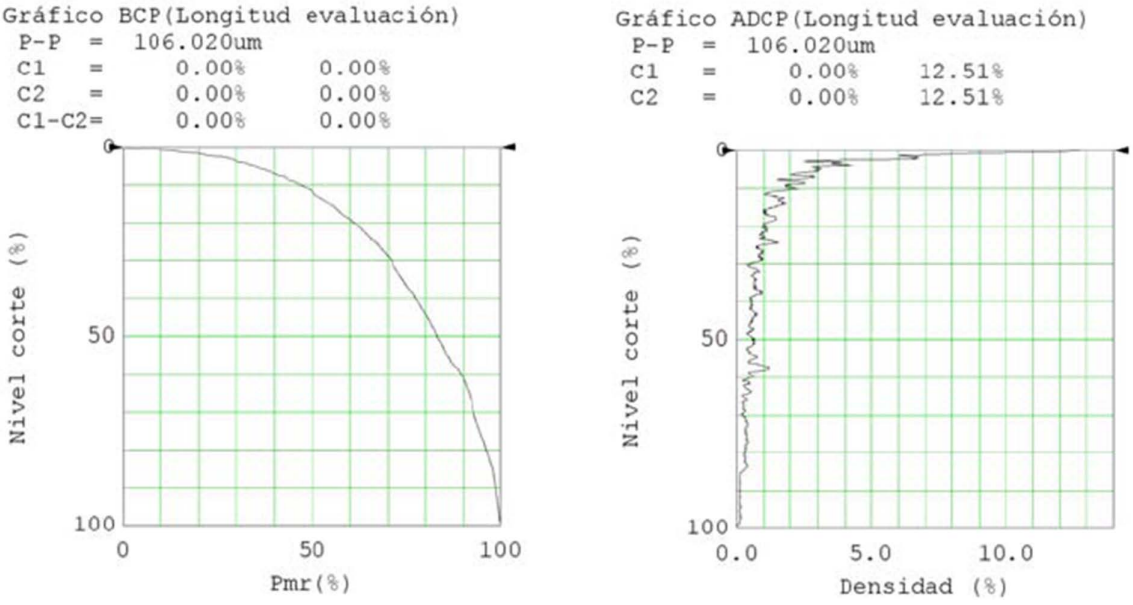

Figure A8. Roughness profile; diagonal 2 before wear in sample E1.

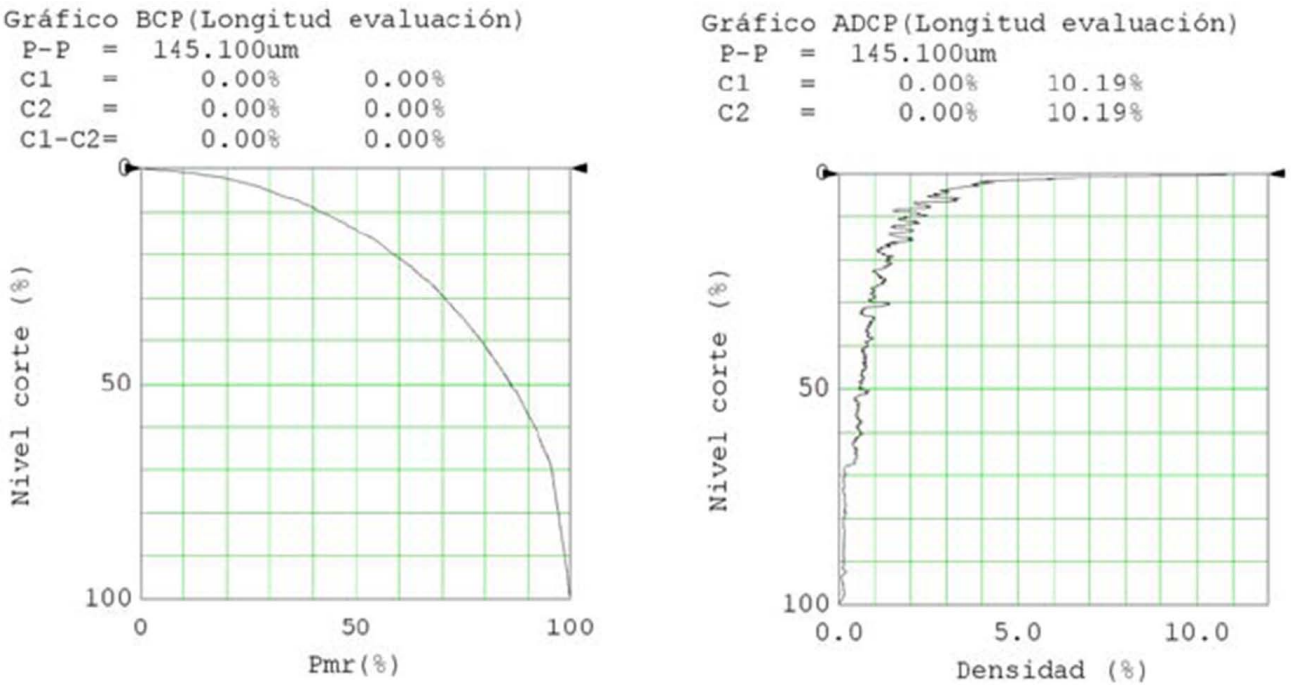

Figure A9. Roughness profile; diagonal 3 before wear in sample E1.

Appendix A.2. Measurements Before Wear in Sample E2

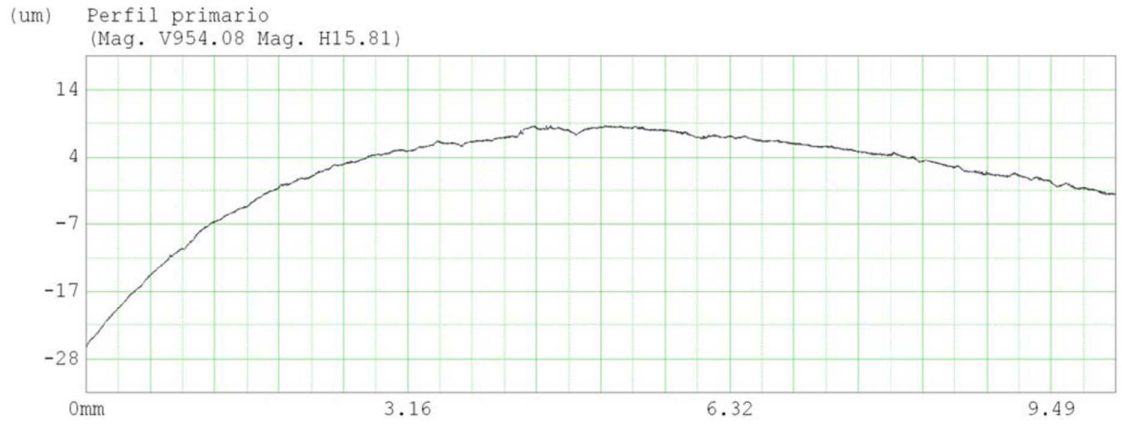

Figure A10. Primary profile; diagonal 1 before wear in sample E2.

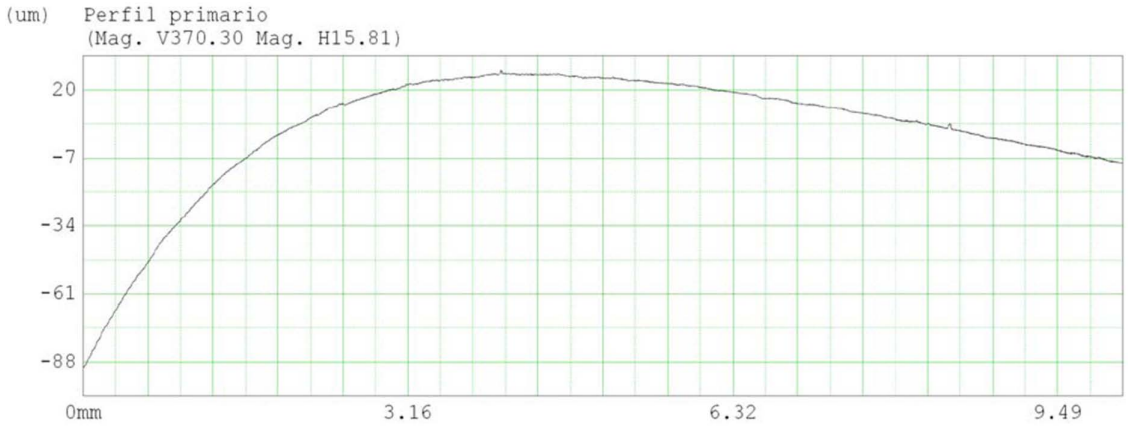

Figure A11. Primary profile; diagonal 2 before wear in sample E2.

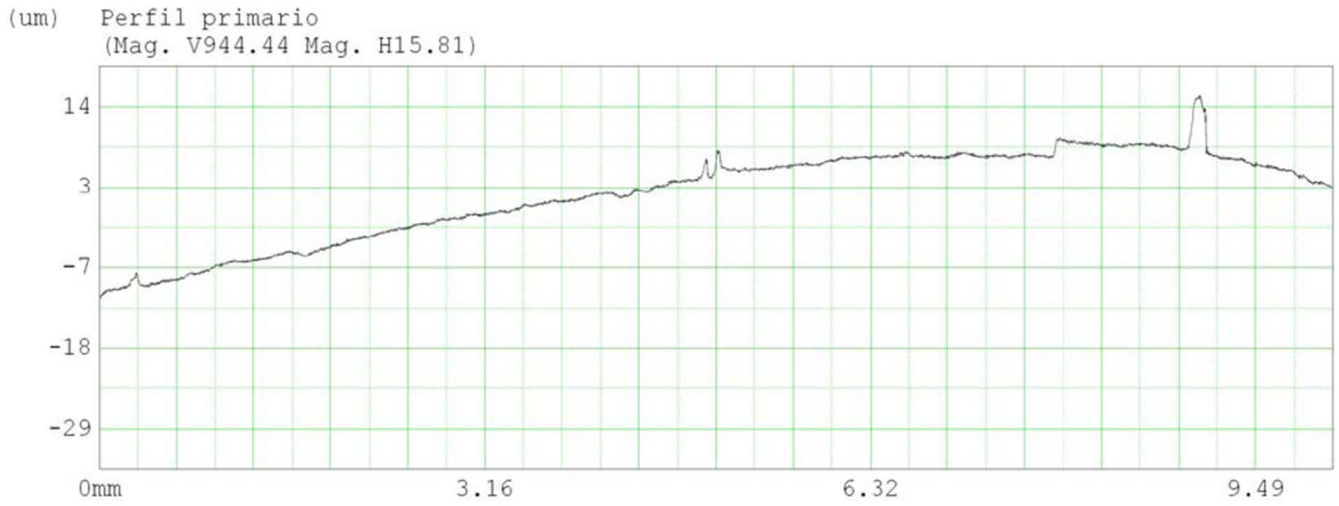

Figure A12. Primary profile; diagonal 3 before wear in sample E2.

Figure A13. Roughness profile; diagonal 1 before wear in sample E2.

Figure A14. Roughness profile; diagonal 2 before wear in sample E2.

Figure A15. Roughness profile; diagonal 3 before wear in sample E2.

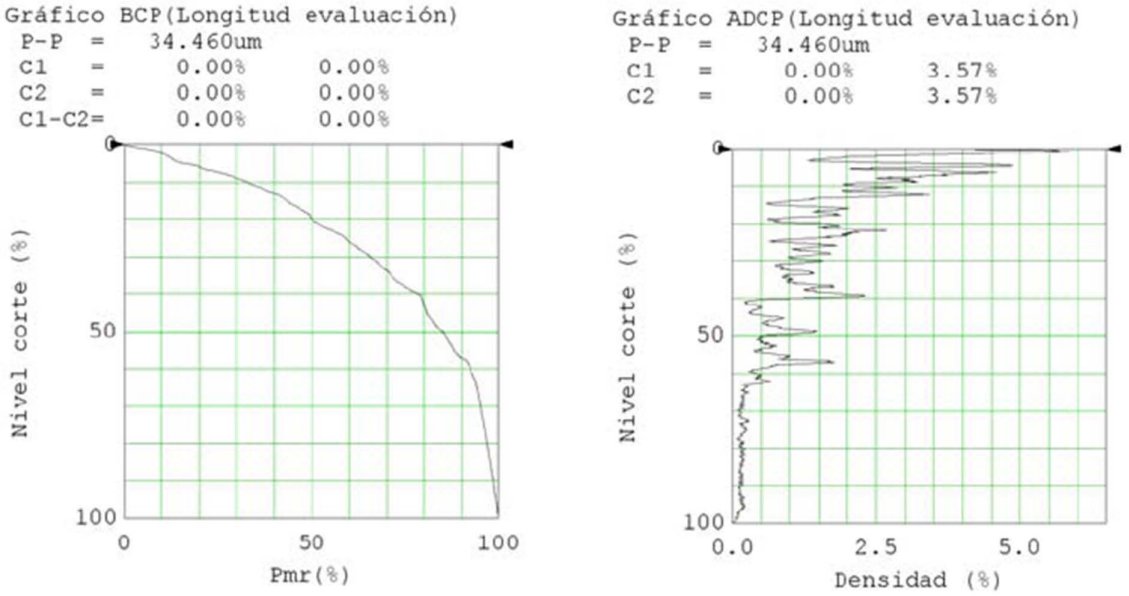

Figure A16. Roughness profile; diagonal 1 before wear in sample E2.

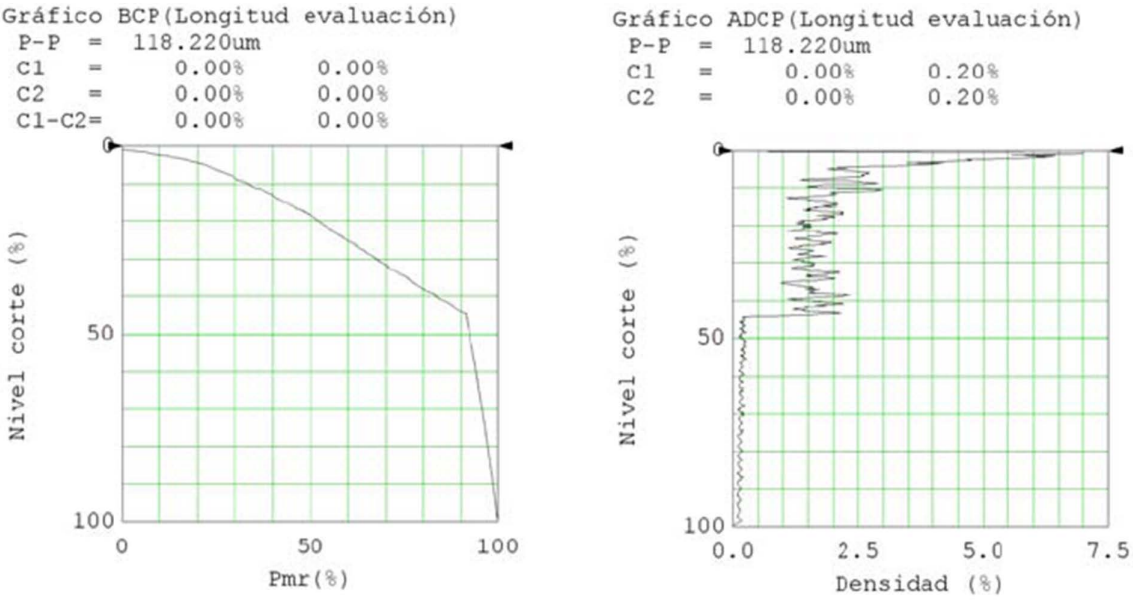

Figure A17. Roughness profile; diagonal 2 before wear in sample E2.

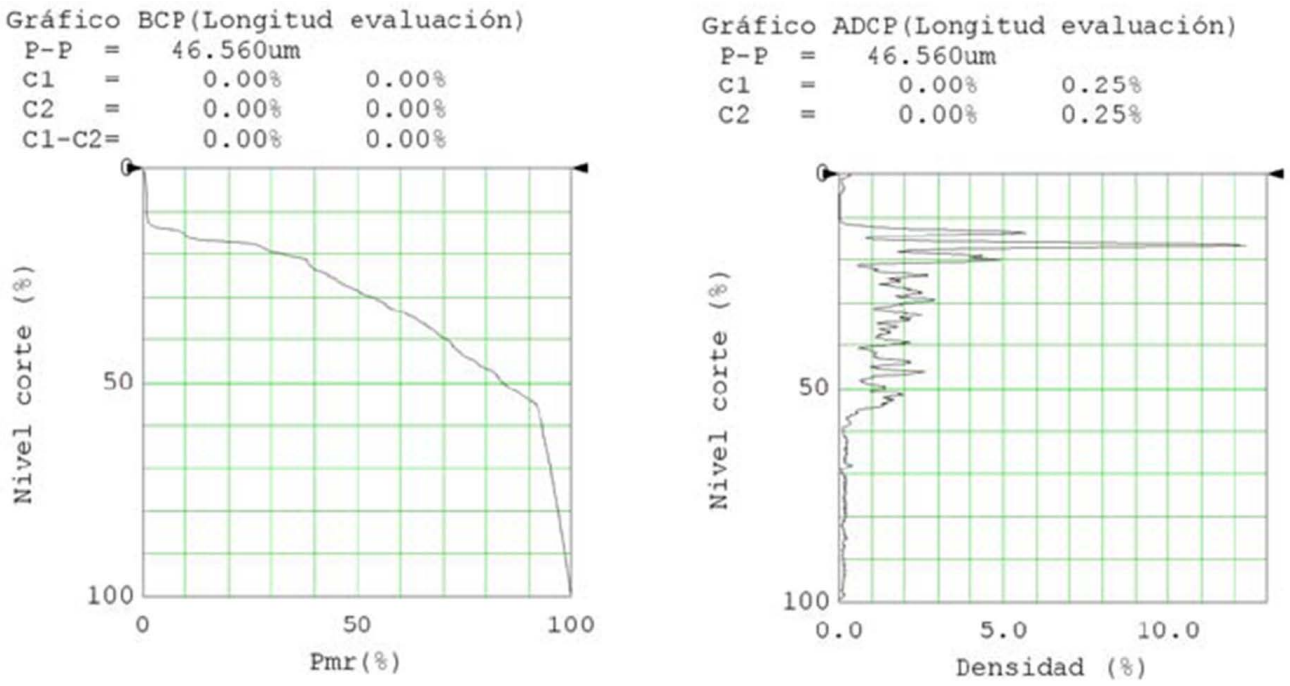

Figure A18. Roughness profile; diagonal 3 before wear in sample E2.

Appendix A.3. Measurements Before Wear in Sample 1M6

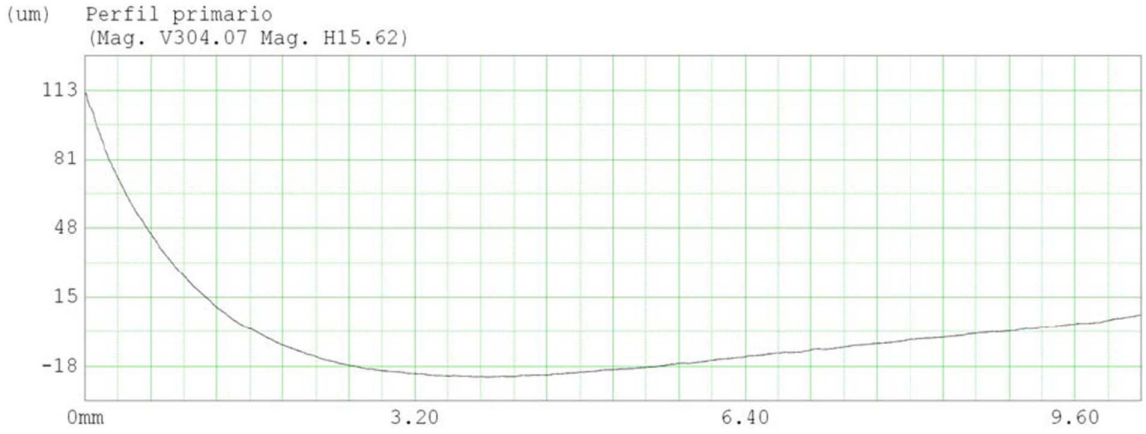

Figure A19. Primary profile; diagonal 1 before wear in sample 1M6.

Figure A20. Primary profile; diagonal 2 before wear in sample 1M6.

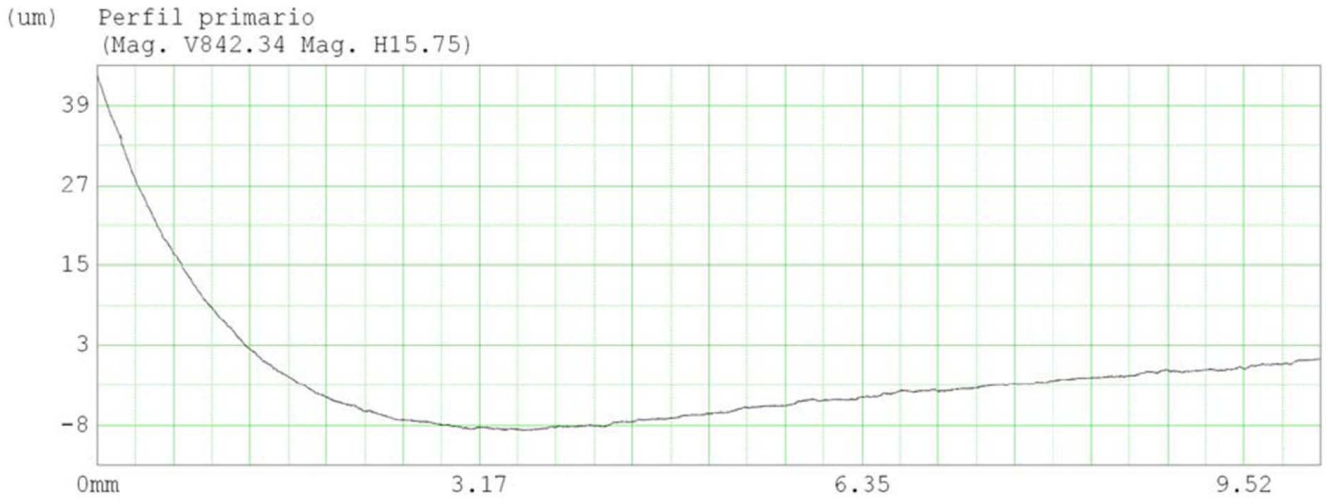

Figure A21. Primary profile; diagonal 3 before wear in sample 1M6.

Figure A22. Roughness profile; diagonal 1 before wear in sample 1M6.

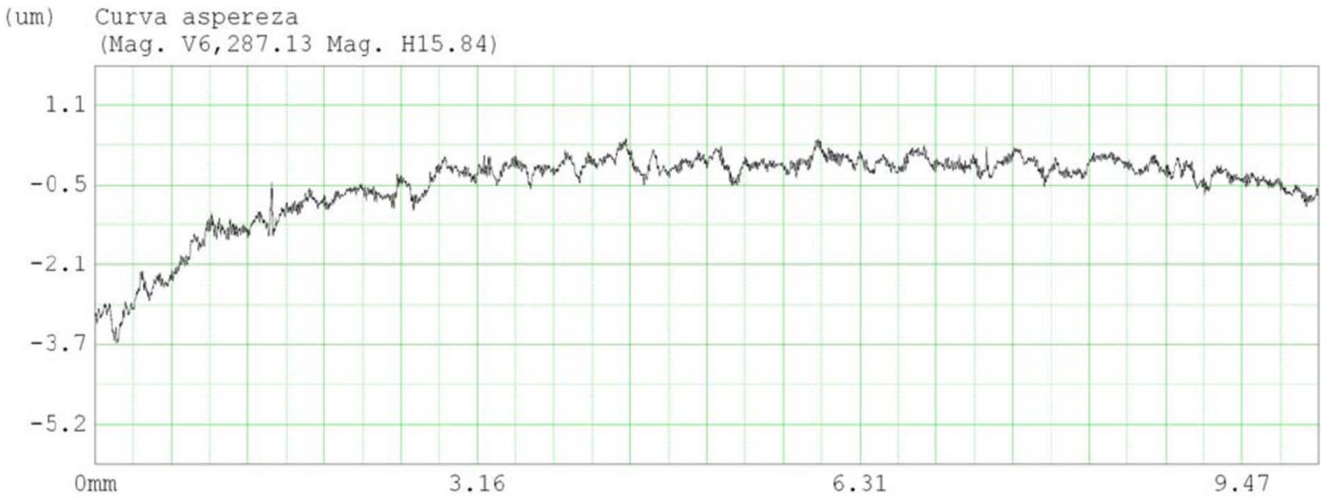

Figure A23. Roughness profile; diagonal 2 before wear in sample 1M6.

Figure A24. Roughness profile; diagonal 3 before wear in sample 1M6.

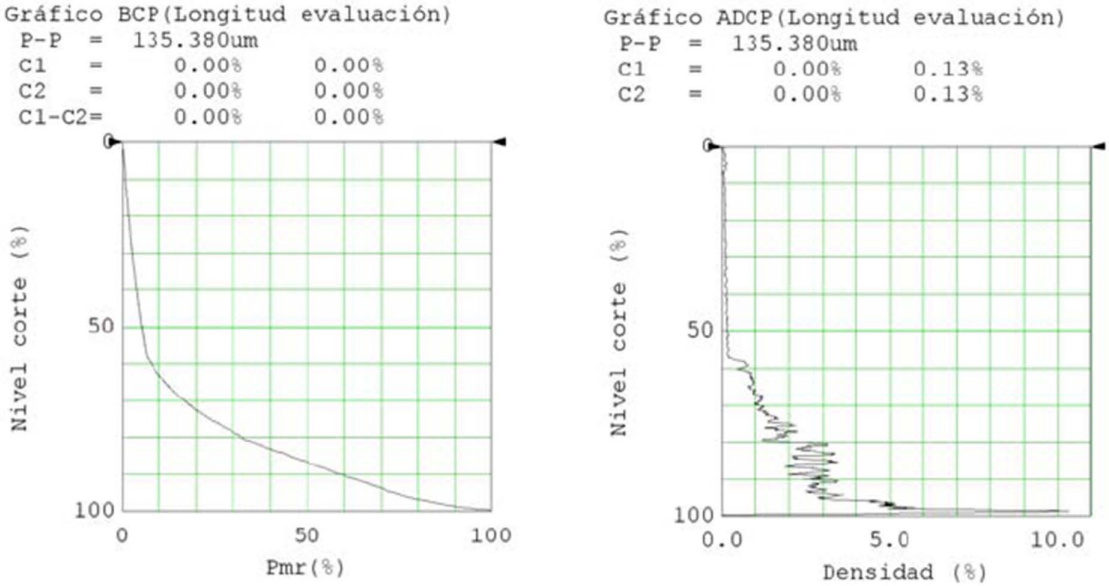

Figure A25. Material graphs along diagonal 1 before wear in sample 1M6.

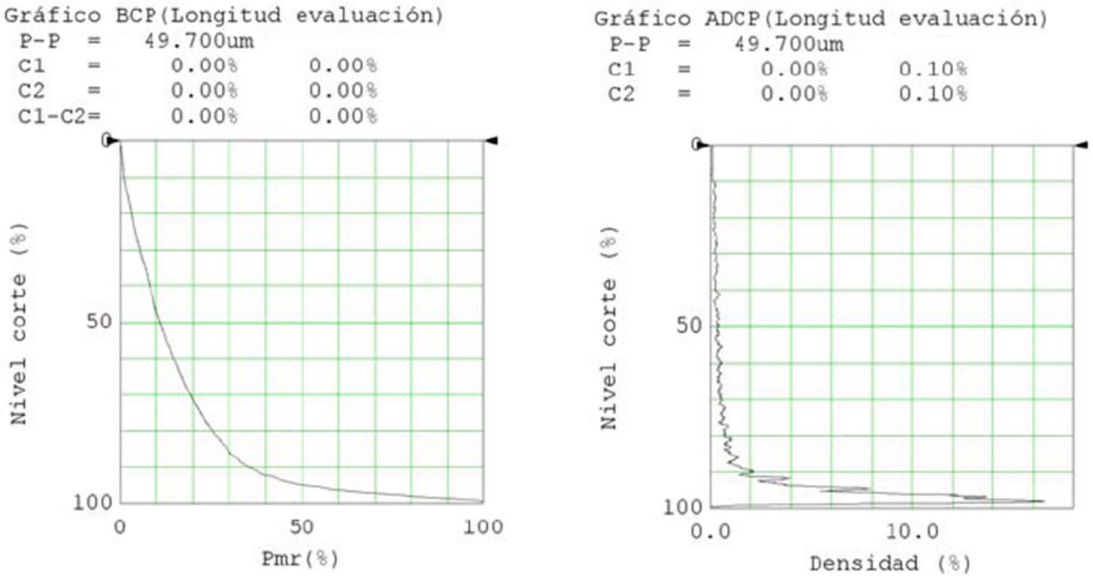

Figure A26. Material graphs along diagonal 2 before wear in sample 1M6.

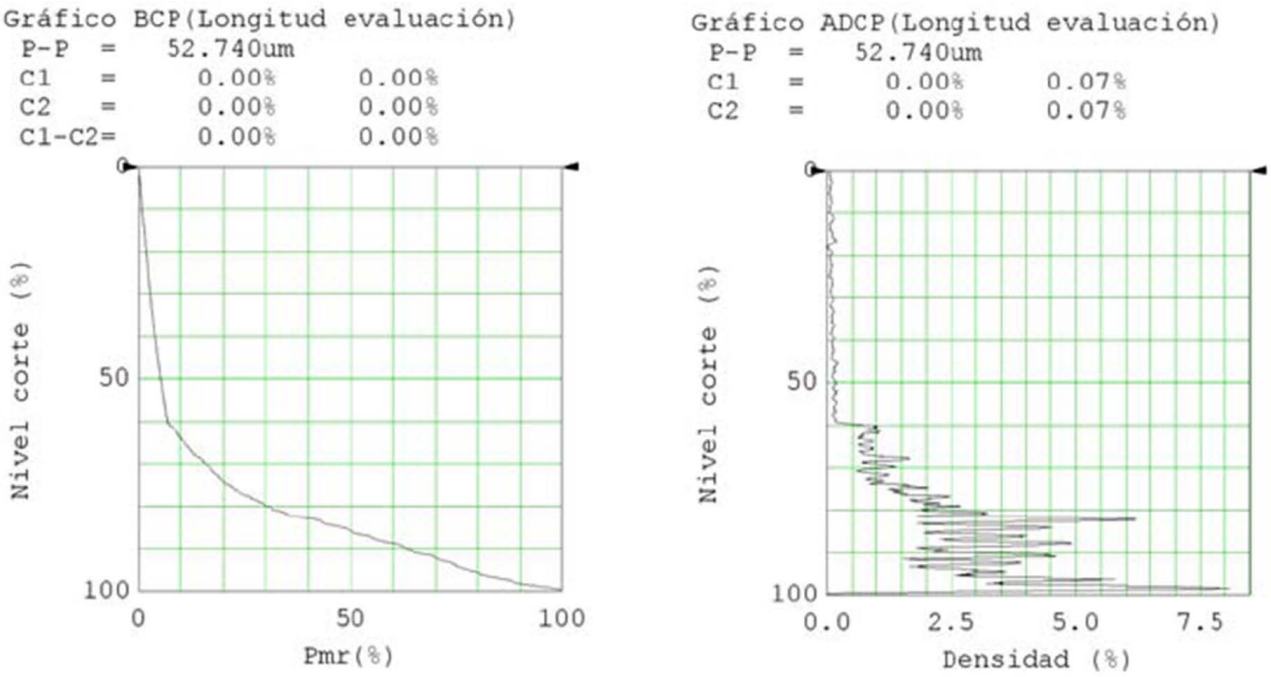

Figure A27. Material graphs along diagonal 3 before wear in sample 1M6.

Appendix A.4. Measurements Before Wear in Sample 2M6

Figure A28. Primary profile; diagonal 1 before wear in sample 2M6.

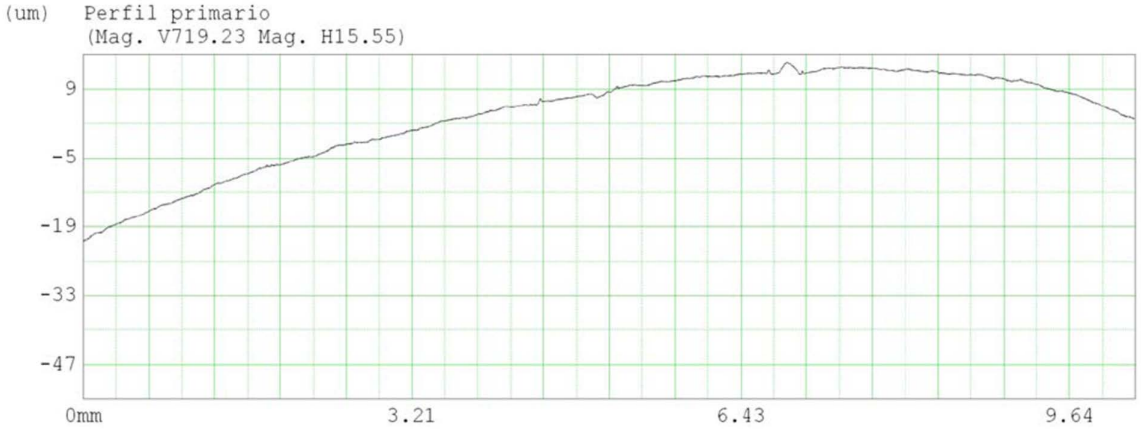

Figure A29. Primary profile; diagonal 2 before wear in sample 2M6.

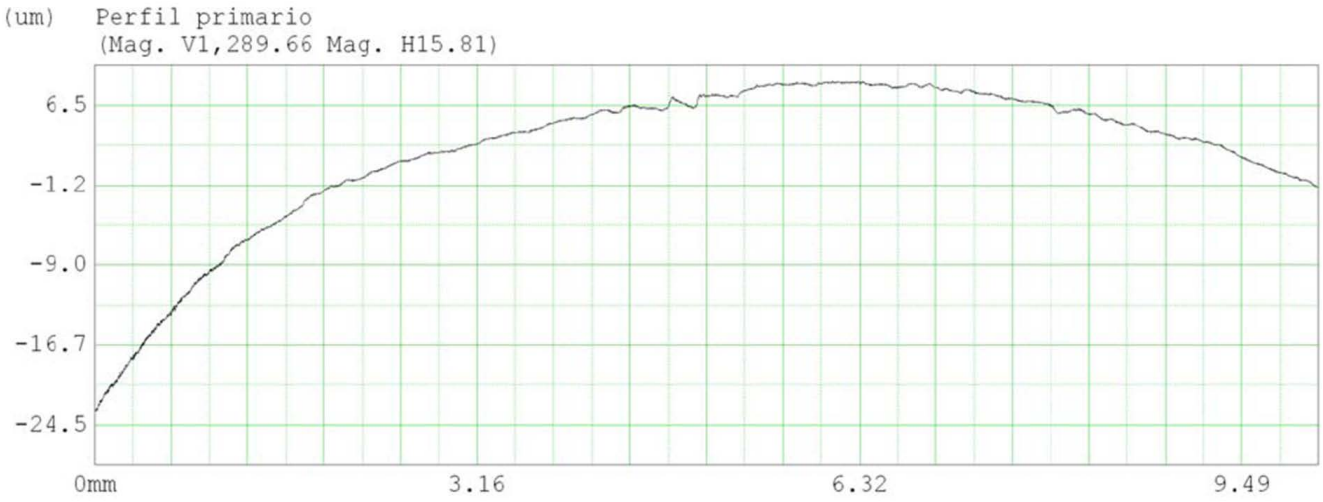

Figure A30. Primary profile; diagonal 3 before wear in sample 2M6.

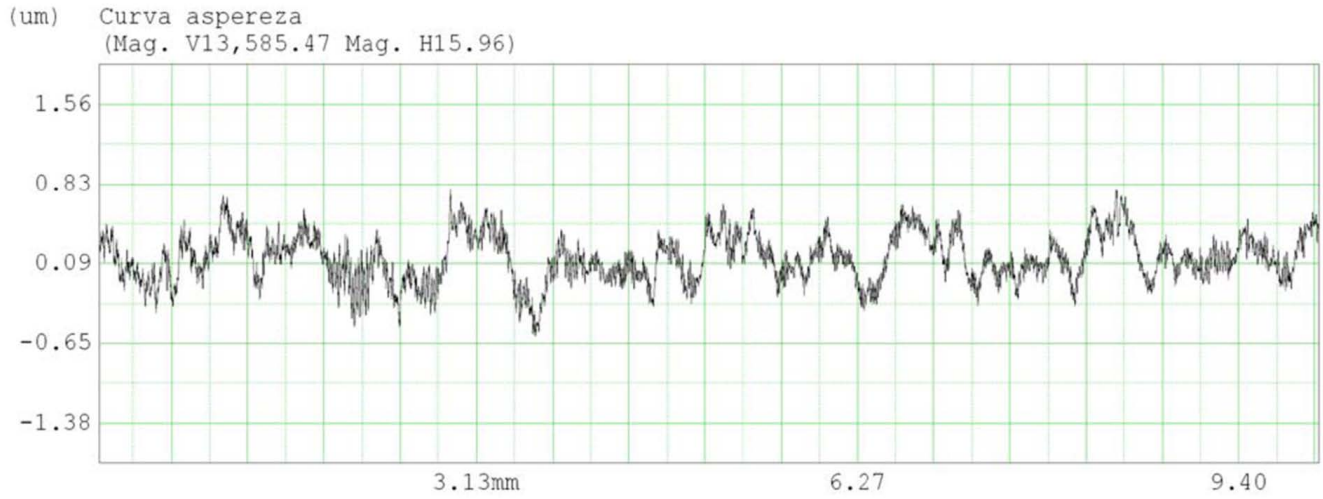

Figure A31. Roughness profile; diagonal 1 before wear in sample 2M6.

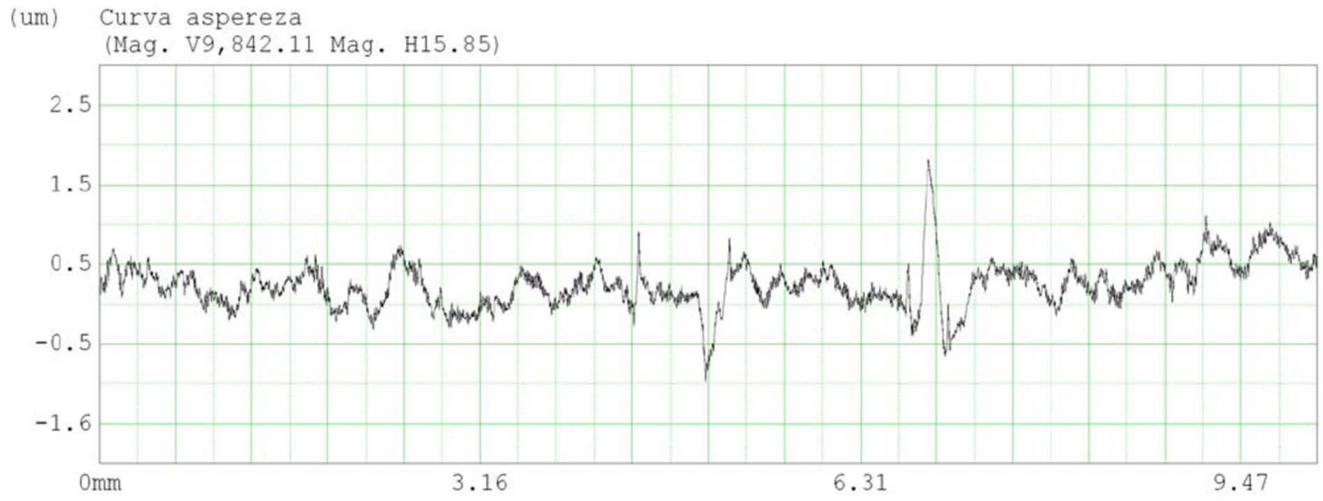

Figure A32. Roughness profile; diagonal 2 before wear in sample 2M6.

Figure A33. Roughness profile; diagonal 3 before wear in sample 2M6.

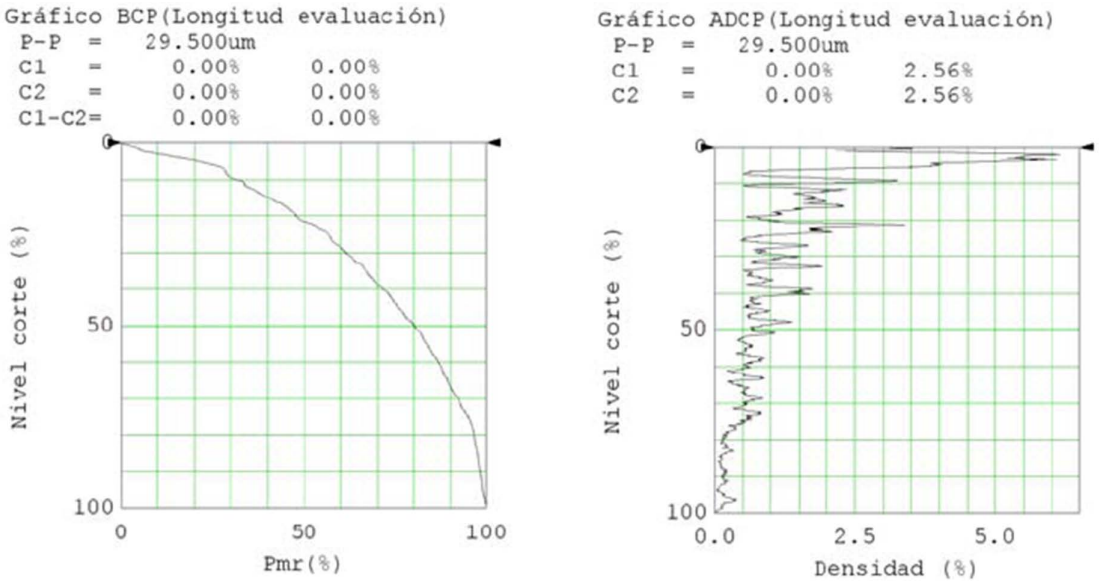

Figure A34. Material graphs along diagonal 1 before wear in sample 2M6.

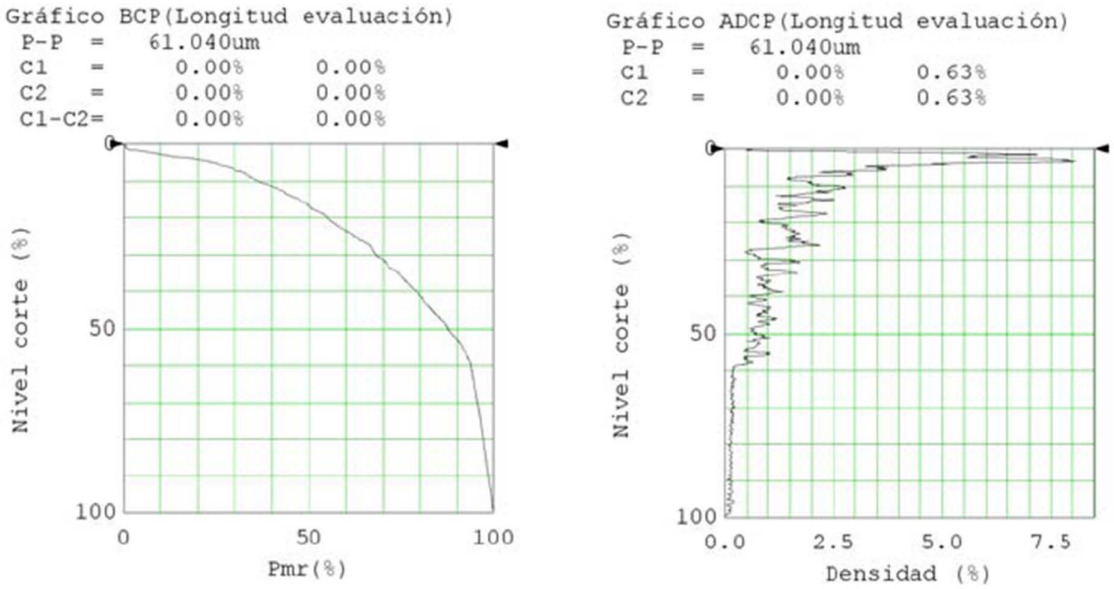

Figure A35. Material graphs along diagonal 2 before wear in sample 2M6.

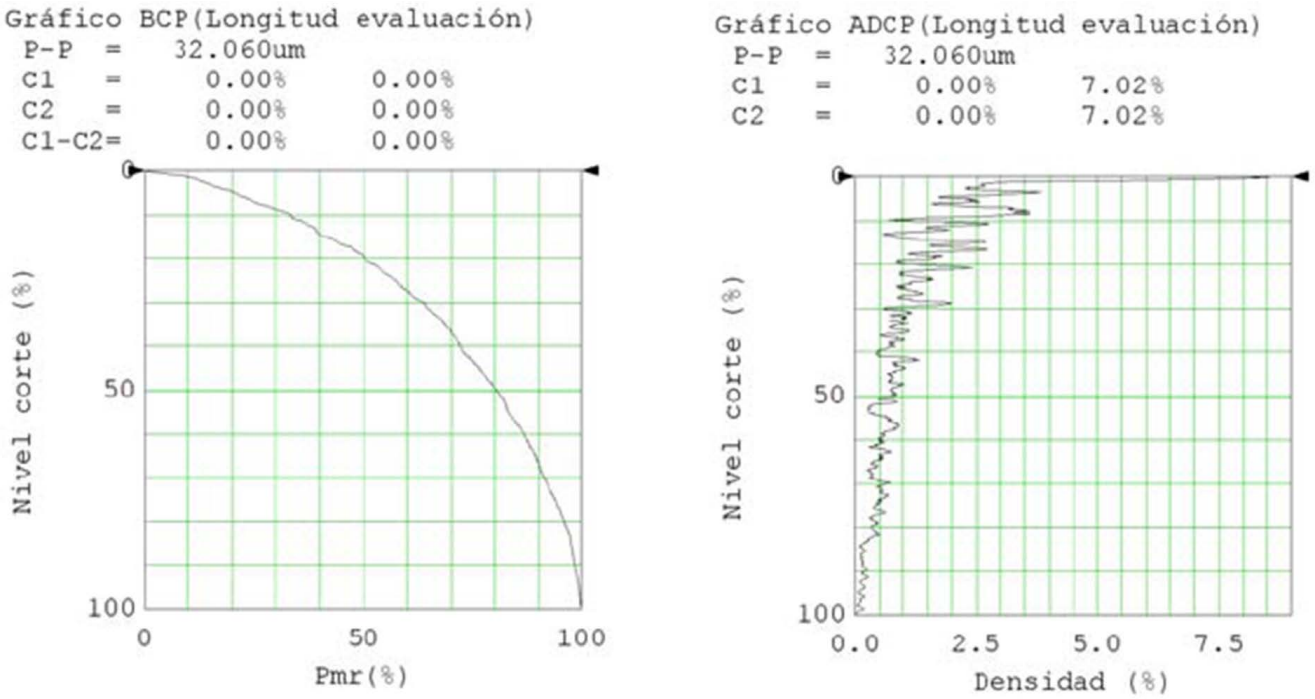

Figure A36. Material graphs along diagonal 3 before wear in sample 2M6.

Appendix A.5. Measurements Before Wear in Sample 1M12

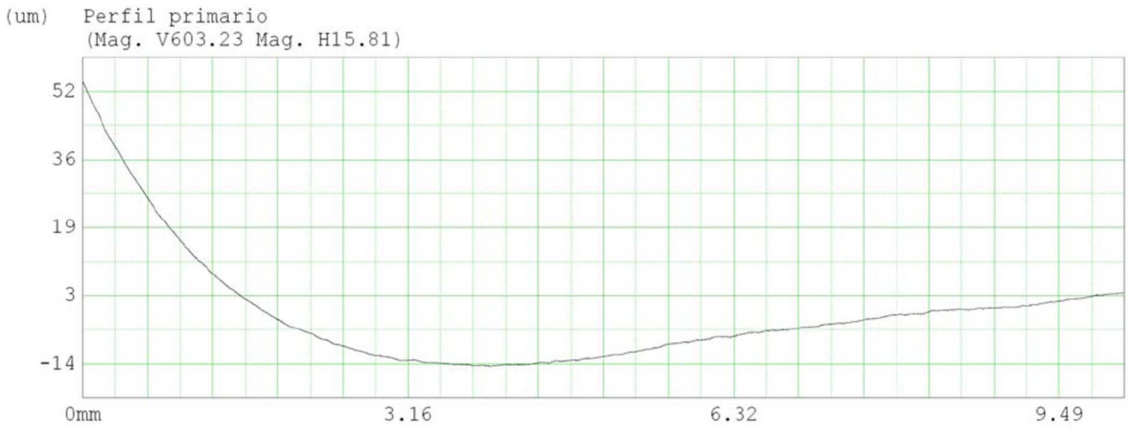

Figure A37. Primary profile; diagonal 1 before wear in sample 1M12.

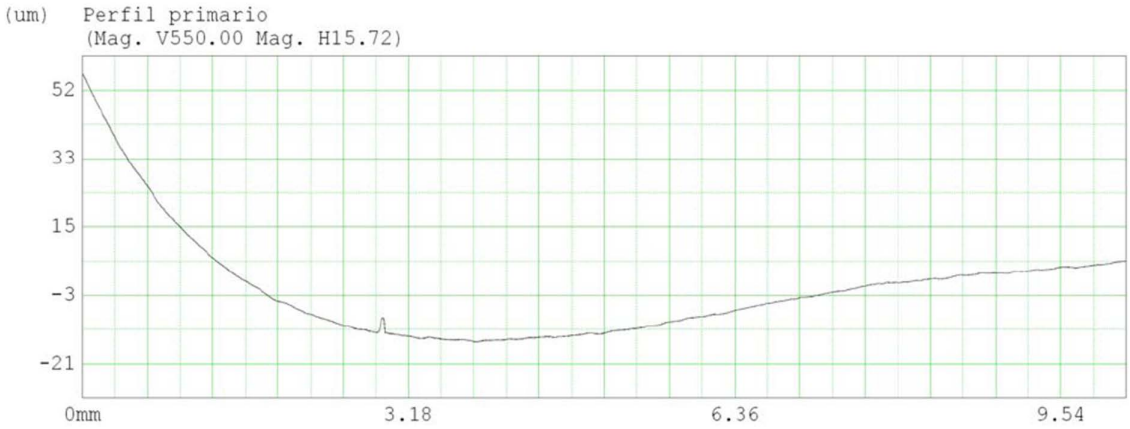

Figure A38. Primary profile; diagonal 2 before wear in sample 1M12.

Figure A39. Primary profile; diagonal 3 before wear in sample 1M12.

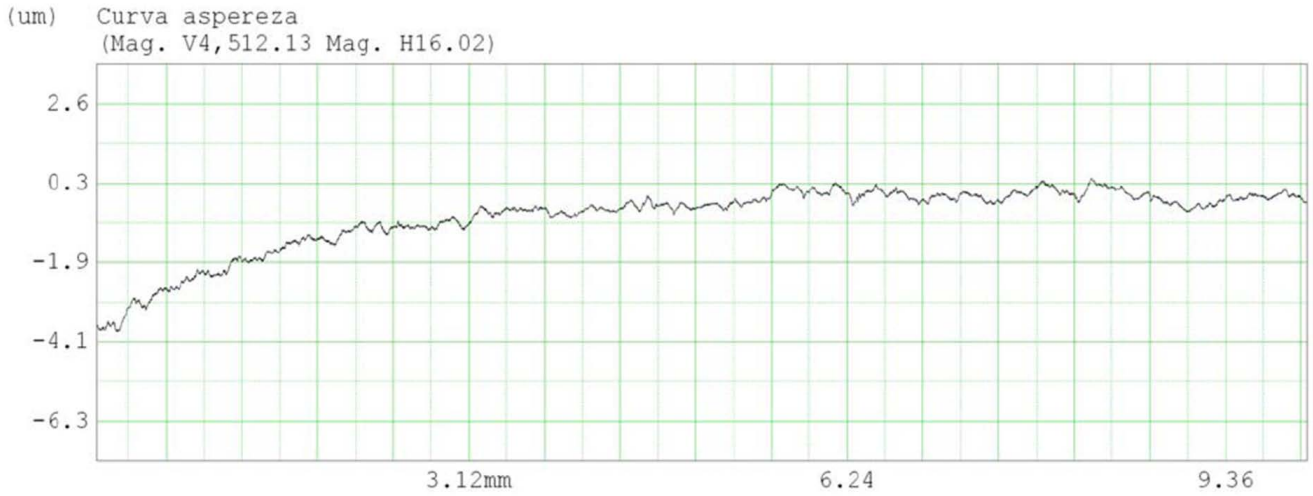

Figure A40. Roughness profile; diagonal 1 before wear in sample 1M12.

Figure A41. Roughness profile; diagonal 2 before wear in sample 1M12.

Figure A42. Roughness profile; diagonal 3 before wear in sample 1M12.

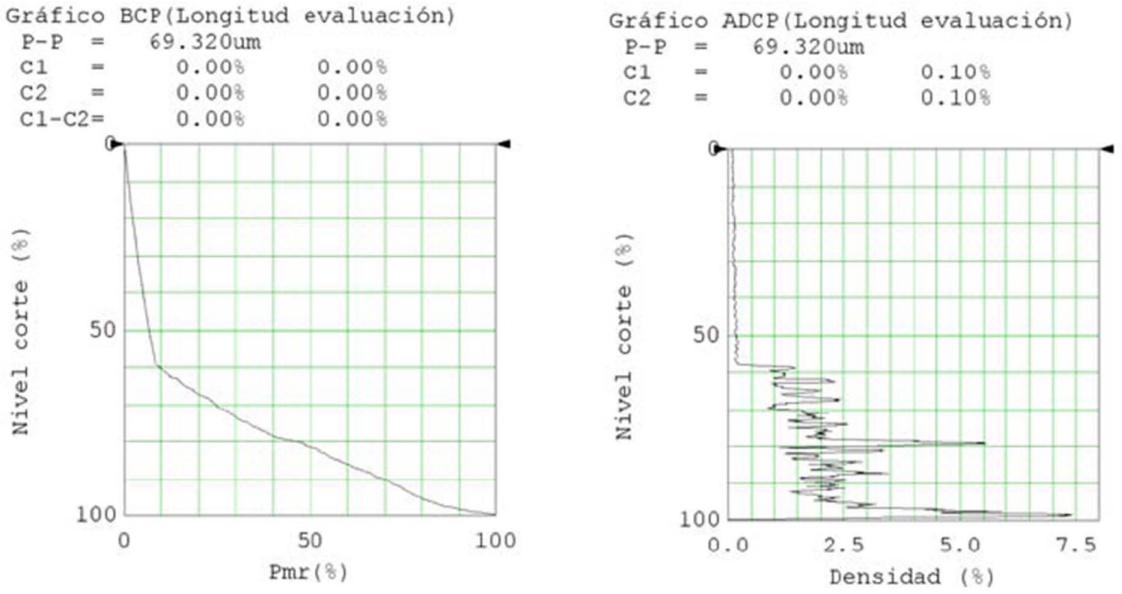

Figure A43. Material graphs along diagonal 1 before wear in sample 1M12.

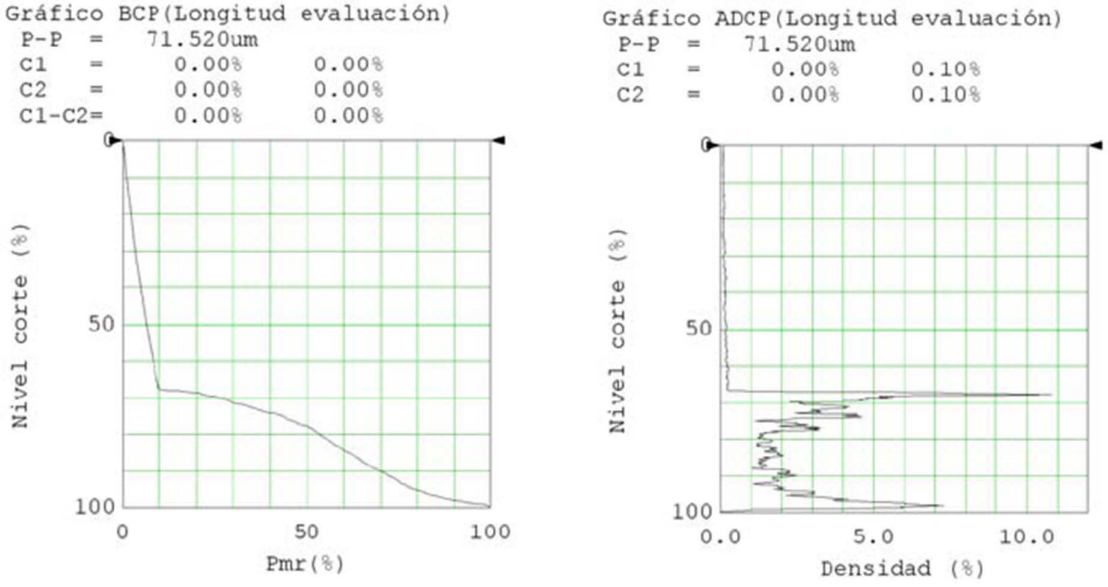

Figure A44. Material graphs along diagonal 2 before wear in sample 1M12.

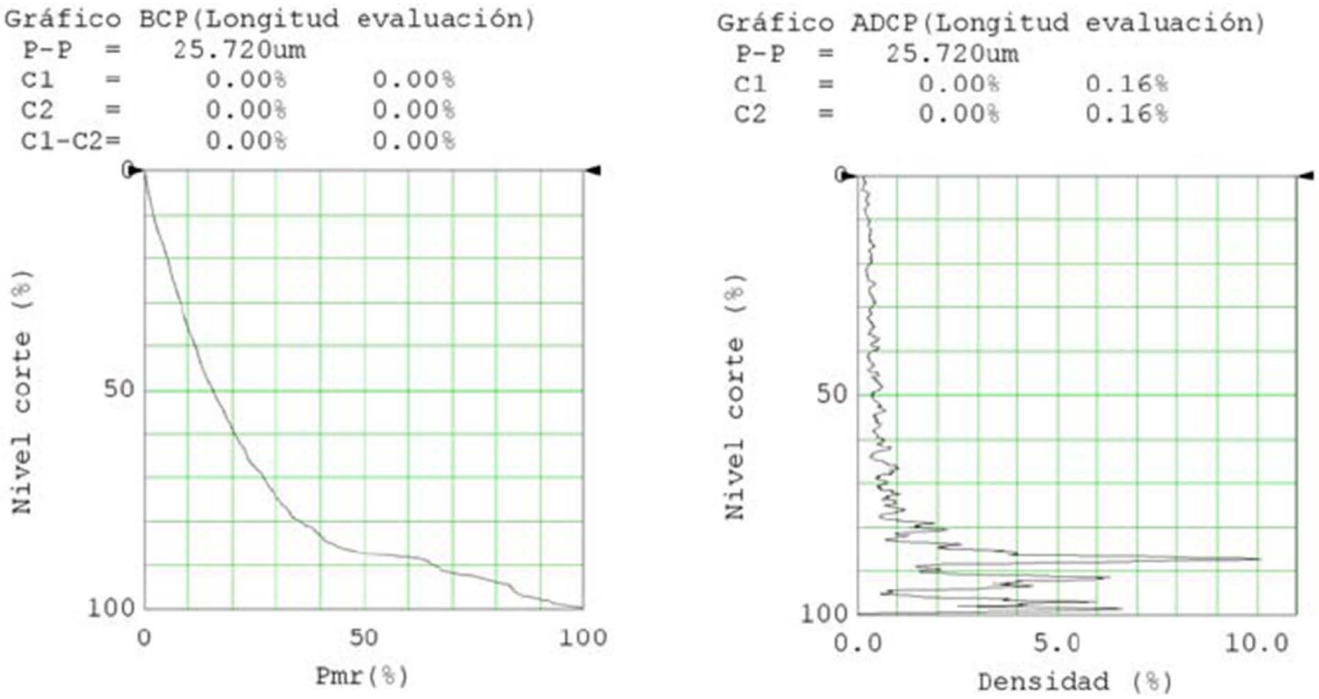

Figure A45. Material graphs along diagonal 3 before wear in sample 1M12.

Appendix A.6. Measurements Before Wear in Sample 3M12

Figure A46. Primary profile; diagonal 1 before wear in sample 3M12.

Figure A47. Primary profile; diagonal 2 before wear in sample 3M12.

Figure A48. Primary profile; diagonal 3 before wear in sample 3M12.

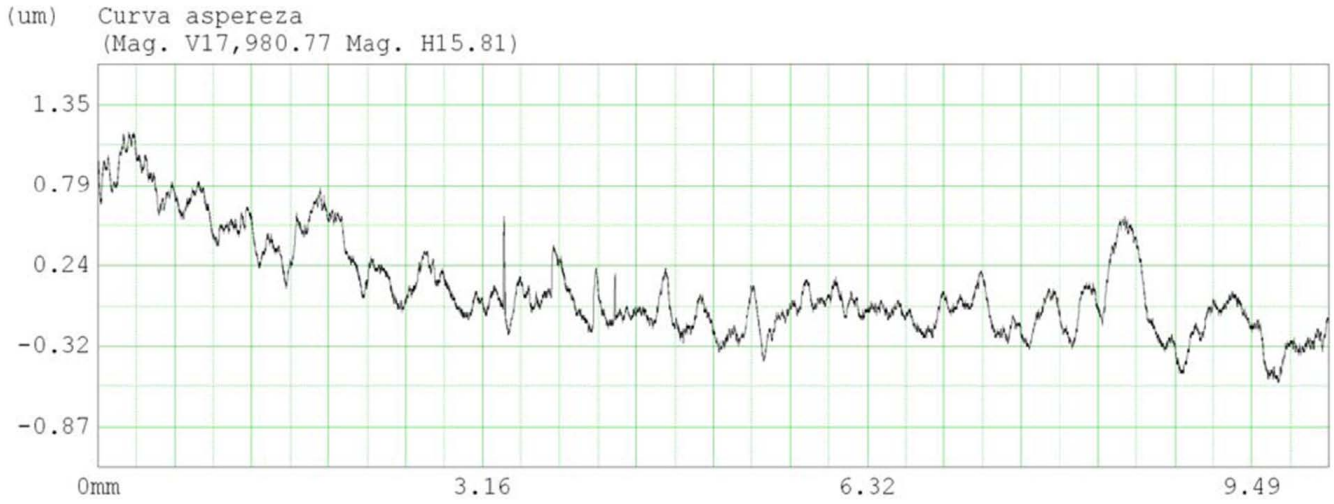

Figure A49. Roughness profile; diagonal 1 before wear in sample 3M12.

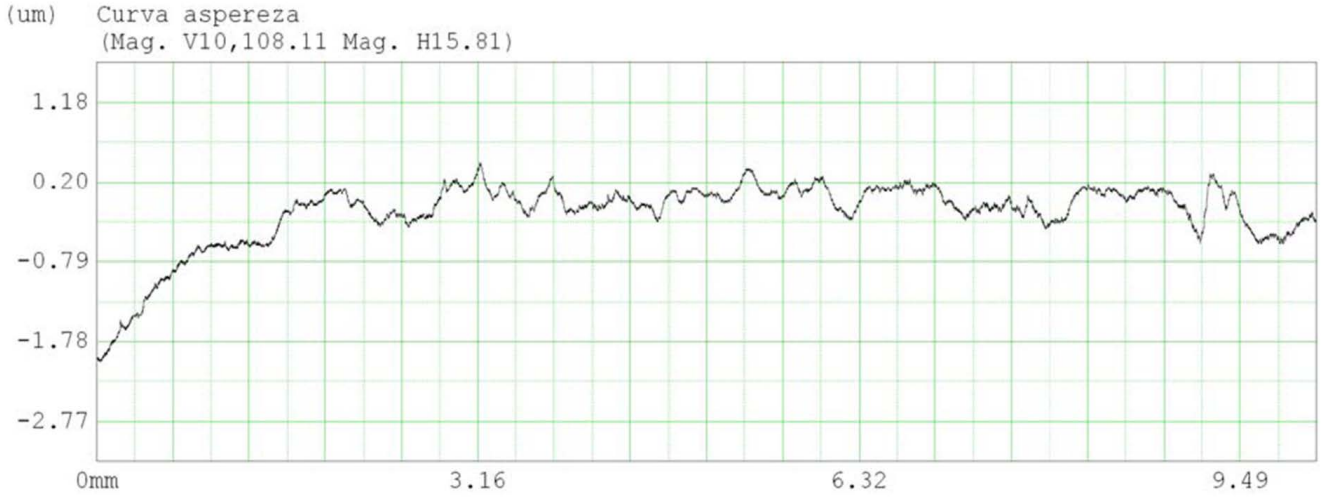

Figure A50. Roughness profile; diagonal 2 before wear in sample 3M12.

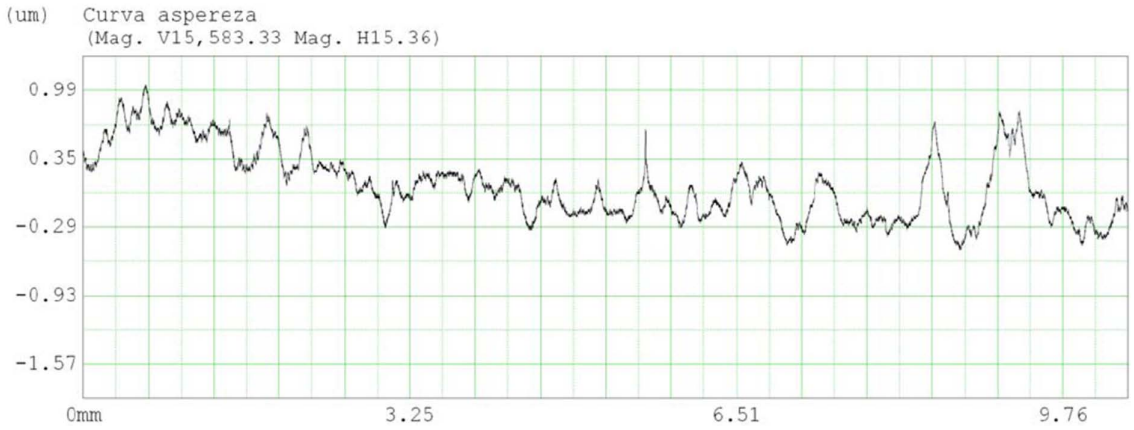

Figure A51. Roughness profile; diagonal 3 before wear in sample 3M12.

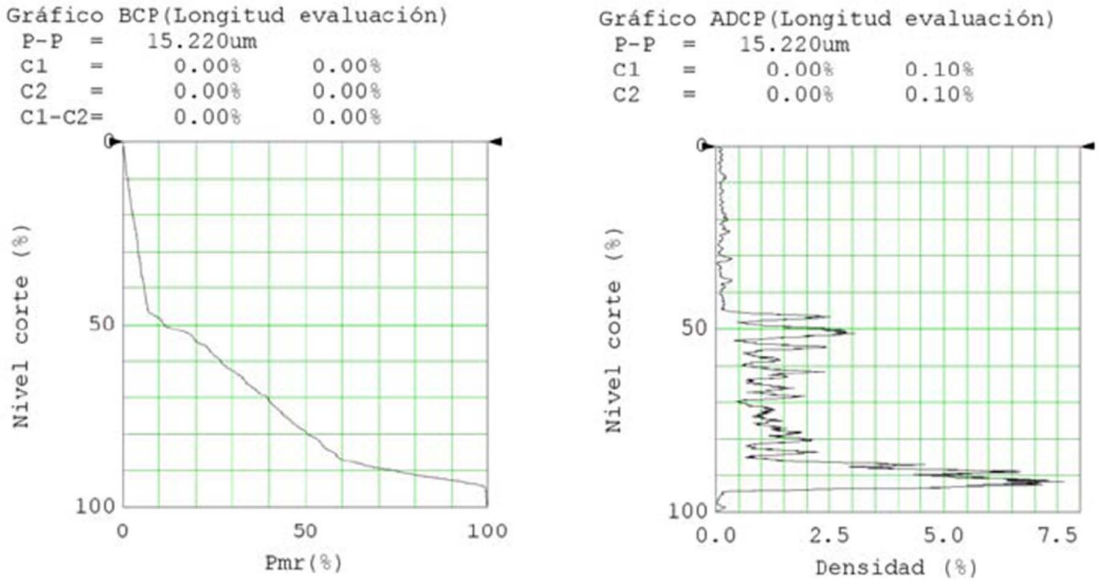

Figure A52. Material graphs along diagonal 1 before wear in sample 3M12.

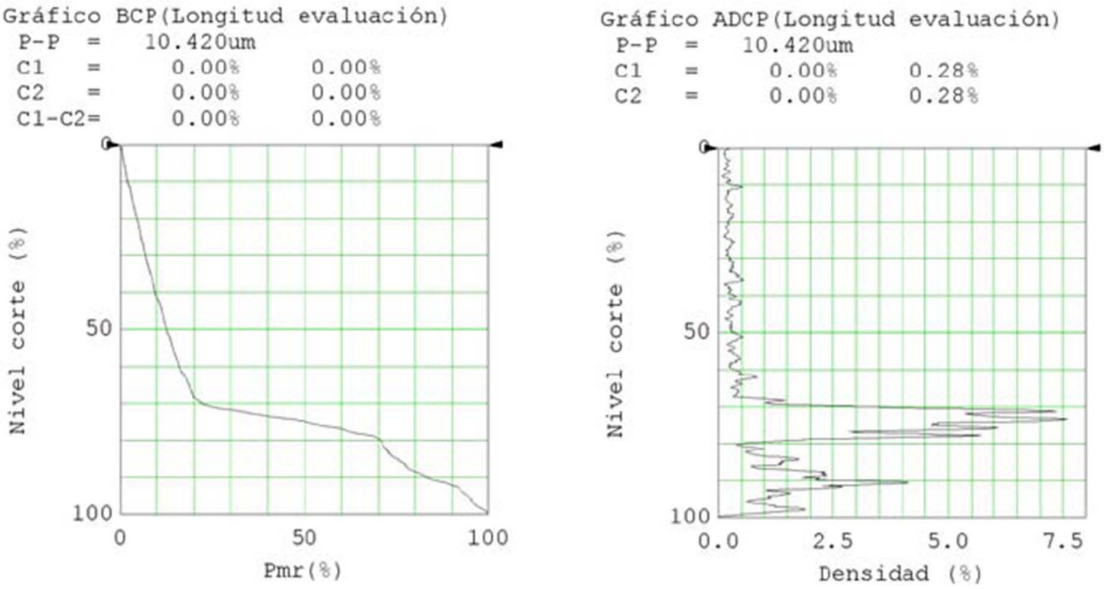

Figure A53. Material graphs along diagonal 2 before wear in sample 3M12.

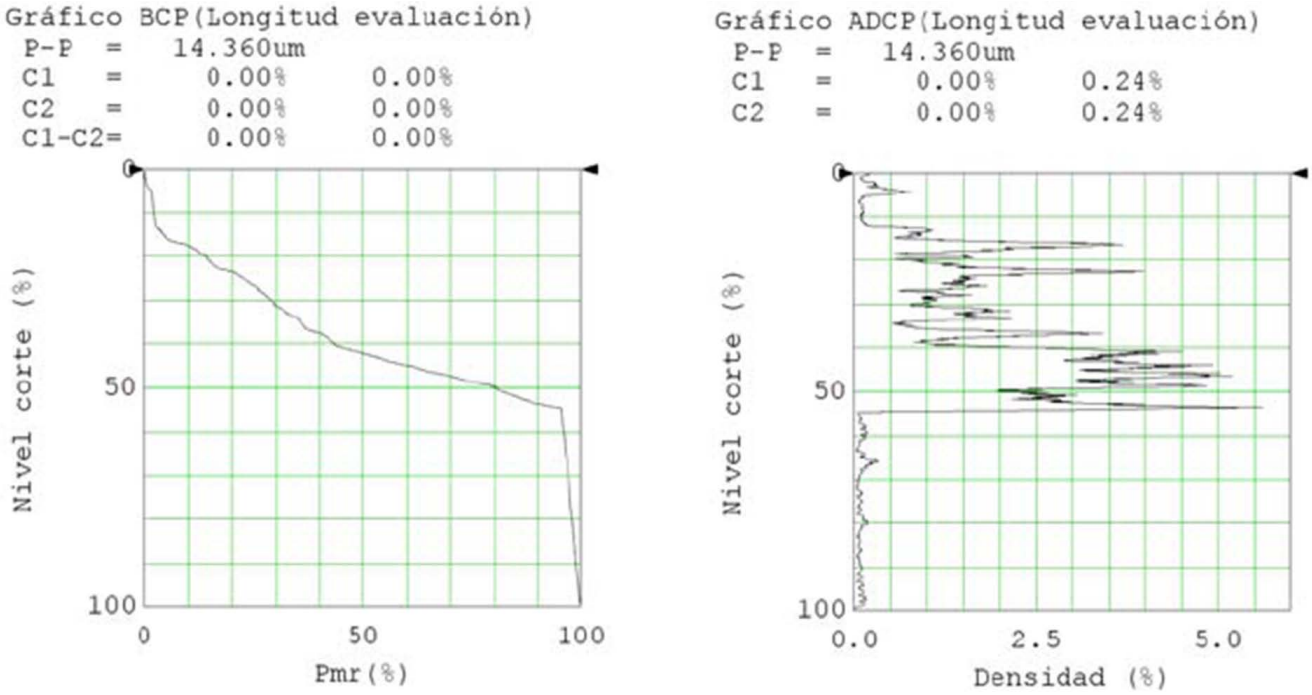

Figure A54. Material graphs along diagonal 3 before wear in sample 3M12.

Appendix A.7. Measurements Before Wear in Sample 1N6

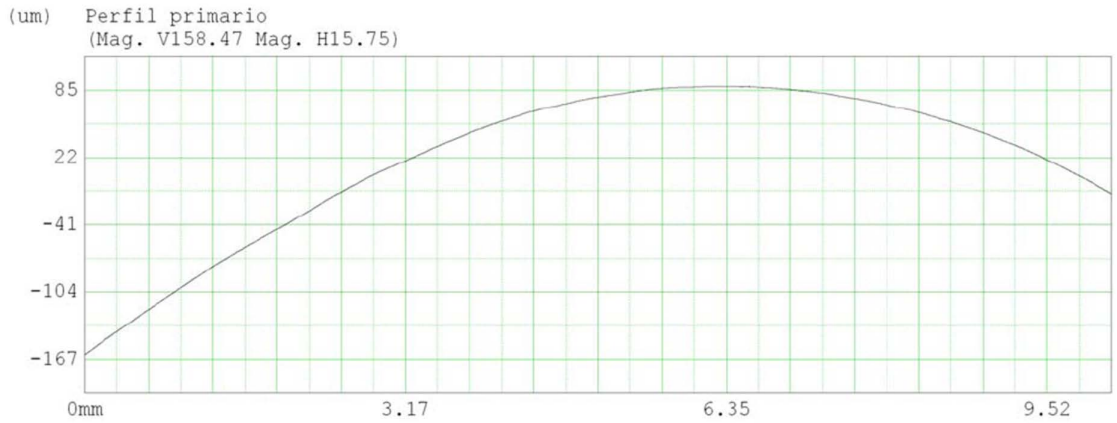

Figure A55. Primary profile; diagonal 1 before wear in sample 1N6.

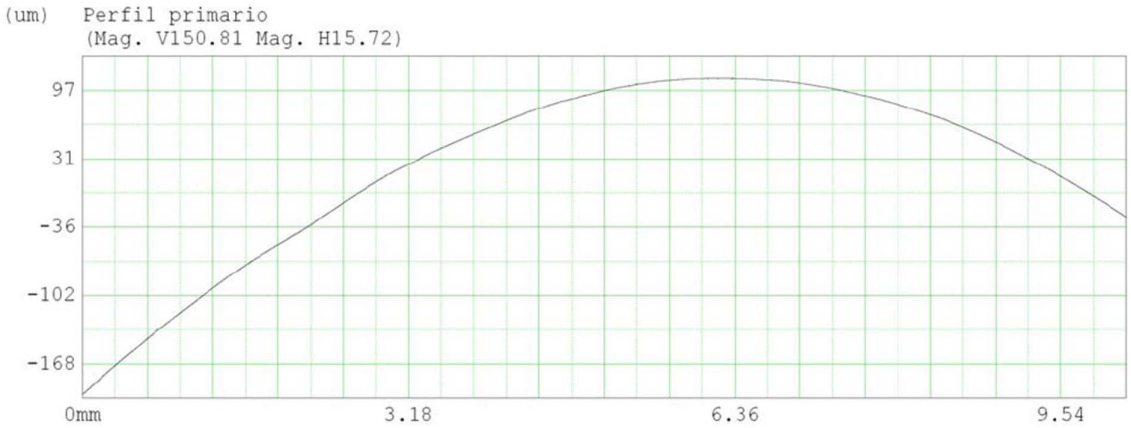

Figure A56. Primary profile; diagonal 2 before wear in sample 1N6.

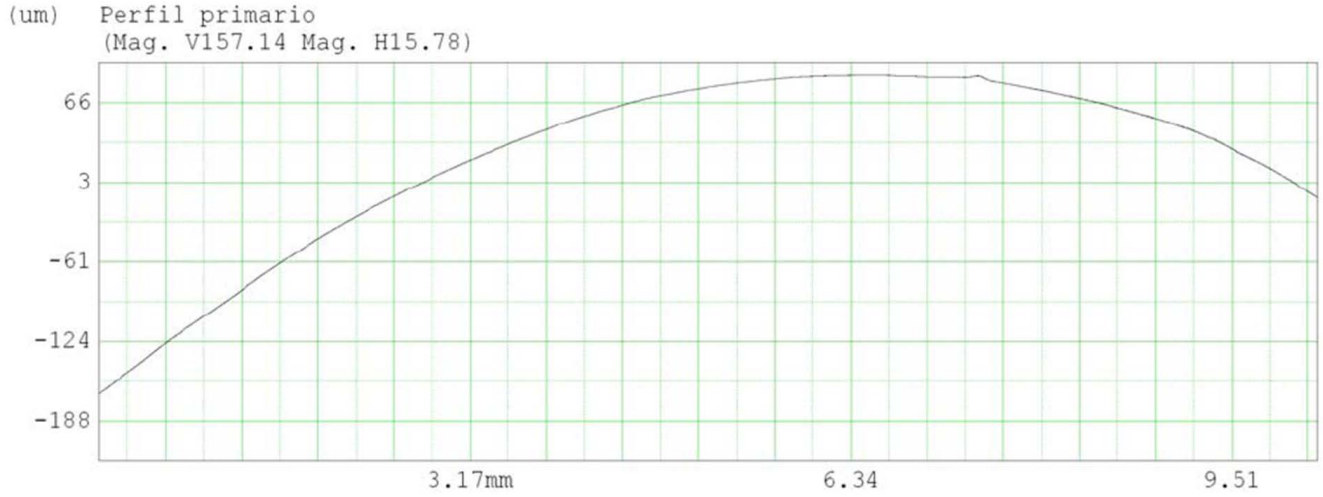

Figure A57. Primary profile; diagonal 3 before wear in sample 1N6.

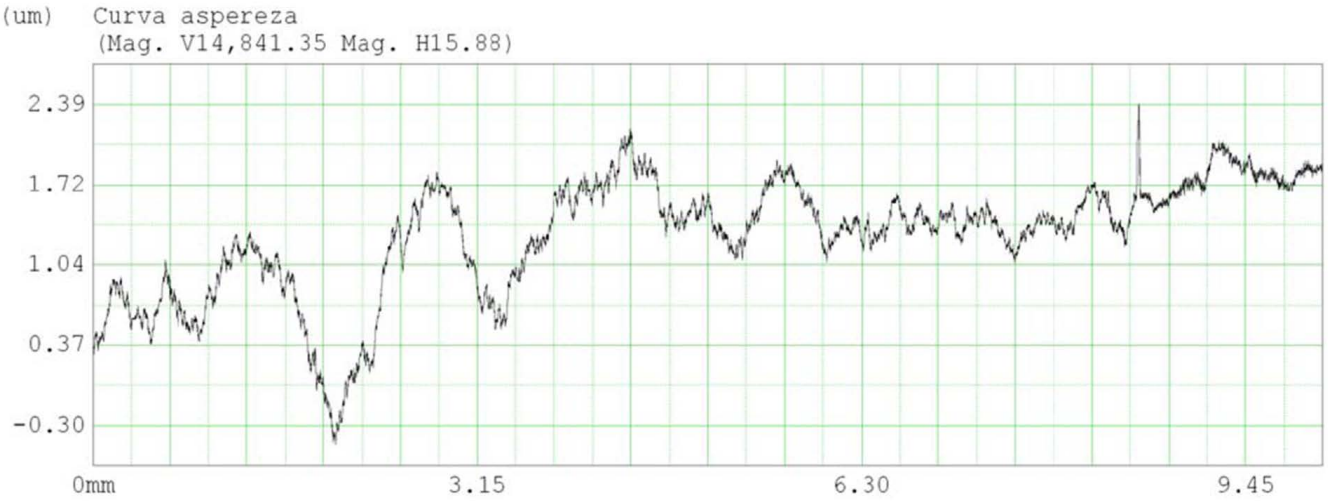

Figure A58. Roughness profile; diagonal 1 before wear in sample 1N6.

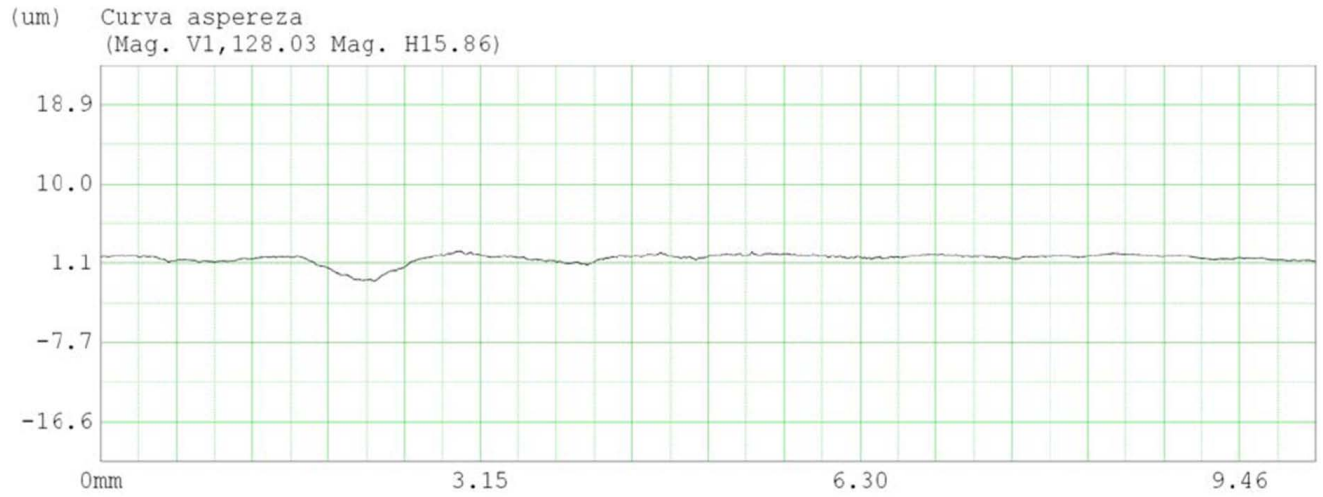

Figure A59. Roughness profile; diagonal 2 before wear in sample 1N6.

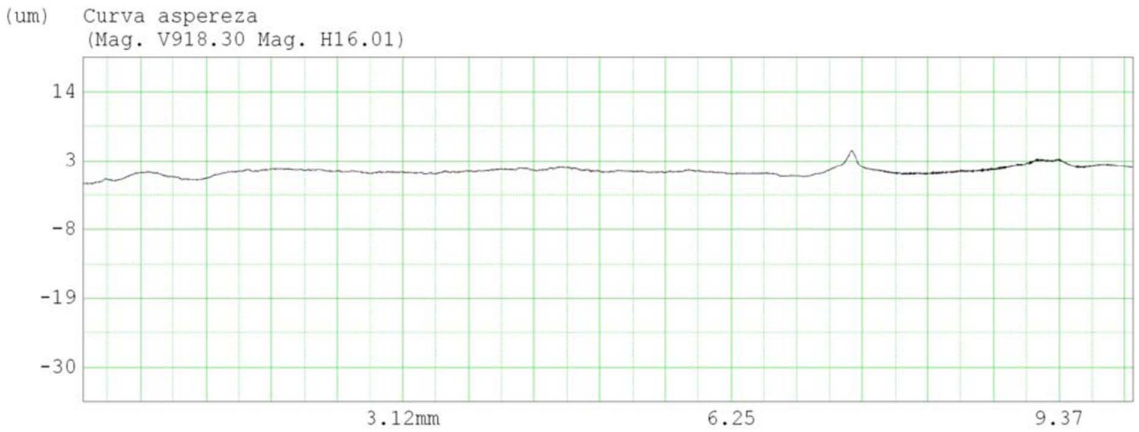

Figure A60. Roughness profile; diagonal 3 before wear in sample 1N6.

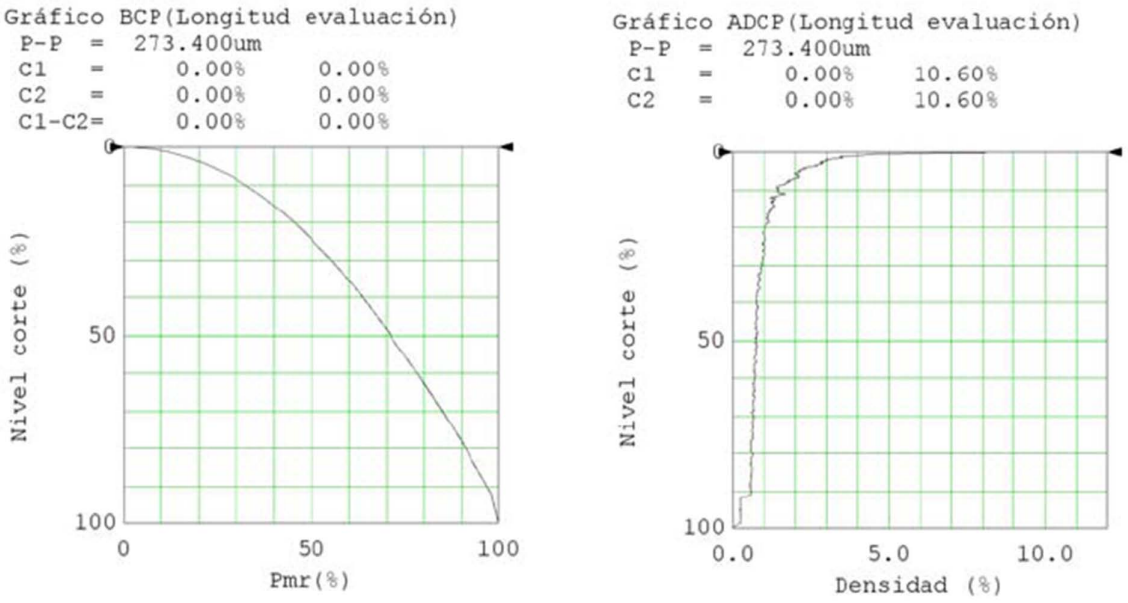

Figure A61. Material graphs along diagonal 1 before wear in sample 1N6.

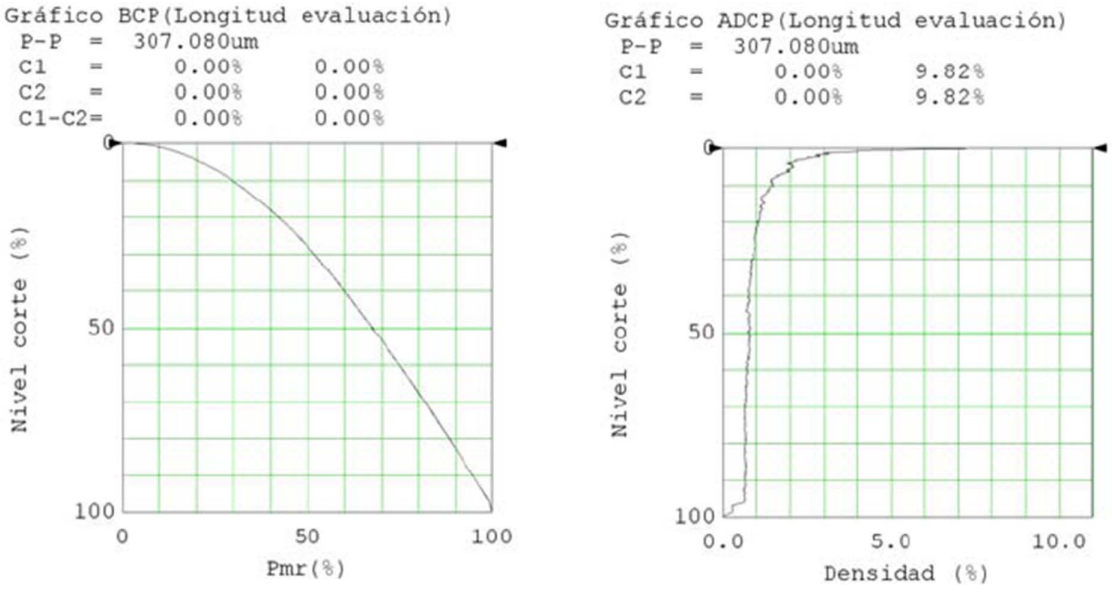

Figure A62. Material graphs along diagonal 2 before wear in sample 1N6.

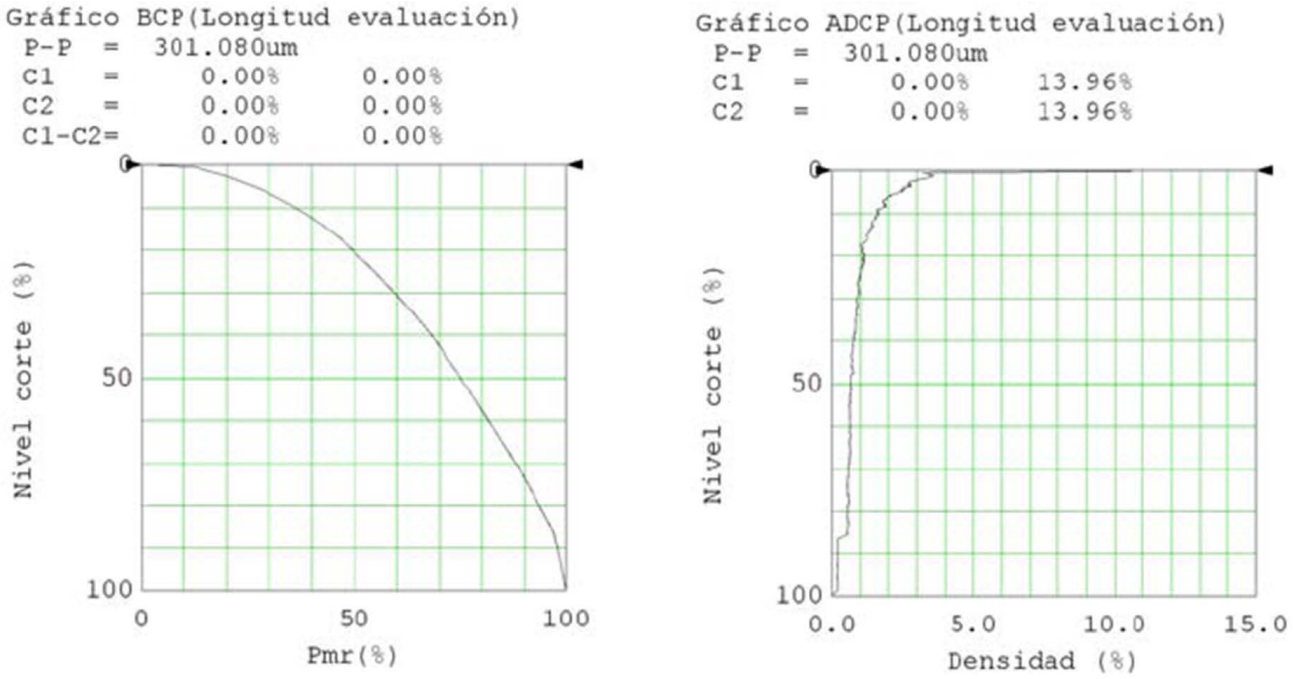

Figure A63. Material graphs along diagonal 3 before wear in sample 1N6.

Appendix A.8. Measurements Before Wear in Sample 3N6

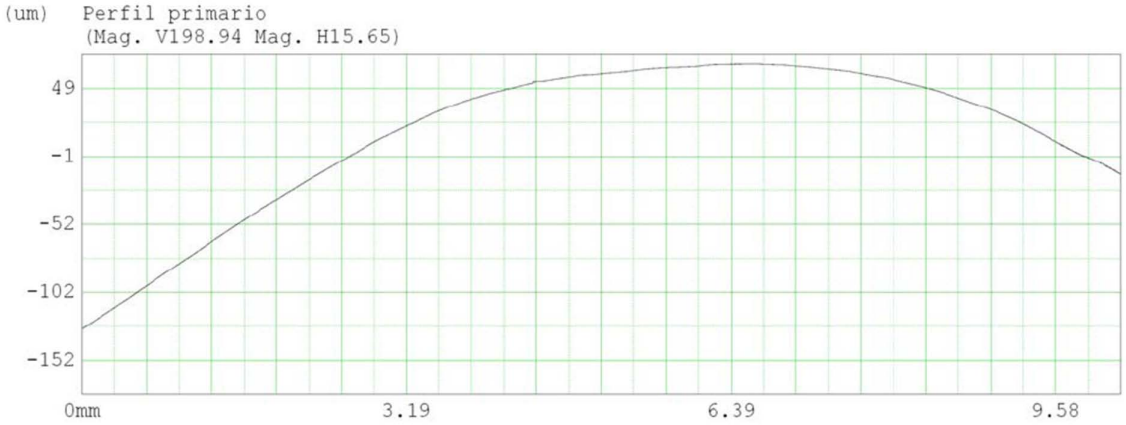

Figure A64. Primary profile; diagonal 1 before wear in sample 3N6.

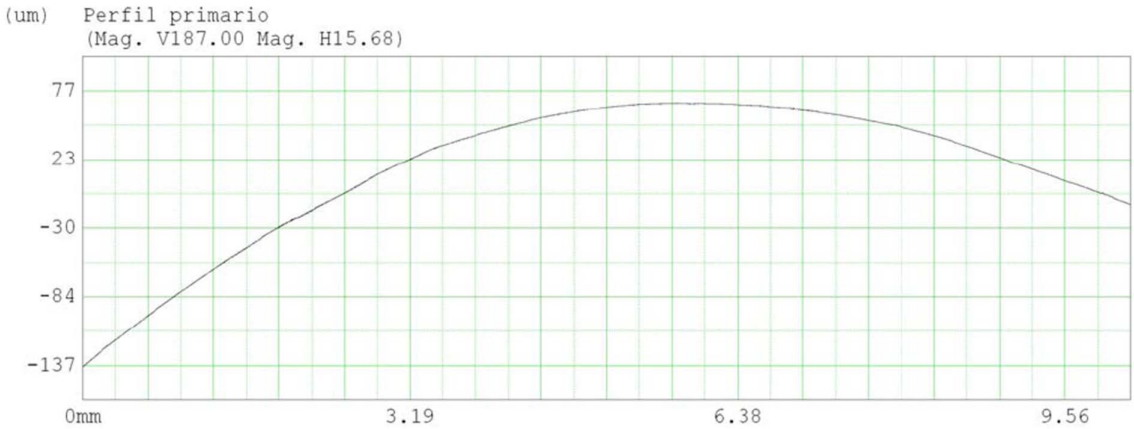

Figure A65. Primary profile; diagonal 2 before wear in sample 3N6.

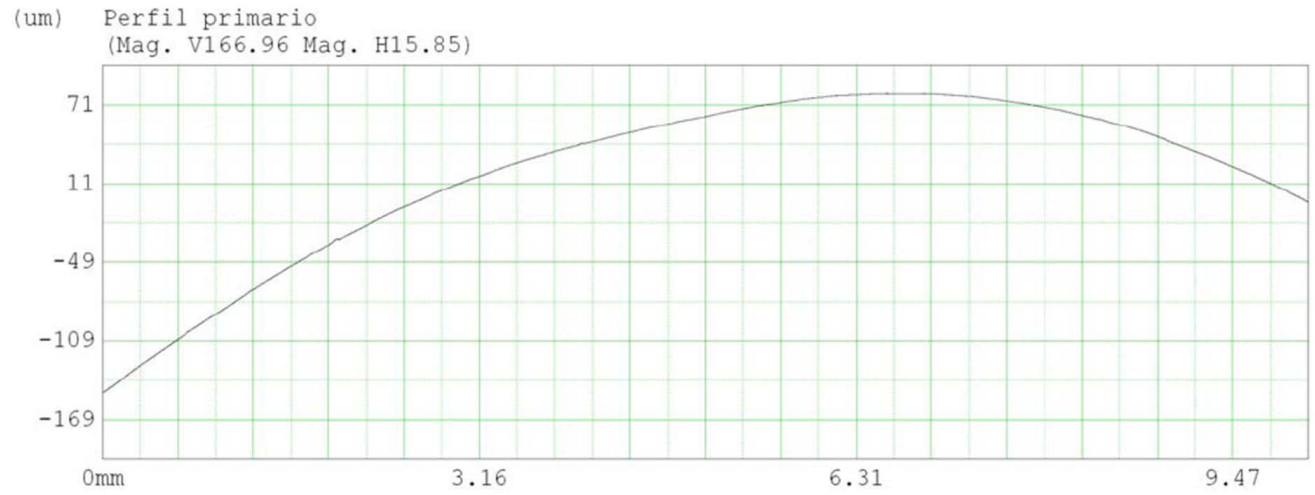

Figure A66. Primary profile; diagonal 3 before wear in sample 3N6.

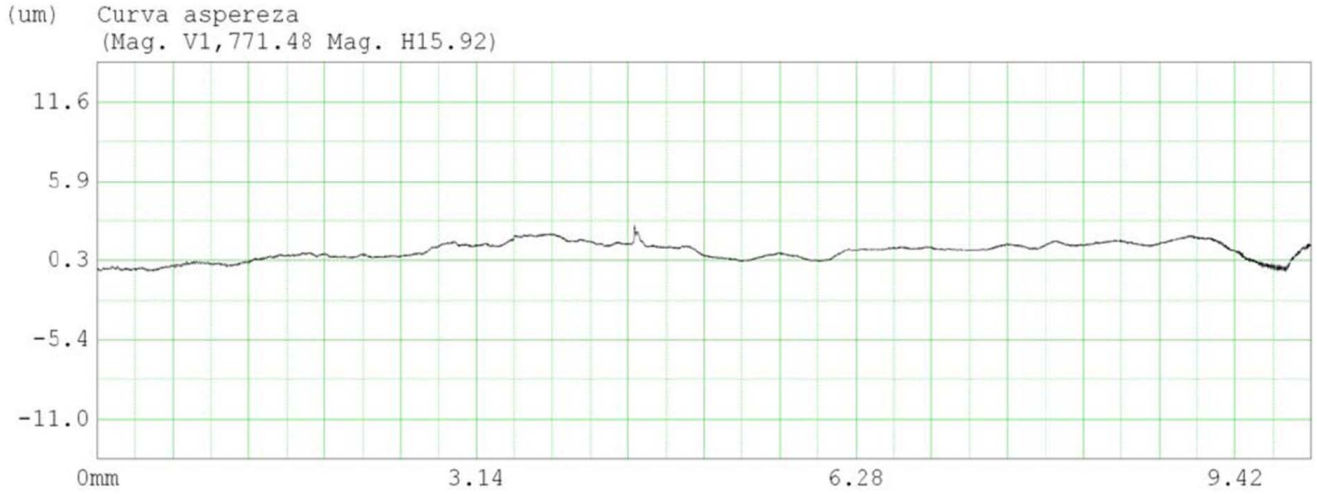

Figure A67. Roughness profile; diagonal 1 before wear in sample 3N6.

Figure A68. Roughness profile; diagonal 2 before wear in sample 3N6.

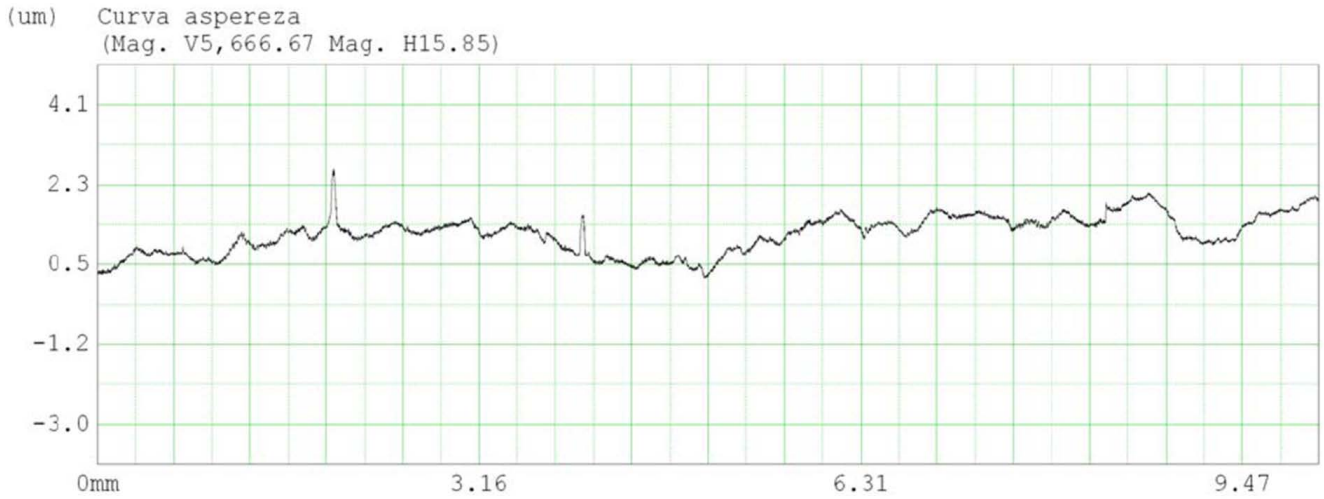

Figure A69. Roughness profile; diagonal 3 before wear in sample 3N6.

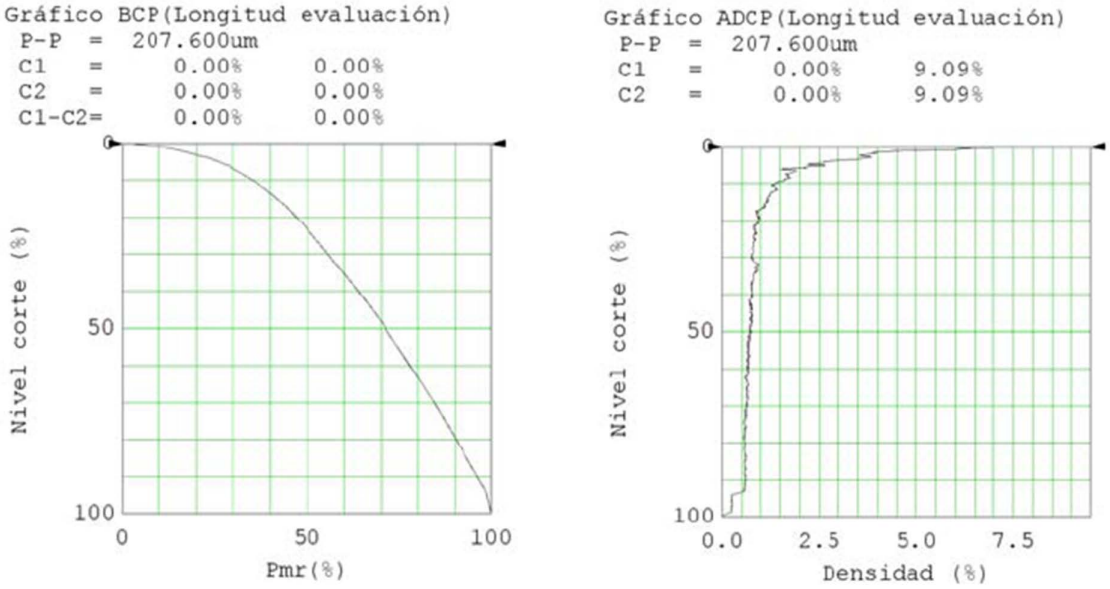

Figure A70. Material graphs along diagonal 1 before wear in sample 3N6.

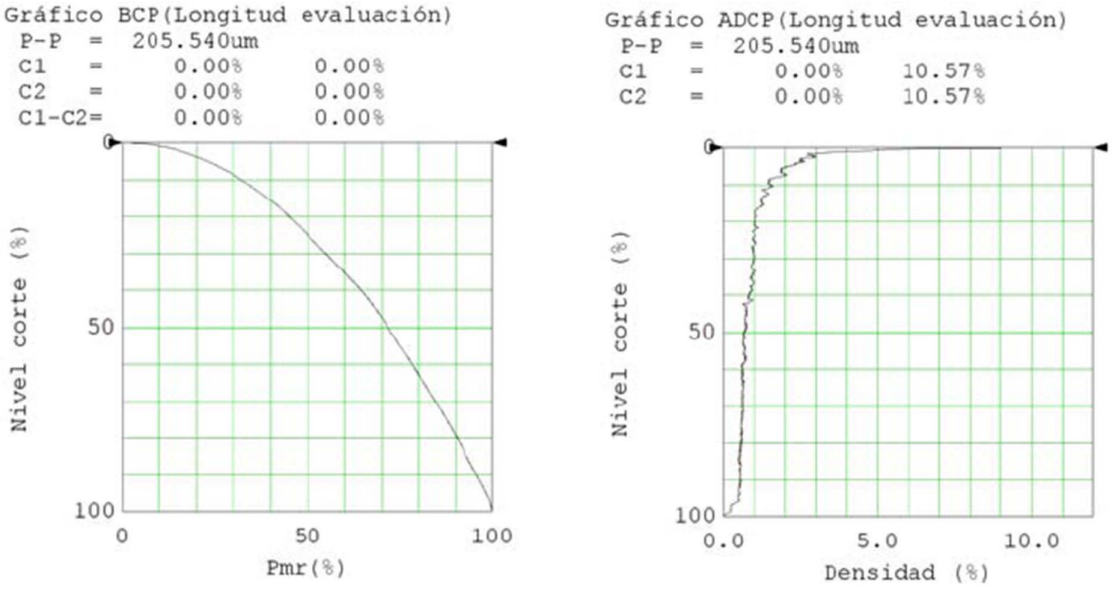

Figure A71. Material graphs along diagonal 2 before wear in sample 3N6.

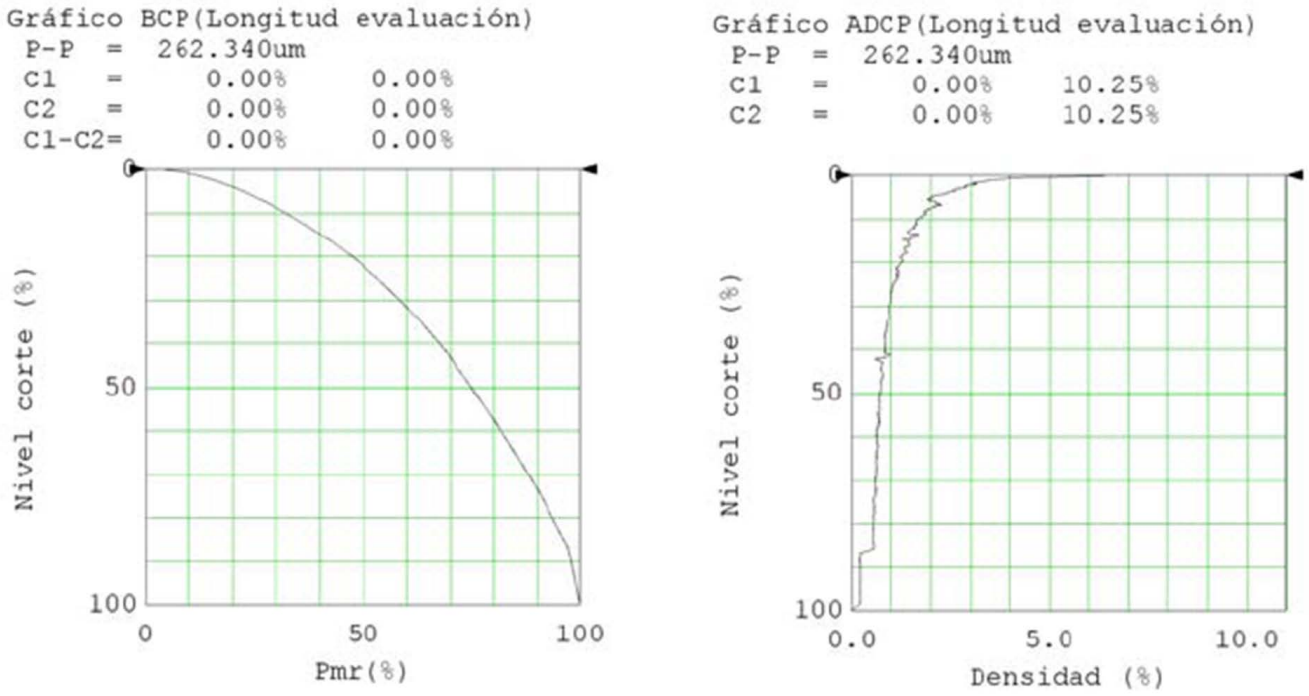

Figure A72. Material graphs along diagonal 3 before wear in sample 3N6.

Appendix A.9. Measurements Before Wear in Sample 1N12

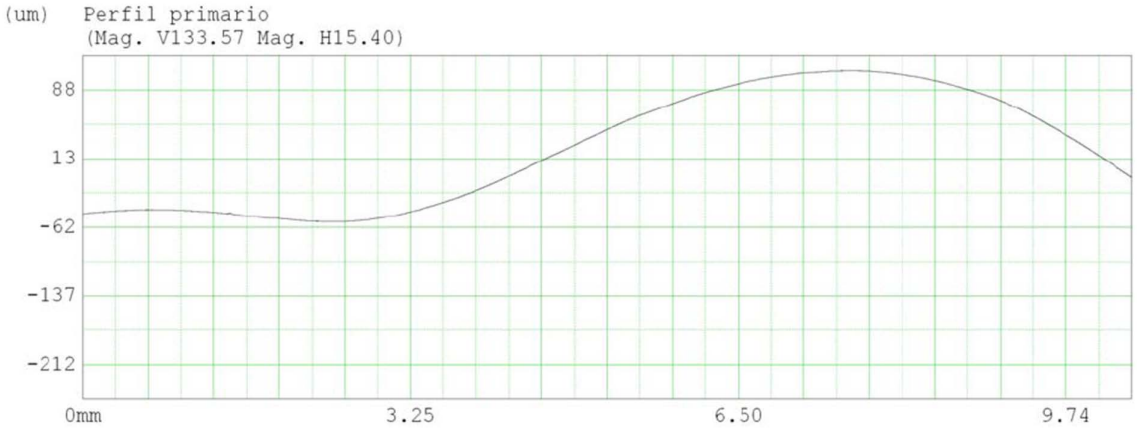

Figure A73. Primary profile; diagonal 1 before wear in sample 1N12.

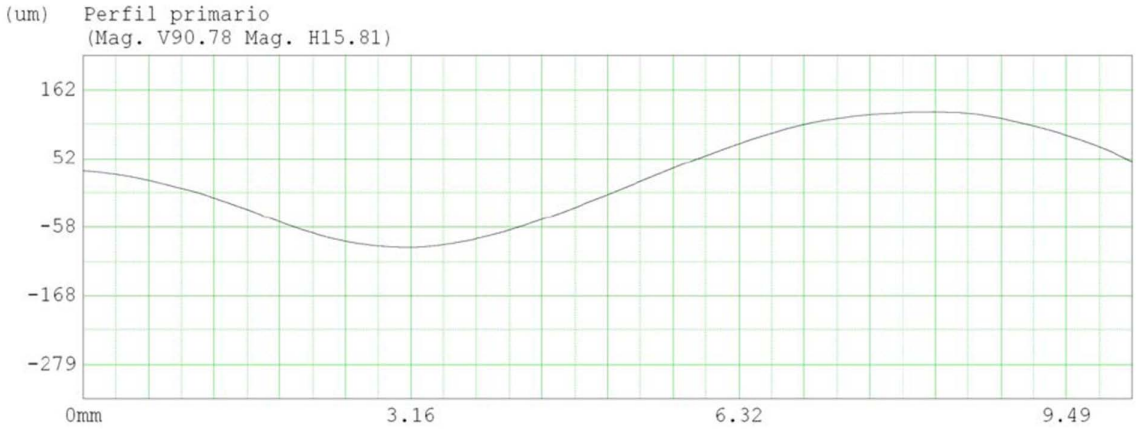

Figure A74. Primary profile; diagonal 2 before wear in sample 1N12.

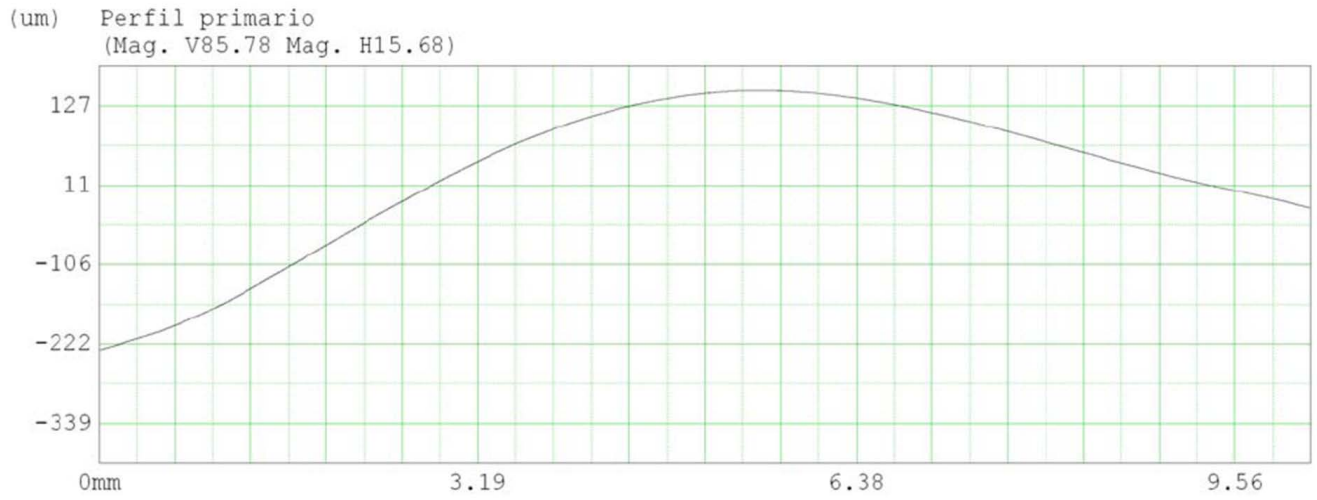

Figure A75. Primary profile; diagonal 3 before wear in sample 1N12.

Figure A76. Roughness profile; diagonal 1 before wear in sample 1N12.

Figure A77. Roughness profile; diagonal 2 before wear in sample 1N12.

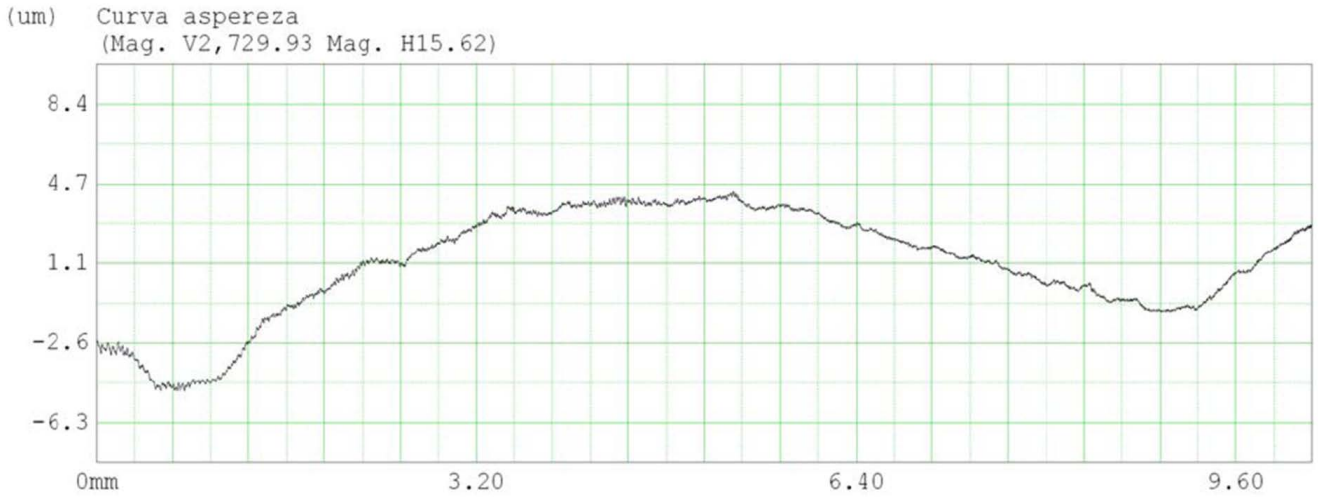

Figure A78. Roughness profile; diagonal 3 before wear in sample 1N12.

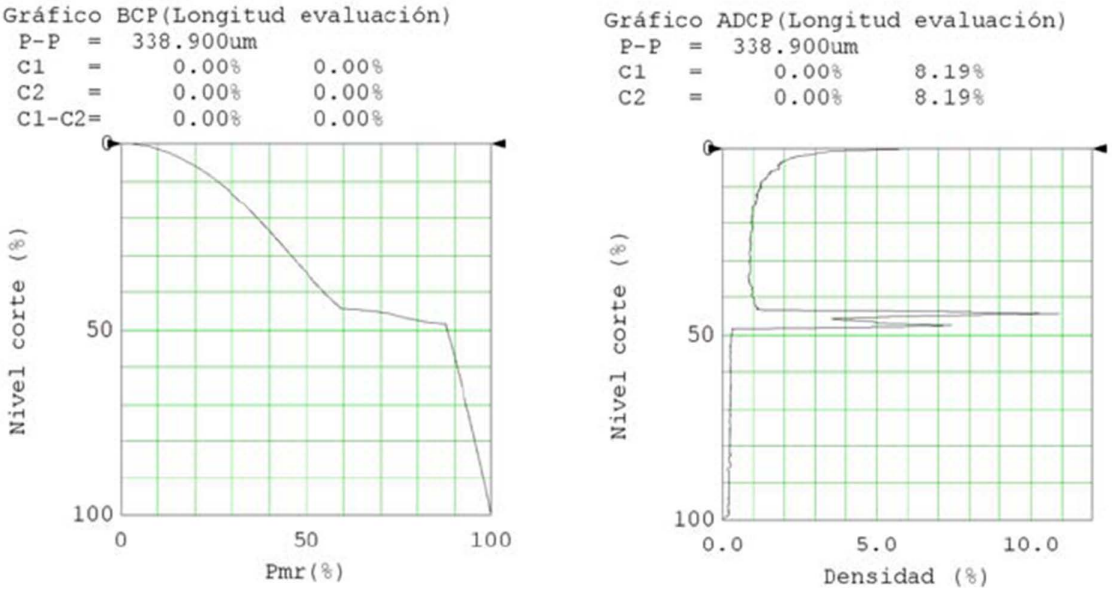

Figure A79. Material graphs along diagonal 1 before wear in sample 1N12.

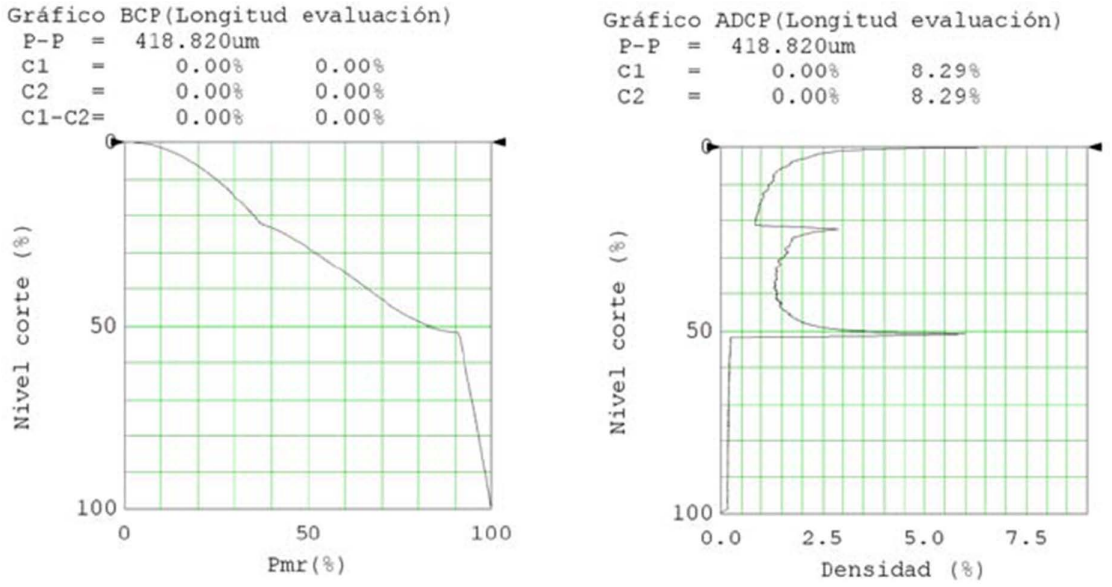

Figure A80. Material graphs along diagonal 2 before wear in sample 1N12.

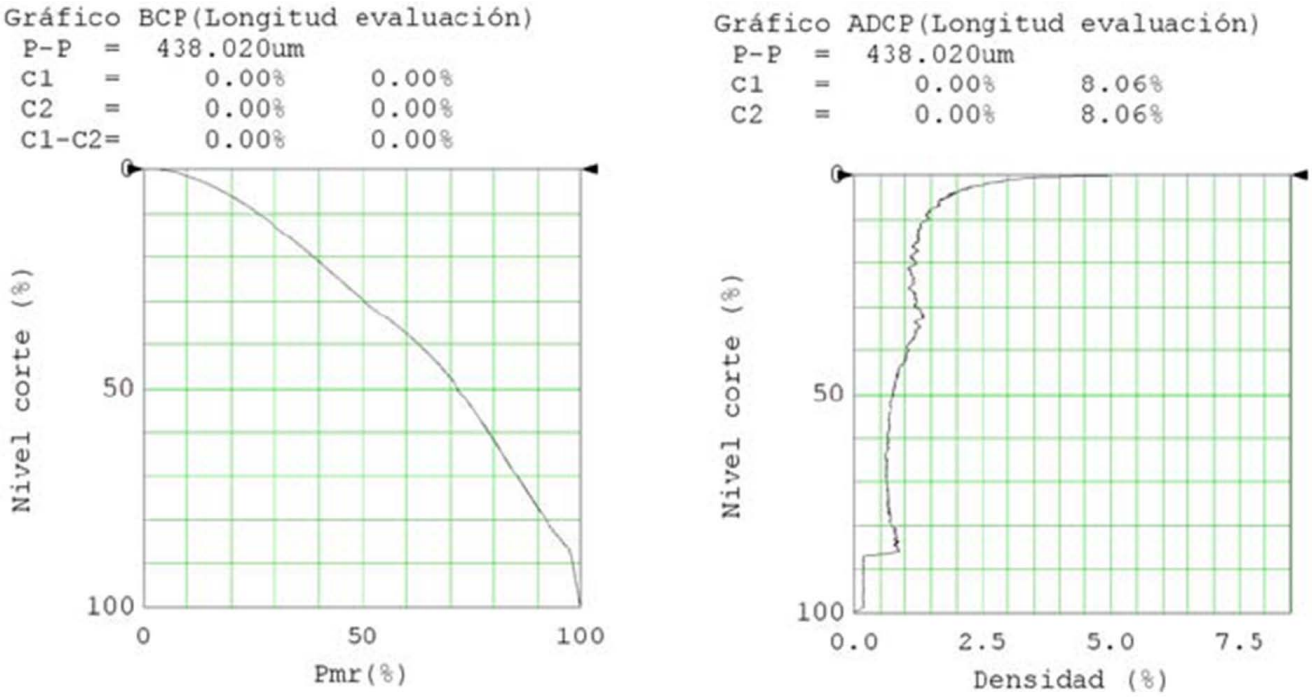

Figure A81. Material graphs along diagonal 3 before wear in sample 1N12.

Appendix A.10. Measurements Before Wear in Sample 2N12

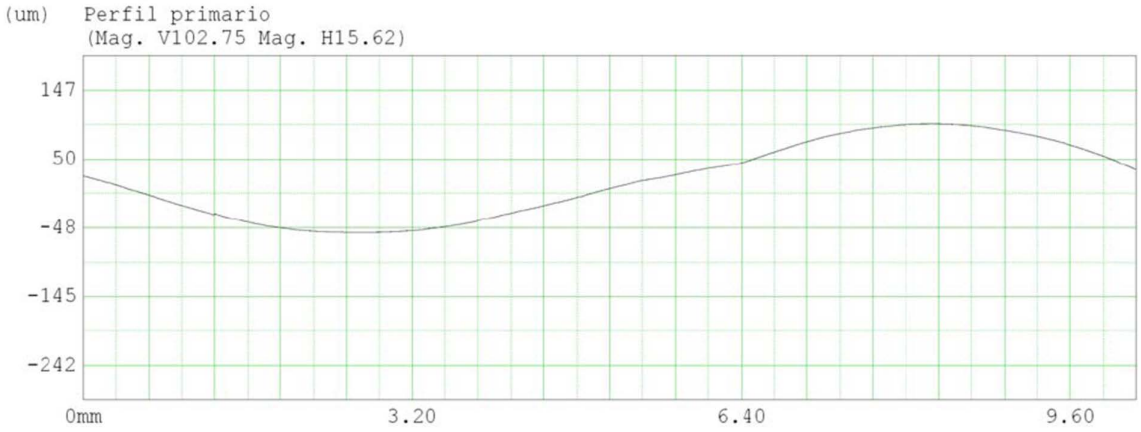

Figure A82. Primary profile; diagonal 1 before wear in sample 2N12.

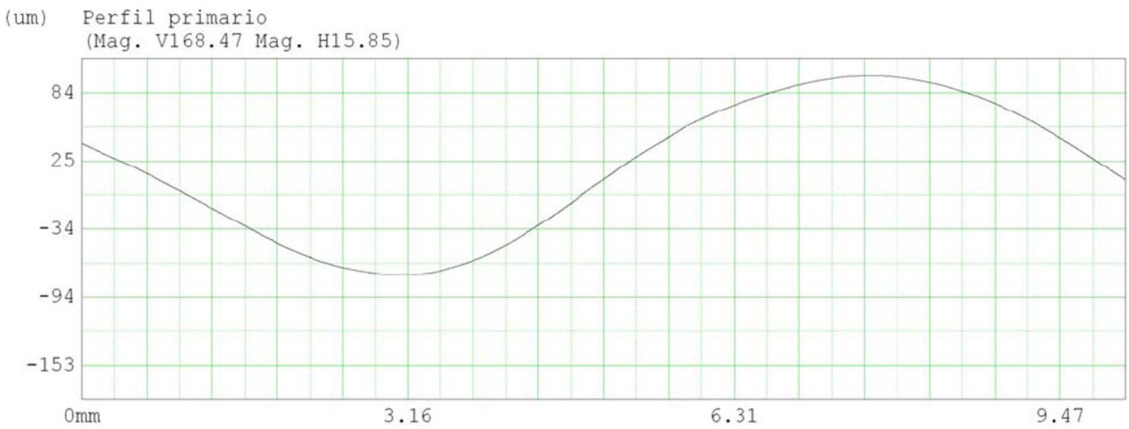

Figure A83. Primary profile; diagonal 2 before wear in sample 2N12.

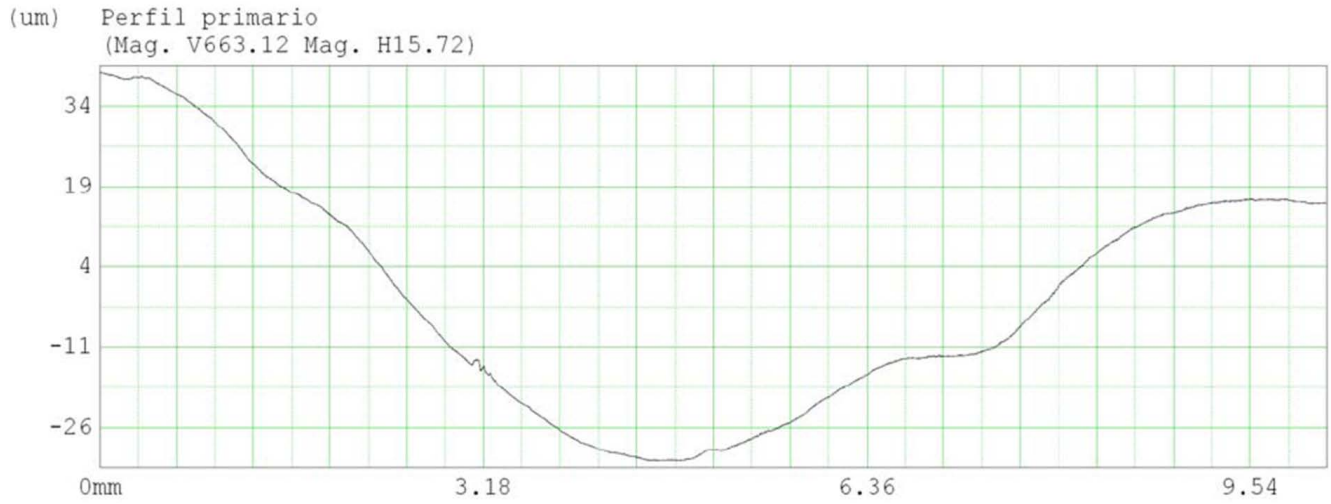

Figure A84. Primary profile; diagonal 3 before wear in sample 2N12.

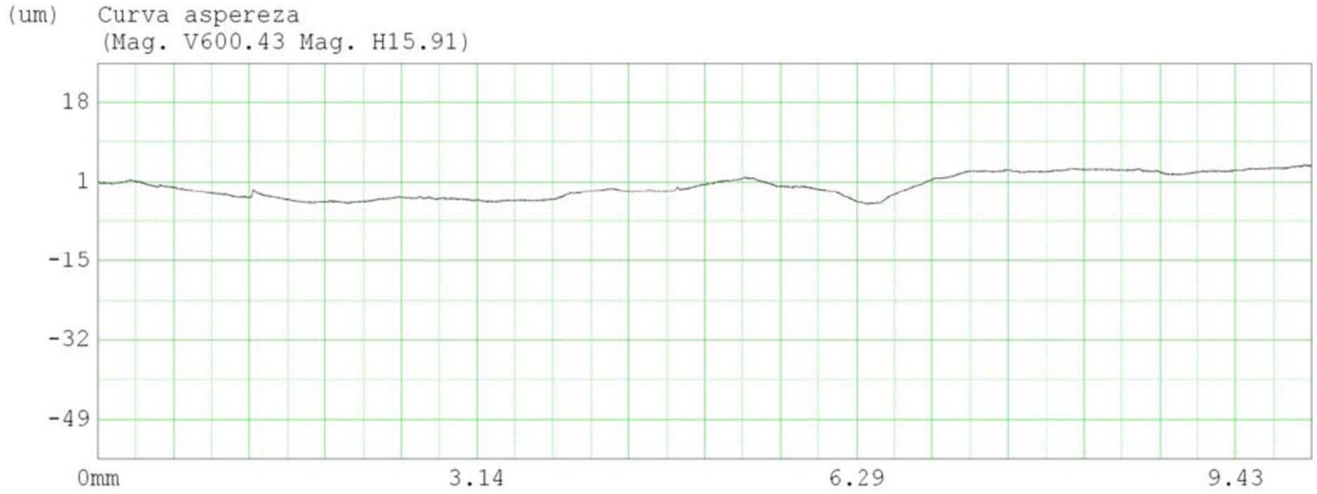

Figure A85. Roughness profile; diagonal 1 before wear in sample 2N12.

Figure A86. Roughness profile; diagonal 2 before wear in sample 2N12.

Figure A87. Roughness profile; diagonal 3 before wear in sample 2N12.

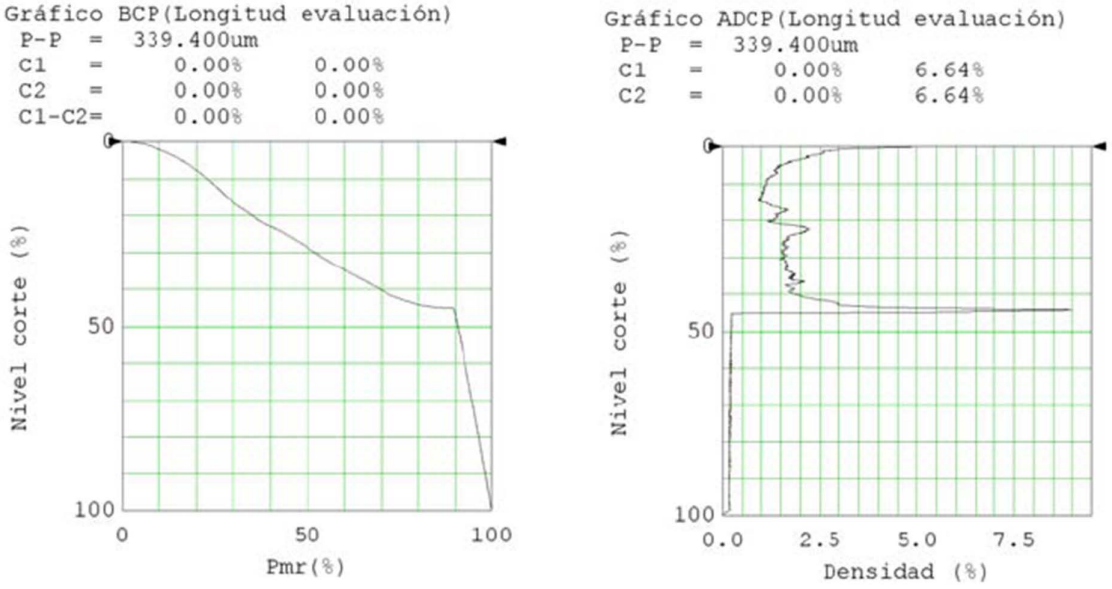

Figure A88. Material graphs along diagonal 1 before wear in sample 2N12.

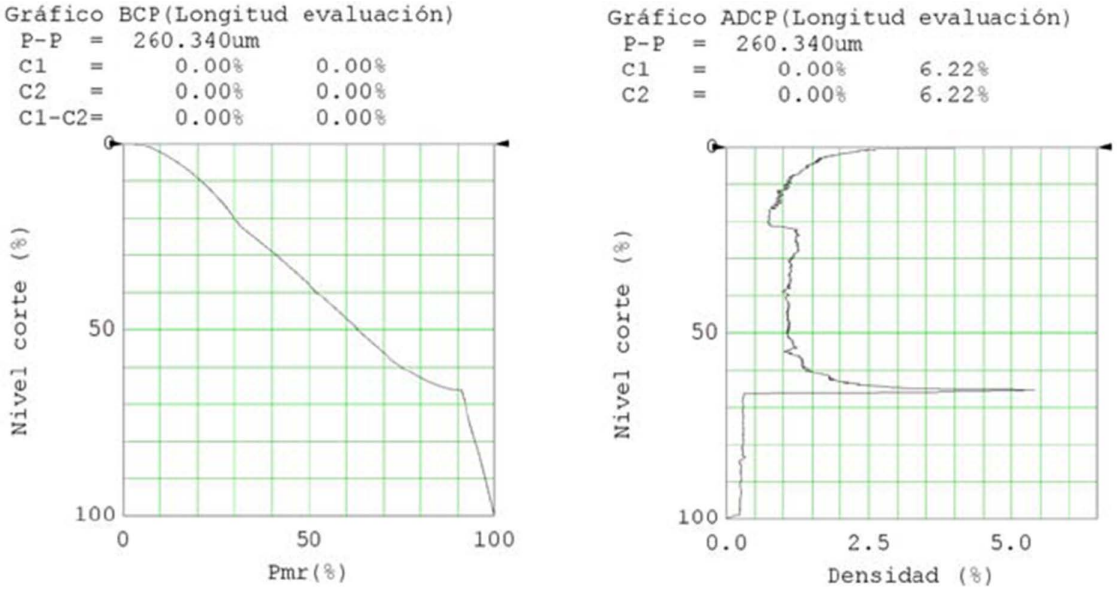

Figure A89. Material graphs along diagonal 2 before wear in sample 2N12.

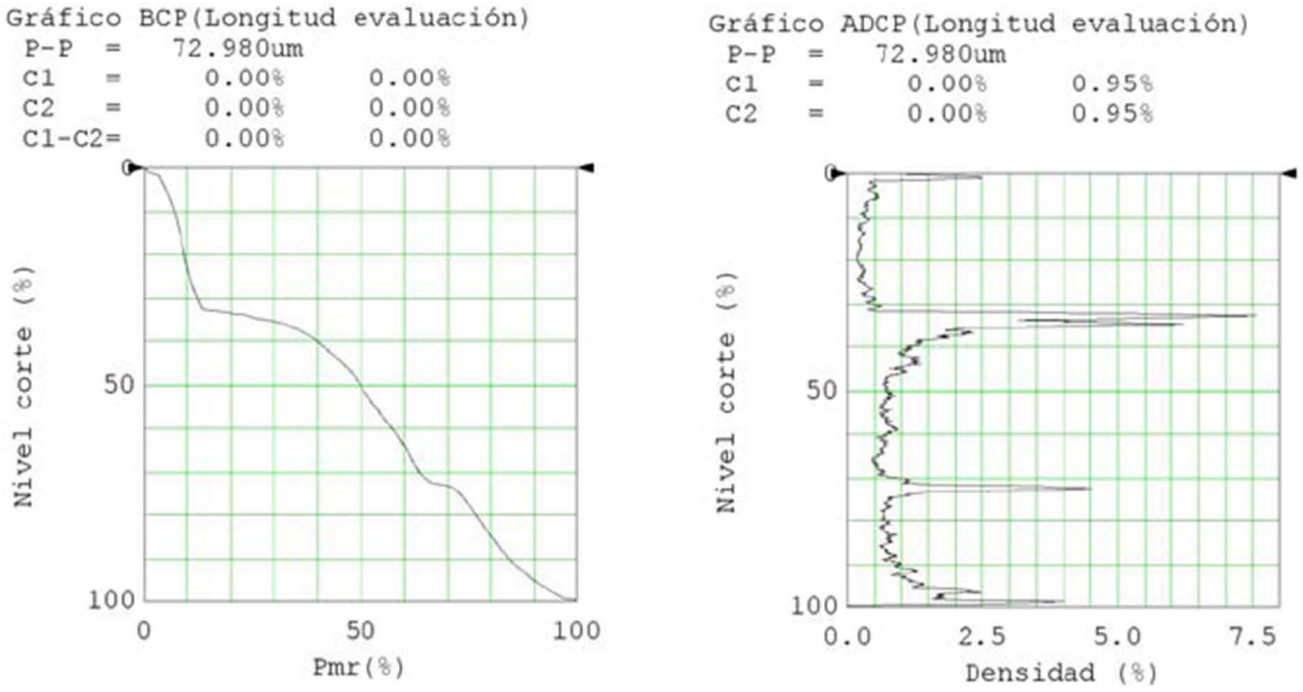

Figure A90. Material graphs along diagonal 3 before wear in sample 2N12.

Appendix A.11. Measurements Before Wear in Sample 1B12

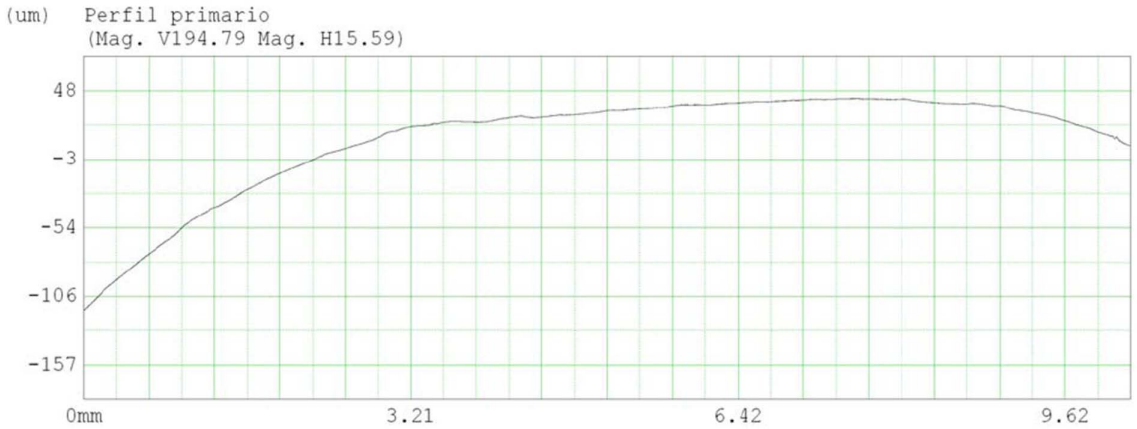

Figure A91. Primary profile; diagonal 1 before wear in sample 1B12.

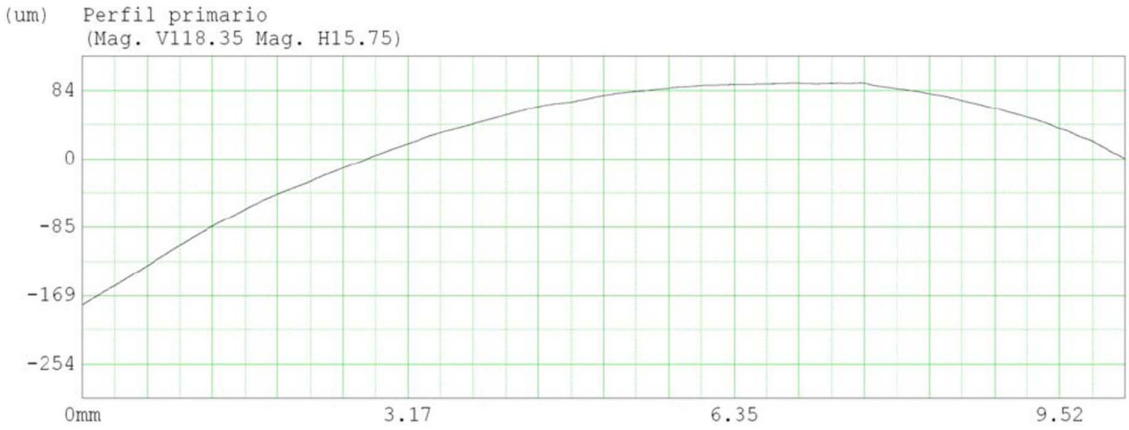

Figure A92. Primary profile; diagonal 2 before wear in sample 1B12.

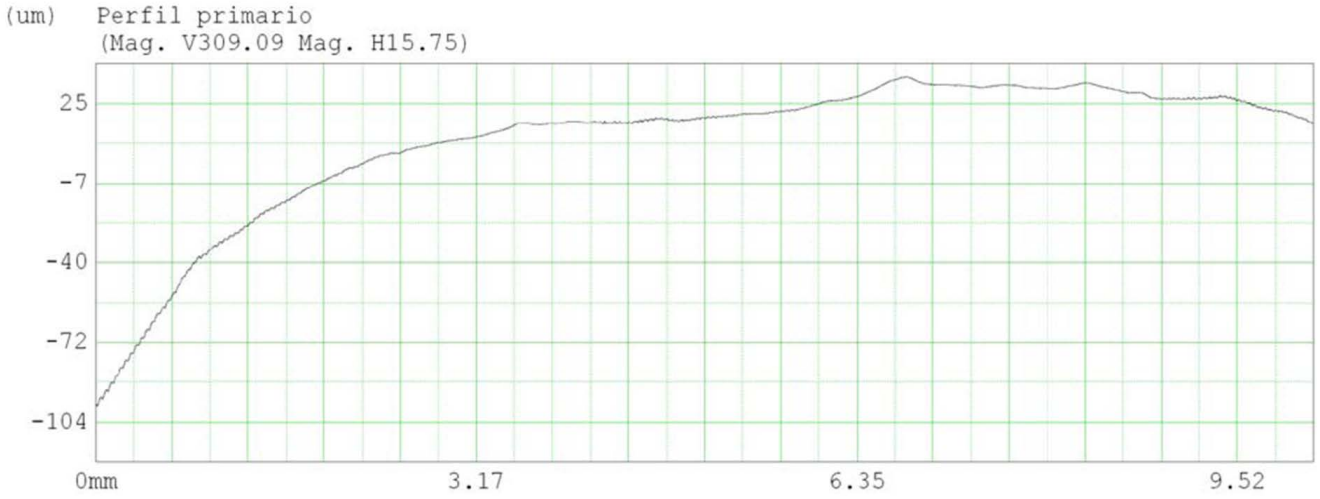

Figure A93. Primary profile; diagonal 3 before wear in sample 1B12.

Figure A94. Roughness profile; diagonal 1 before wear in sample 1B12.

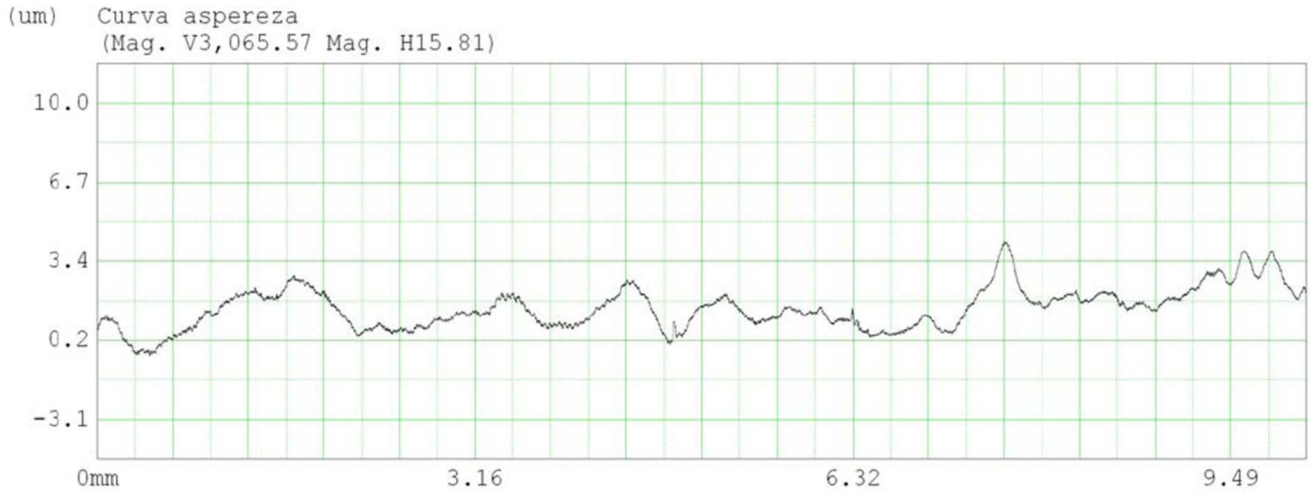

Figure A95. Roughness profile; diagonal 2 before wear in sample 1B12.

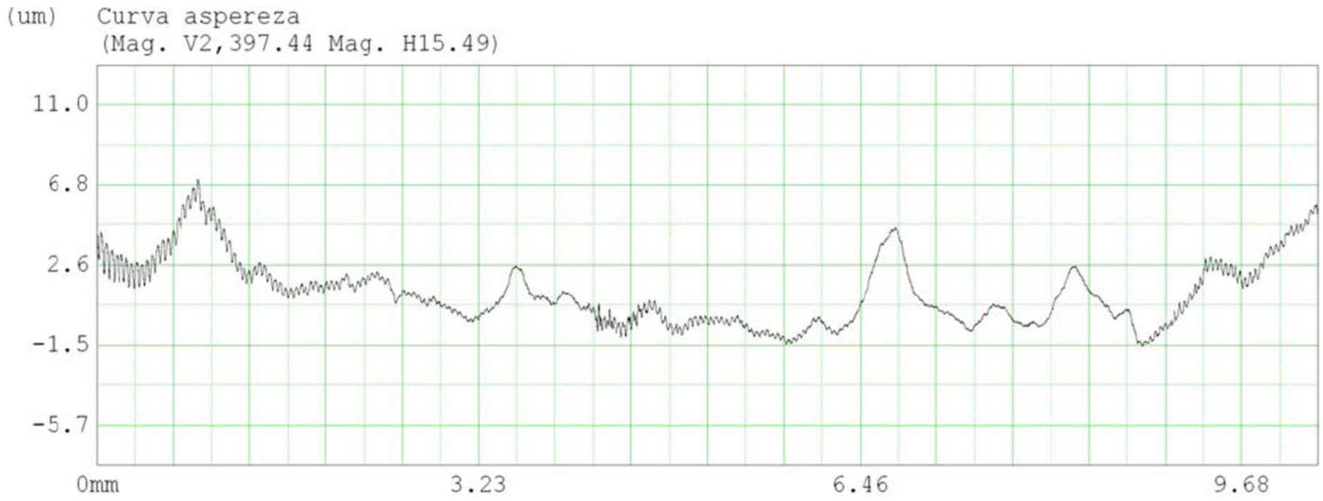

Figure A96. Roughness profile; diagonal 3 before wear in sample 1B12.

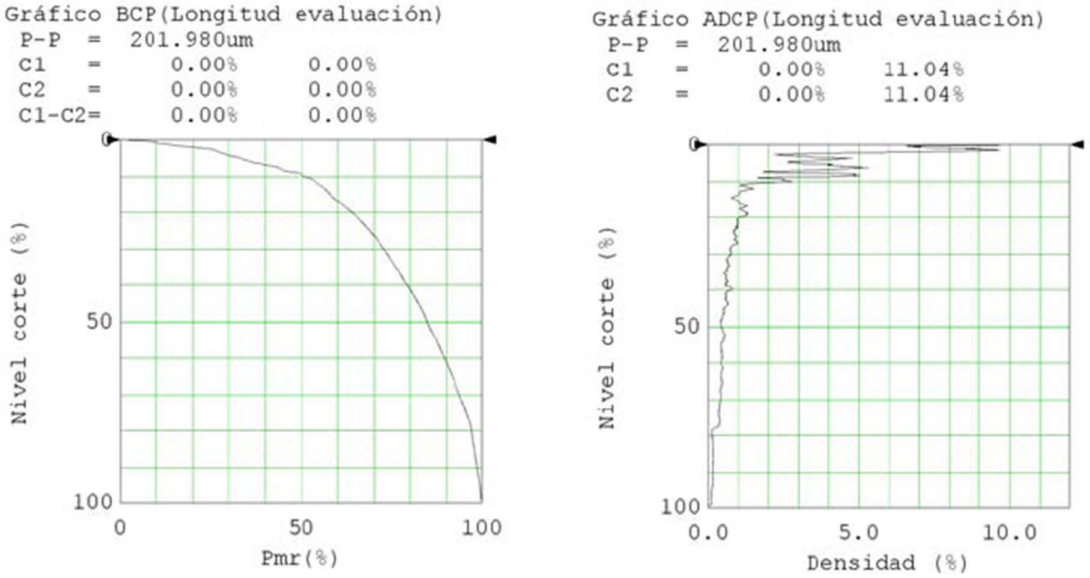

Figure A97. Material graphs along diagonal 1 before wear in sample 1B12.

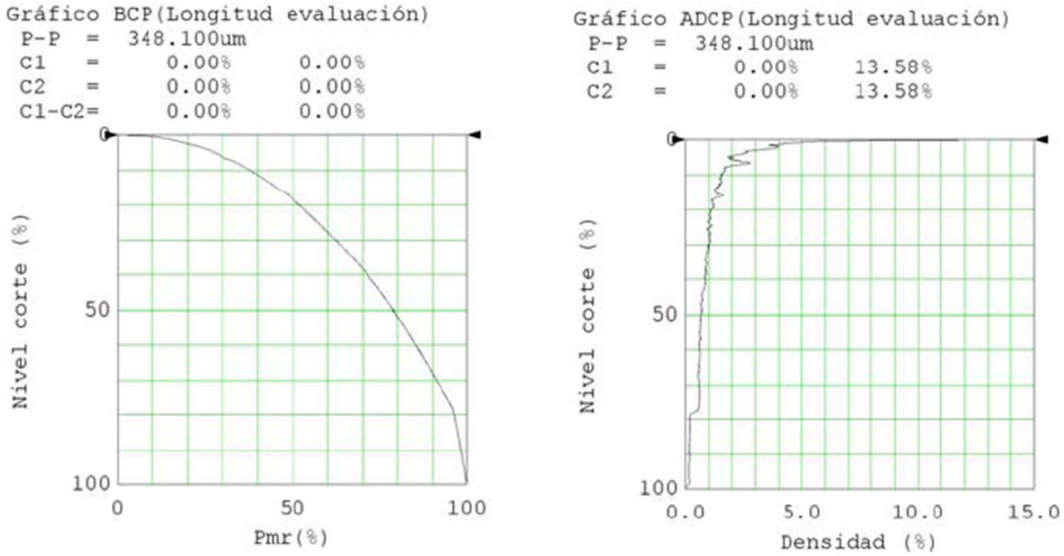

Figure A98. Material graphs along diagonal 2 before wear in sample 1B12.

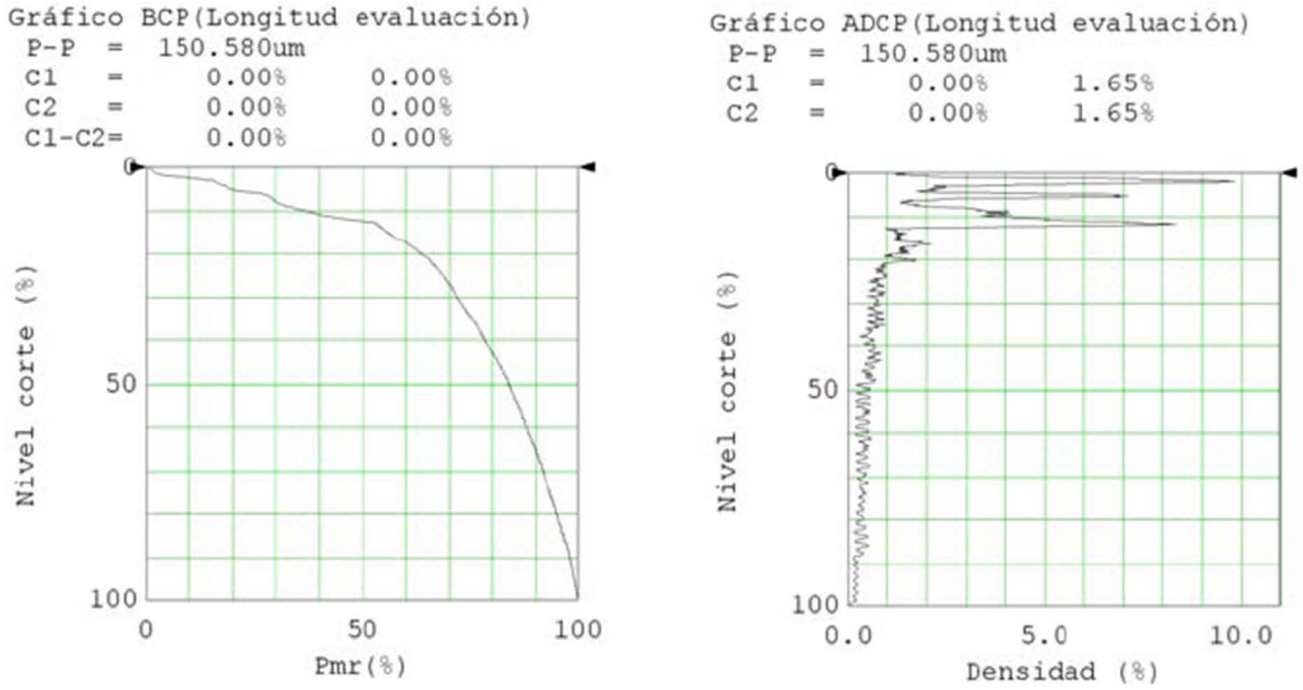

Figure A99. Material graphs along diagonal 3 before wear in sample 1B12.

Appendix A.12. Measurements Before Wear in Sample 2B12

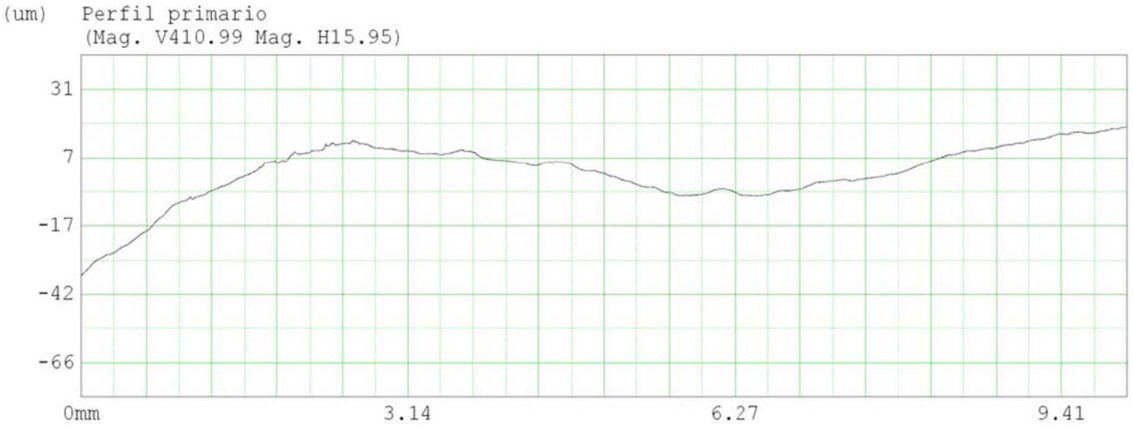

Figure A100. Primary profile; diagonal 1 before wear in sample 2B12.

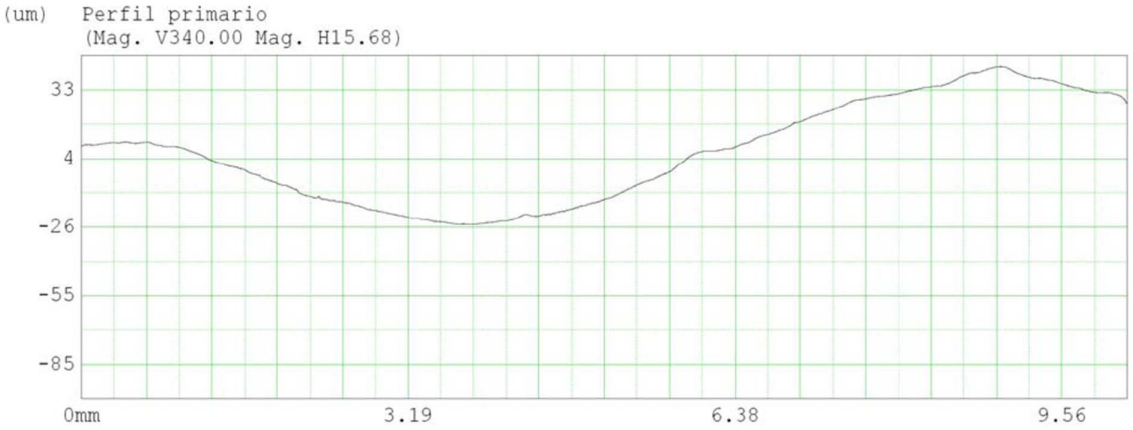

Figure A101. Primary profile; diagonal 2 before wear in sample 2B12.

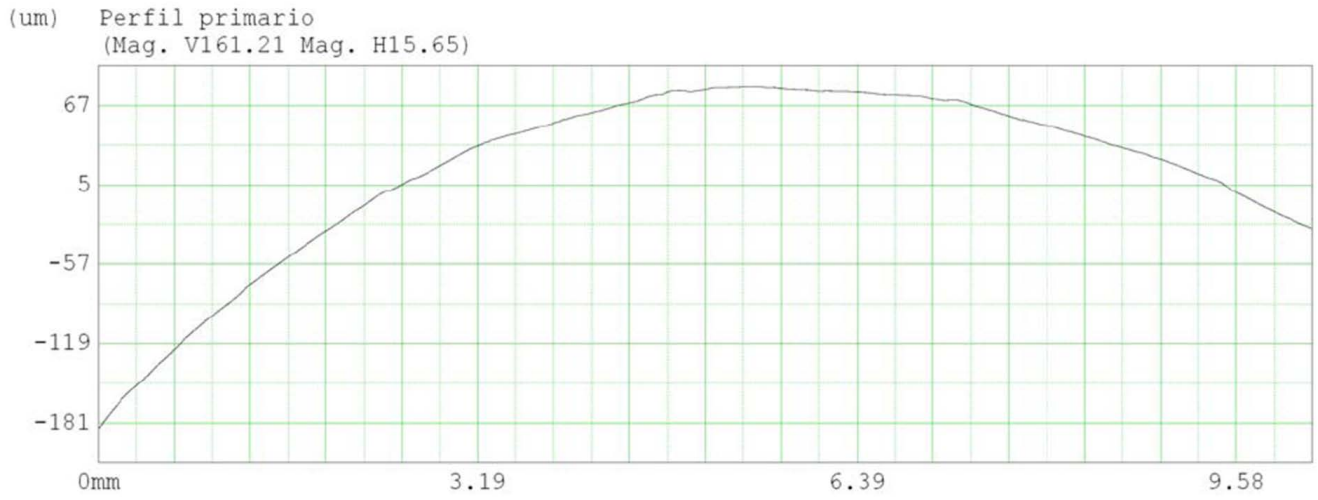

Figure A102. Primary profile; diagonal 3 before wear in sample 2B12.

Figure A103. Roughness profile; diagonal 1 before wear in sample 2B12.

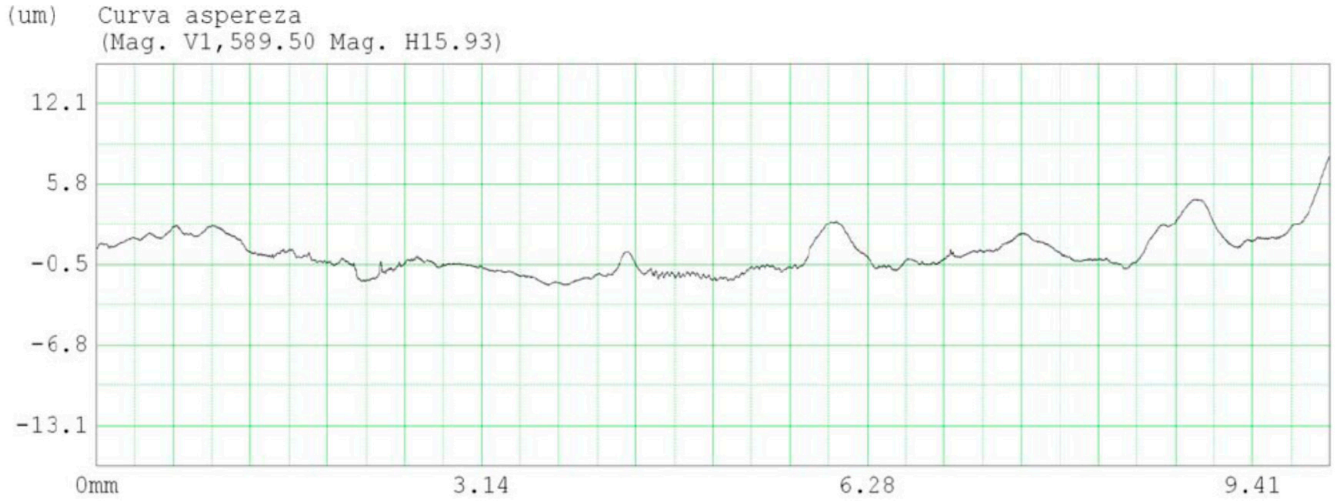

Figure A104. Roughness profile; diagonal 2 before wear in sample 2B12.

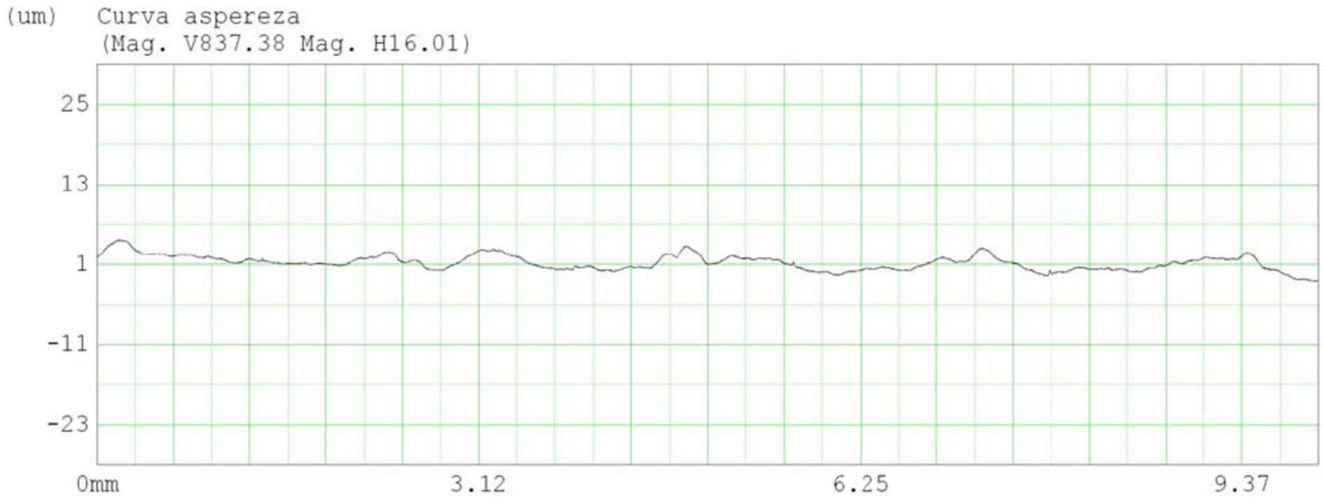

Figure A105. Roughness profile; diagonal 3 before wear in sample 2B12.

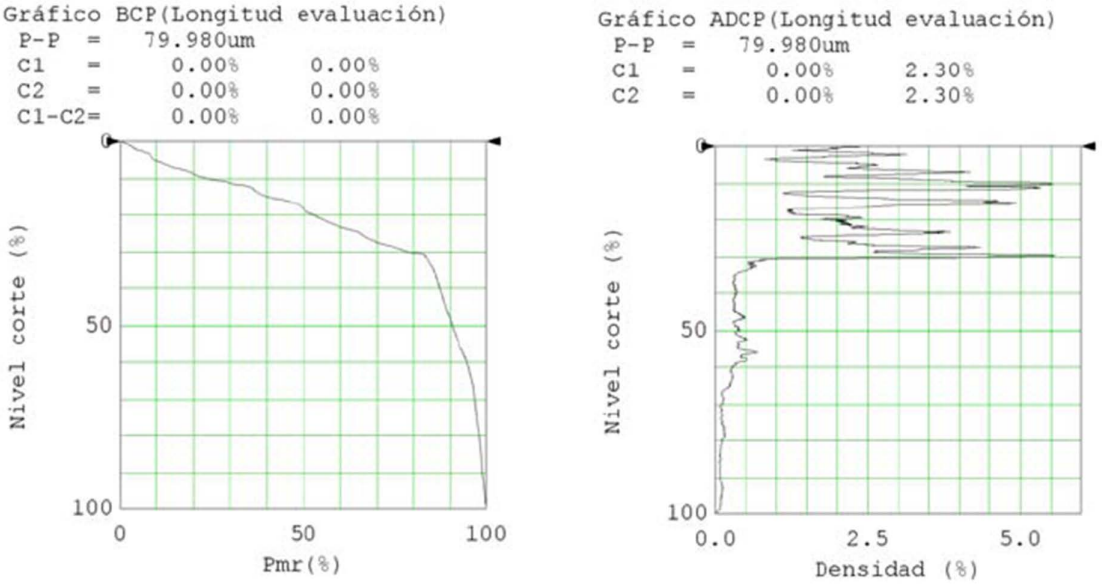

Figure A106. Material graphs along diagonal 1 before wear in sample 2B12.

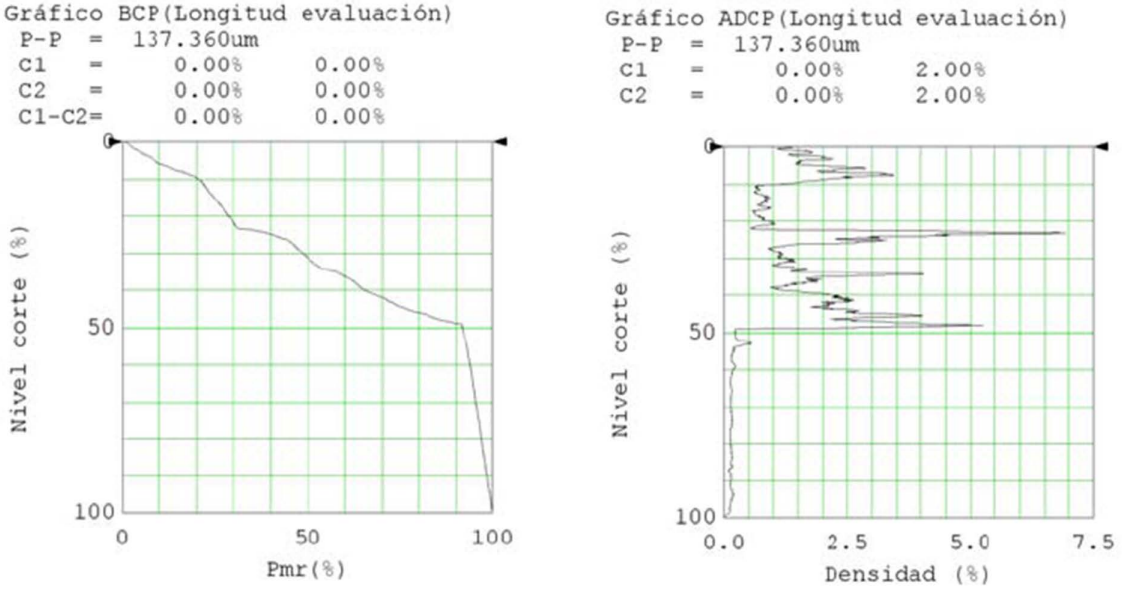

Figure A107. Material graphs along diagonal 2 before wear in sample 2B12.

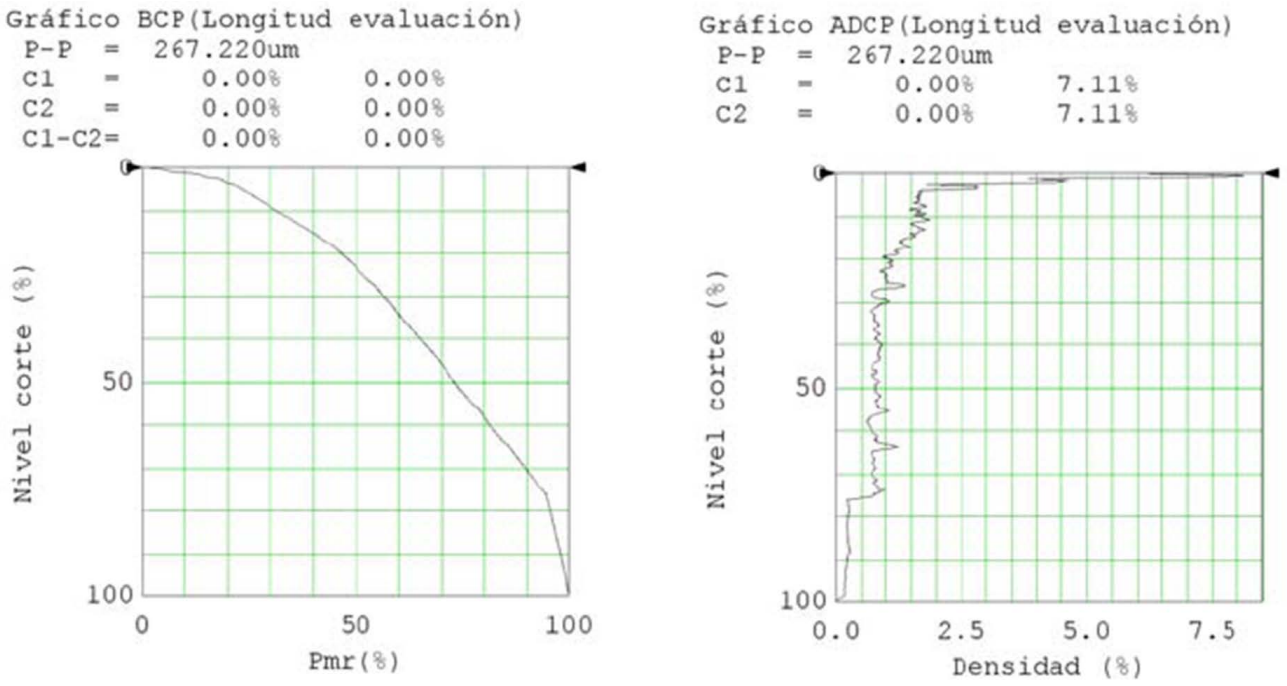

Figure A108. Material graphs along diagonal 3 before wear in sample 2B12.

Appendix B. Measurements After Wear

Appendix B.1. Measurements After Wear in Sample E1

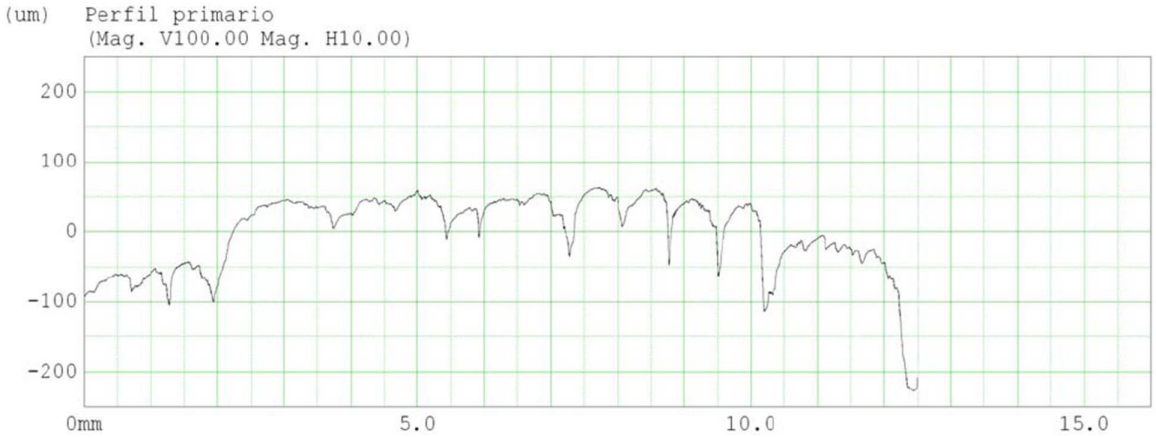

Figure A109. Primary profile; diagonal 1 after wear in sample E1.

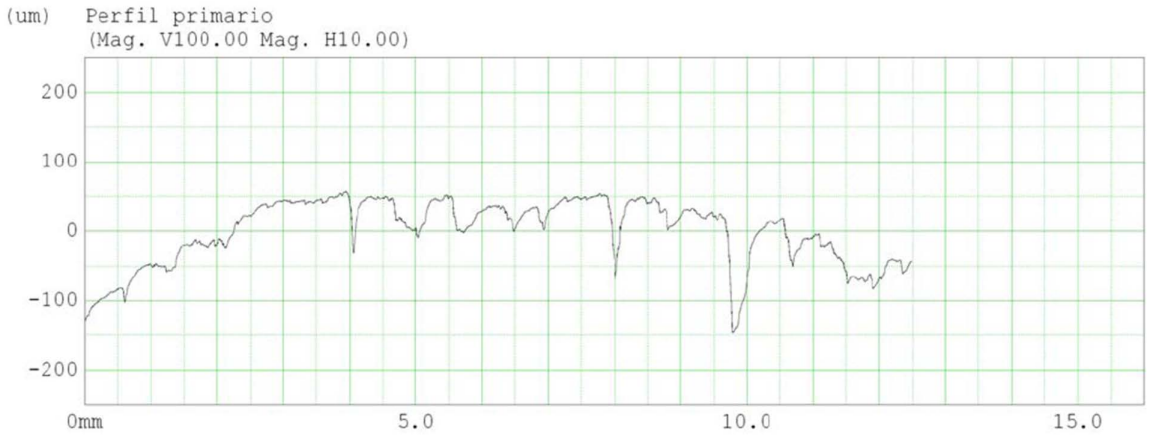

Figure A110. Primary profile; diagonal 2 after wear in sample E1.

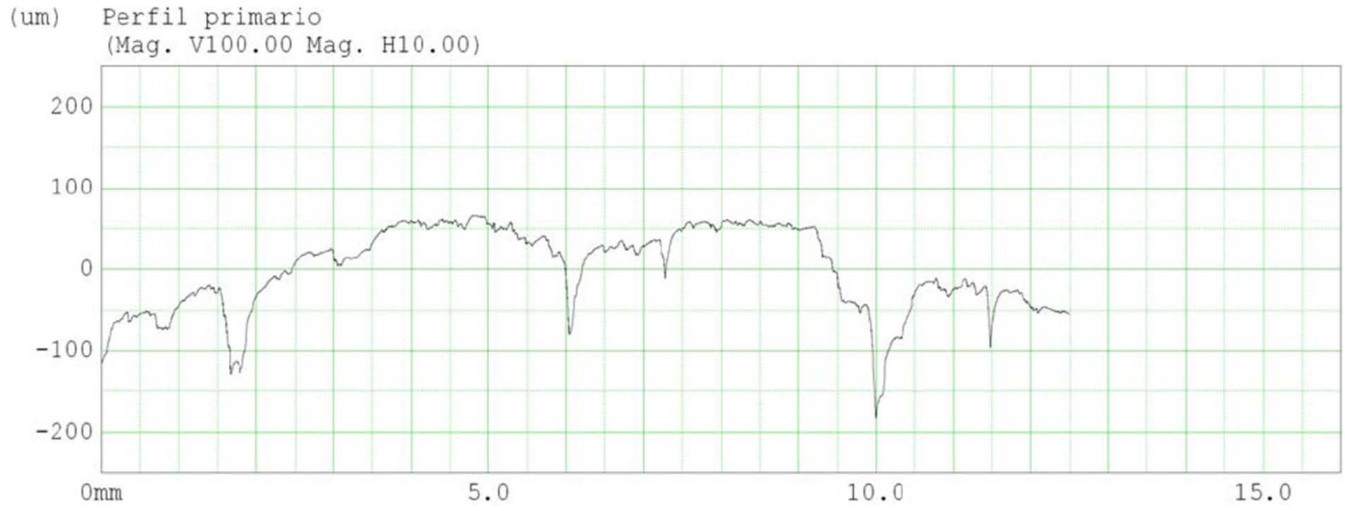

Figure A111. Primary profile; diagonal 3 after wear in sample E1.

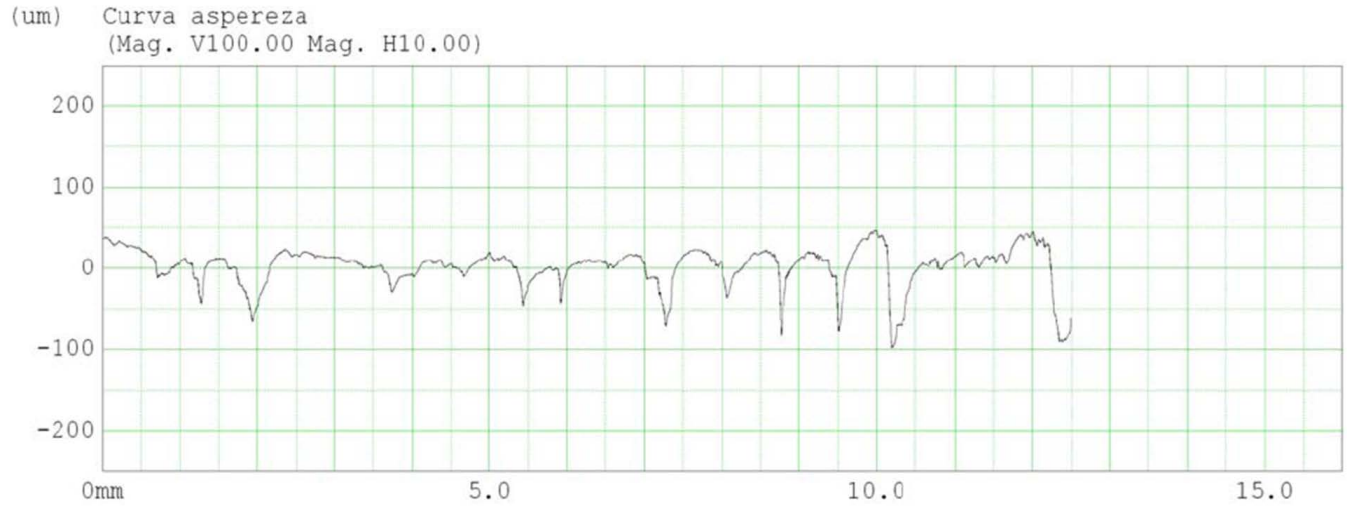

Figure A112. Roughness profile; diagonal 1 after wear in sample E1.

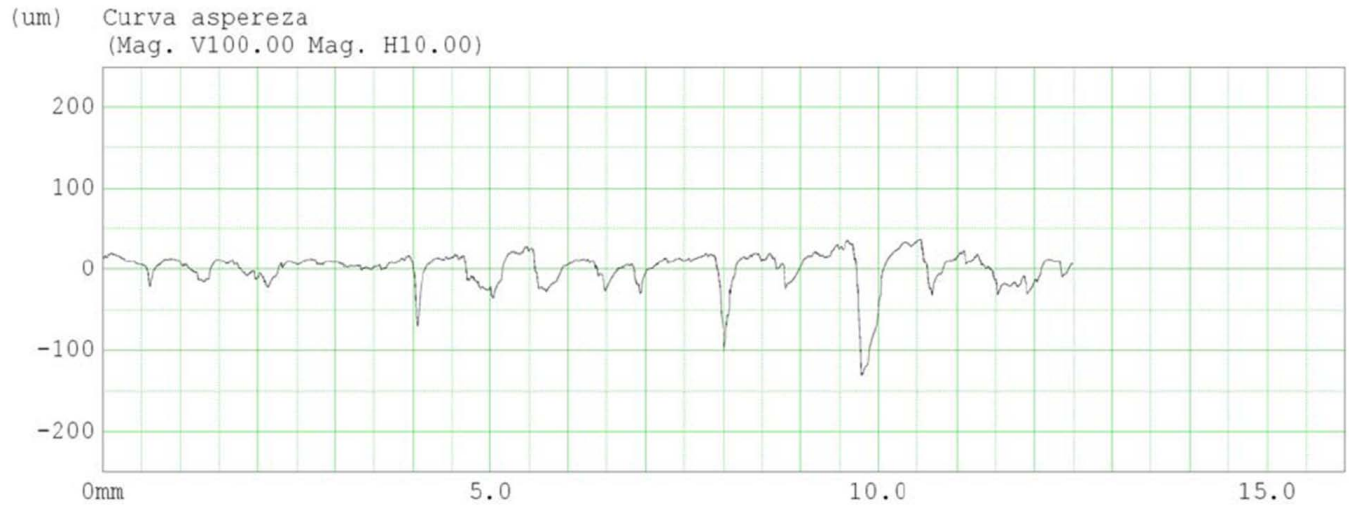

Figure A113. Roughness profile; diagonal 2 after wear in sample E1.

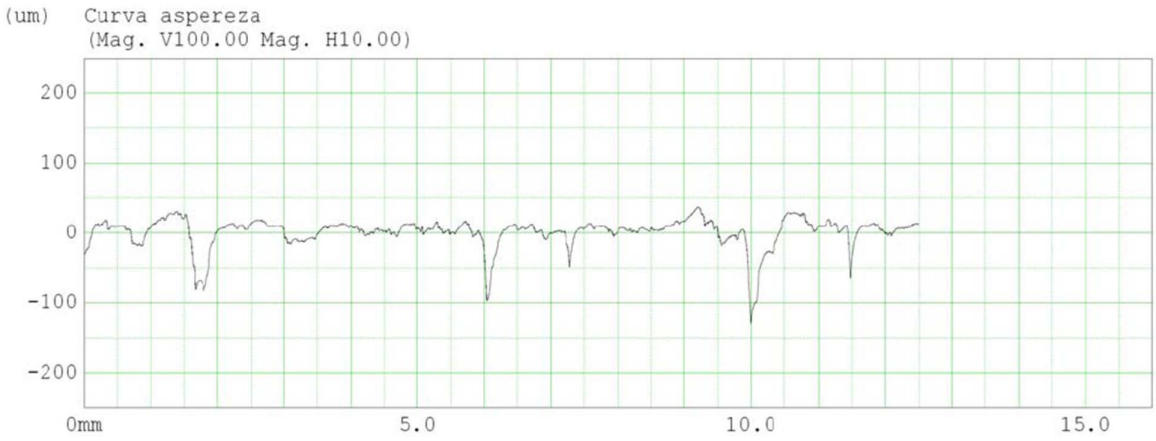

Figure A114. Roughness profile; diagonal 3 after wear in sample E1.

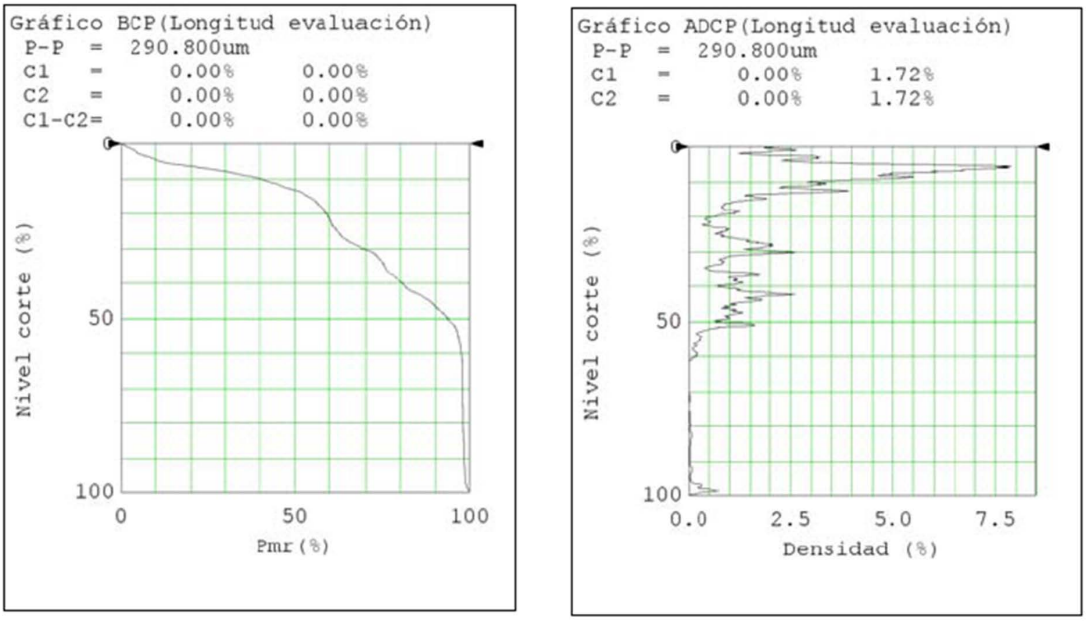

Figure A115. Material graphs along diagonal 1 after wear in sample E1.

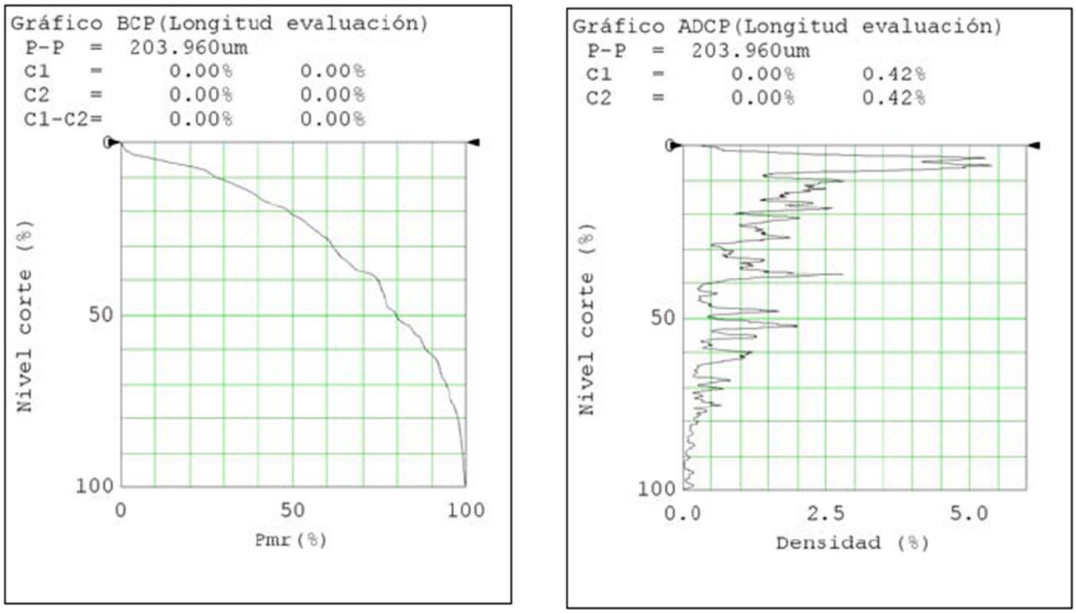

Figure A116. Material graphs along diagonal 2 after wear in sample E1.

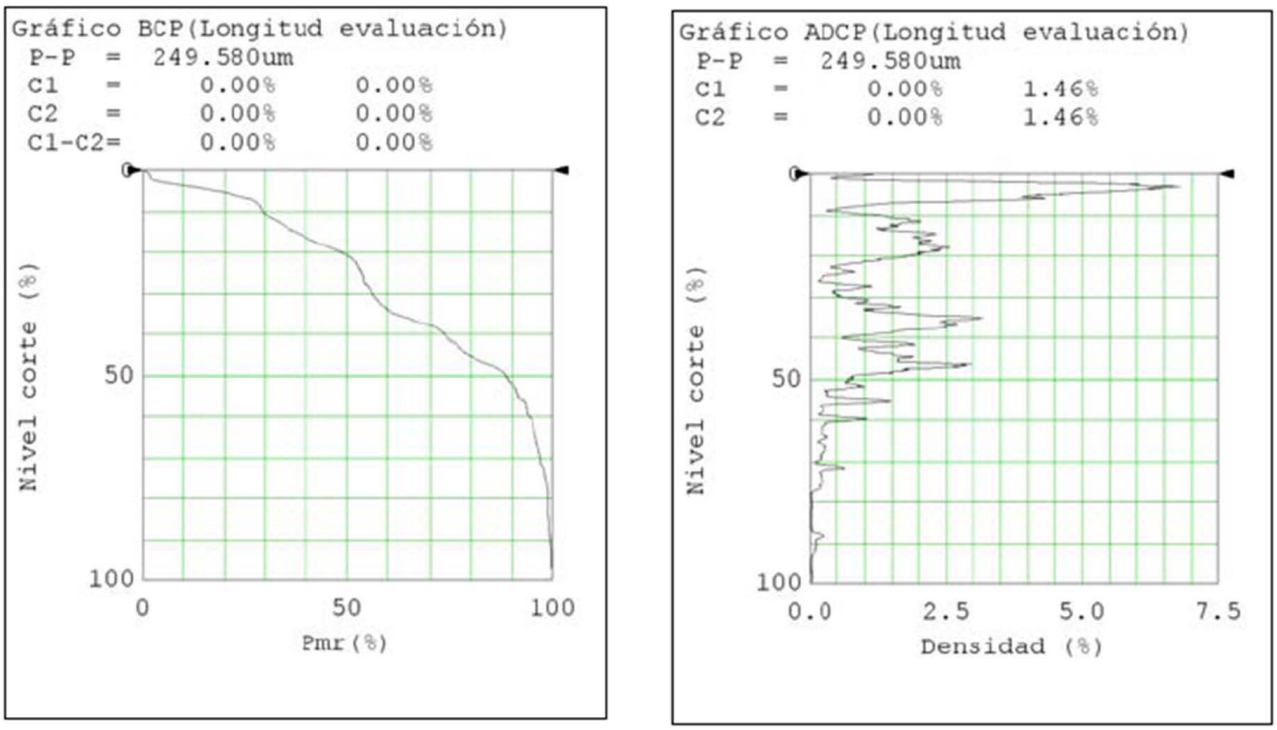

Figure A117. Material graphs along diagonal 3 after wear in sample E1.

Appendix B.2. Measurements After Wear in Sample E2

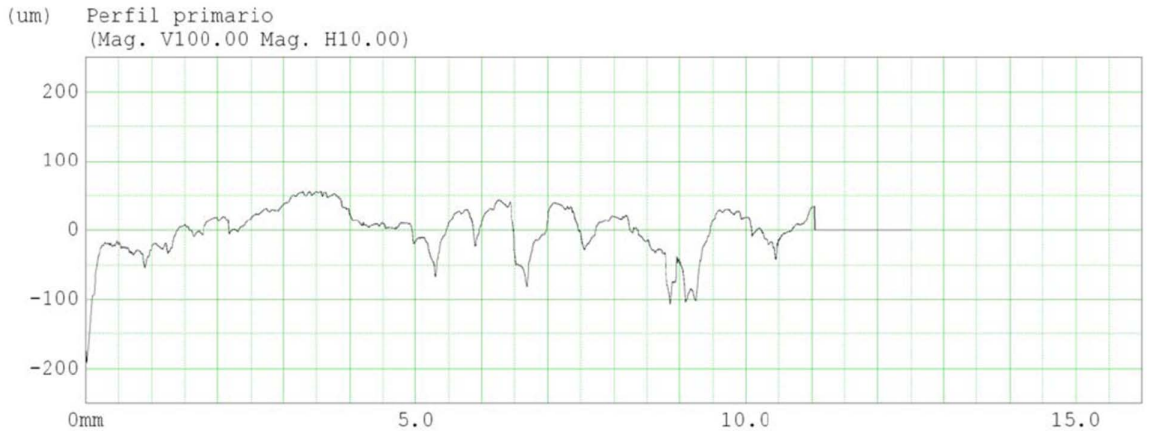

Figure A118. Primary profile; diagonal 1 after wear in sample E2.

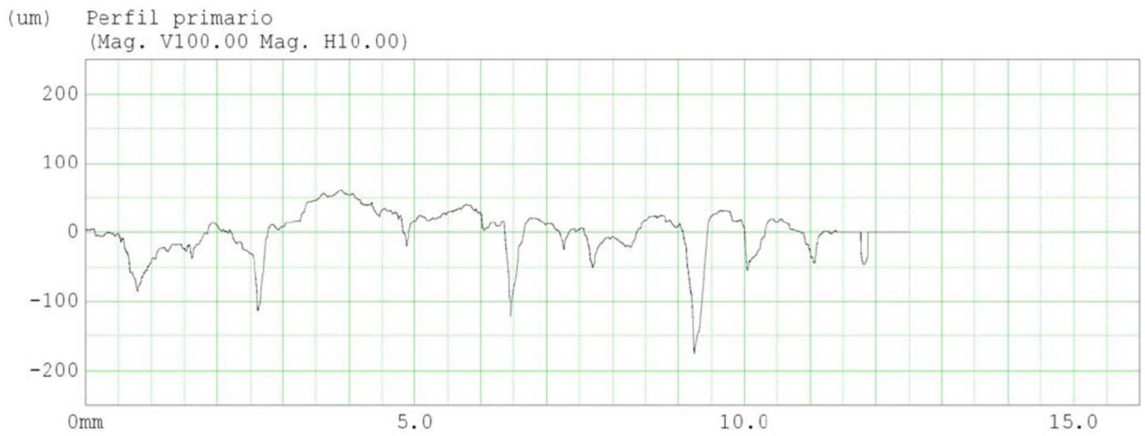

Figure A119. Primary profile; diagonal 2 after wear in sample E2.

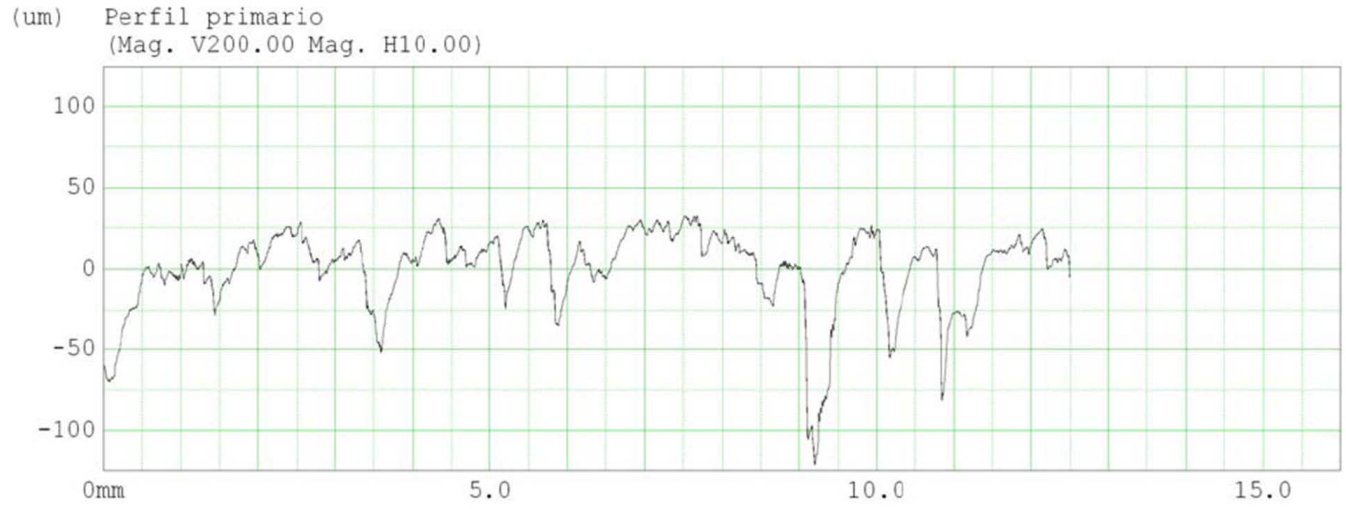

Figure A120. Primary profile; diagonal 3 after wear in sample E2.

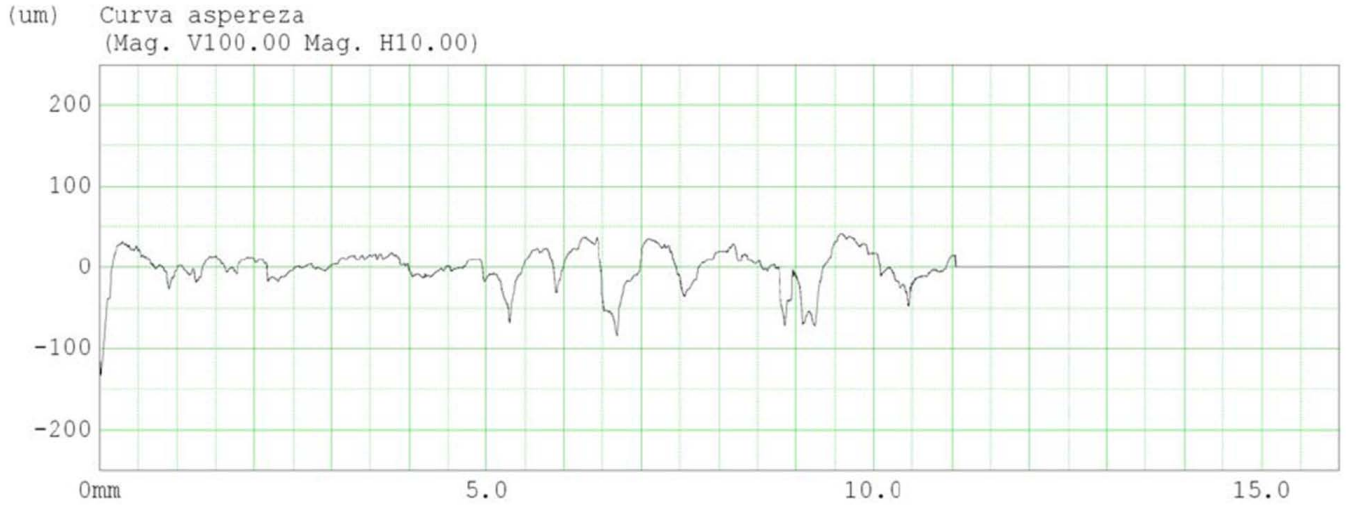

Figure A121. Roughness profile; diagonal 1 after wear in sample E2.

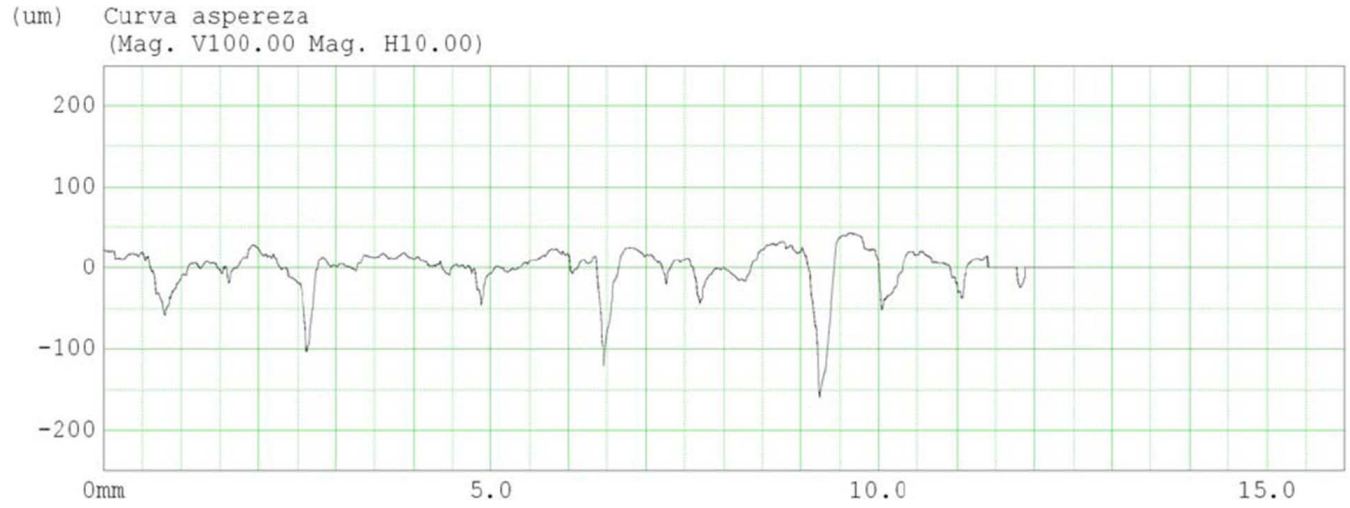

Figure A122. Roughness profile; diagonal 2 after wear in sample E2.

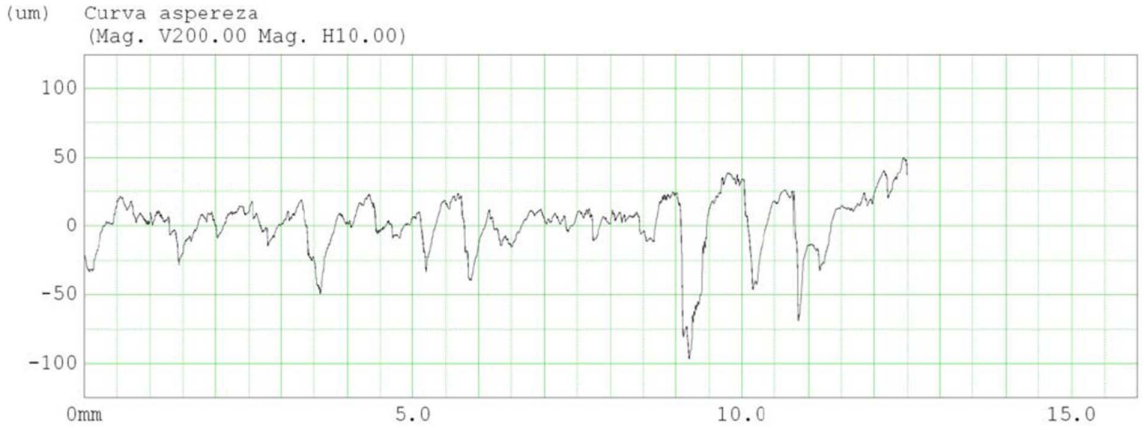

Figure A123. Roughness profile; diagonal 3 after wear in sample E2.

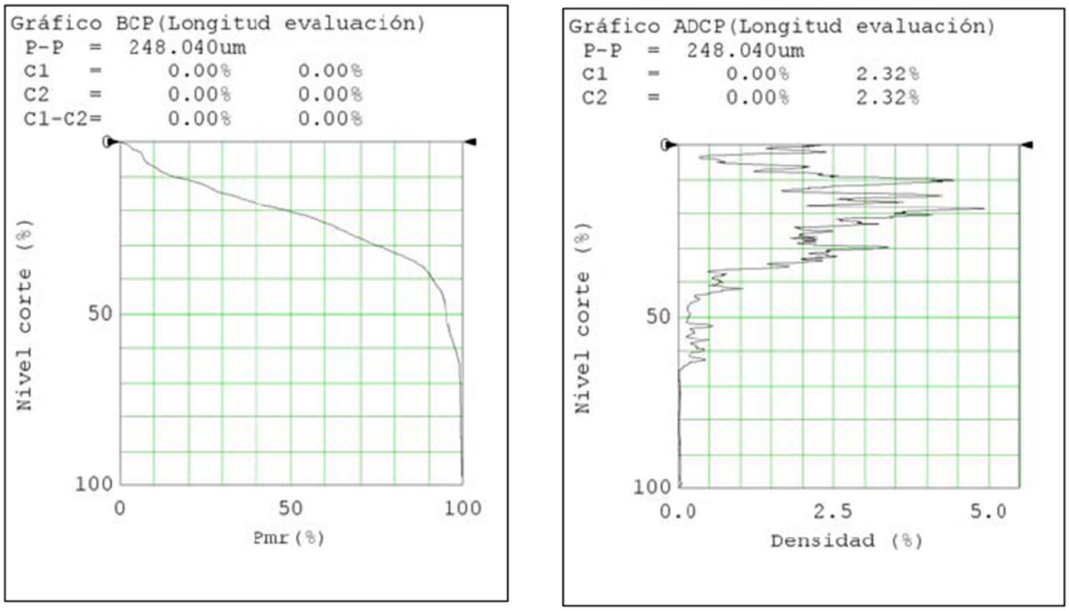

Figure A124. Material graphs along diagonal 1 after wear in sample E2.

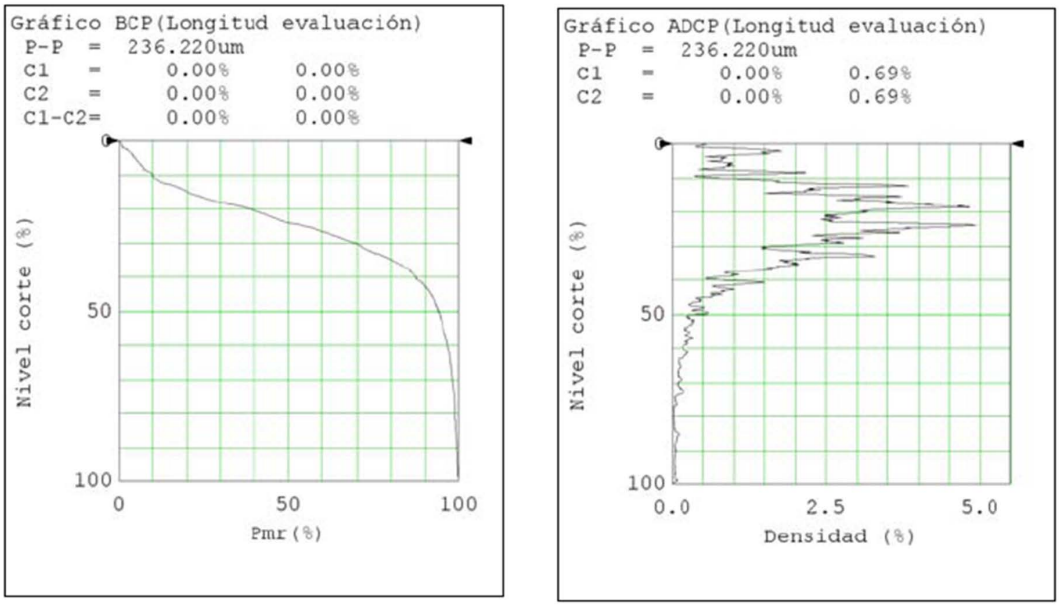

Figure A125. Material graphs along diagonal 2 after wear in sample E2.

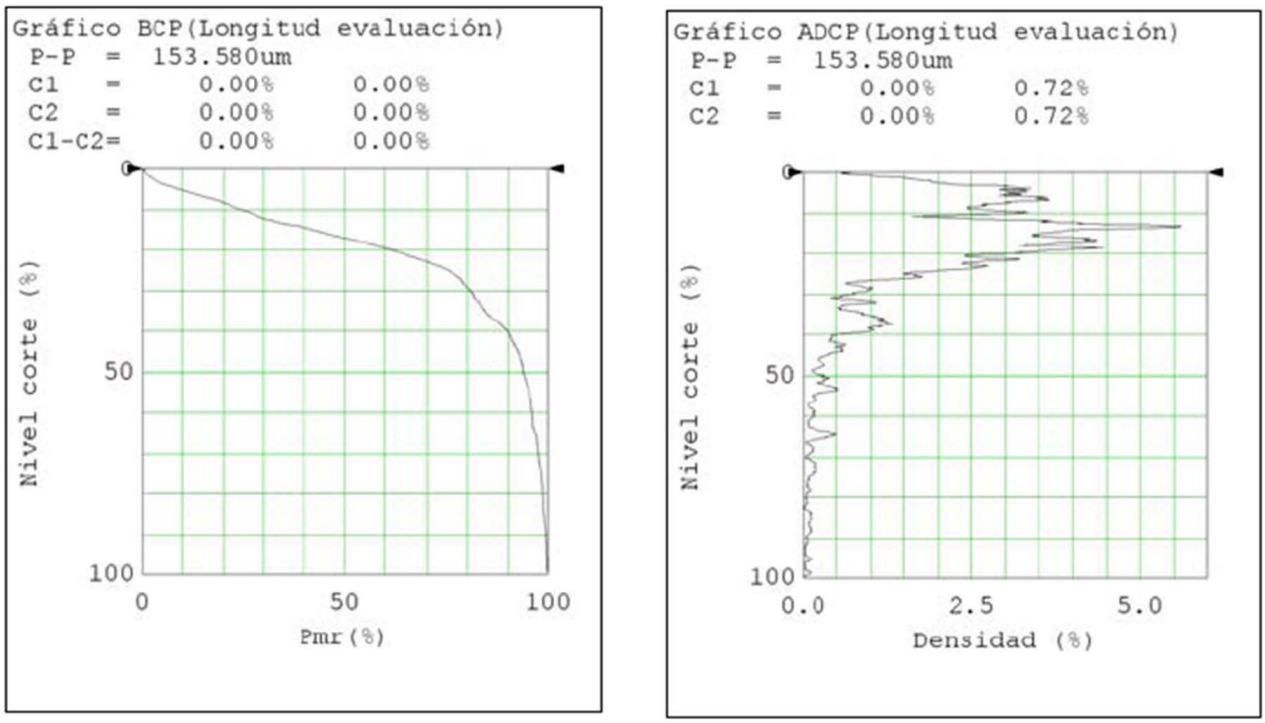

Figure A126. Material graphs along diagonal 3 after wear in sample E2.

Appendix B.3. Measurements After Wear in Sample 1M6

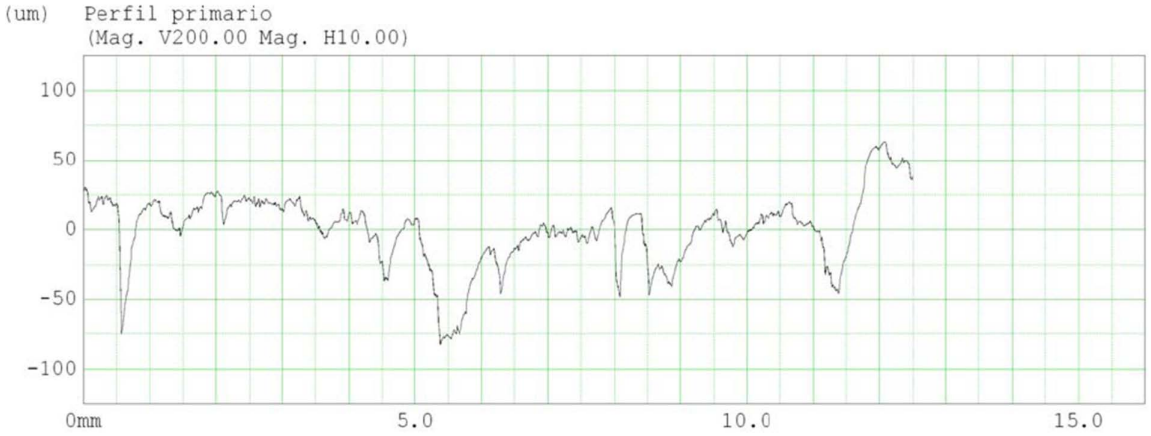

Figure A127. Primary profile; diagonal 1 after wear in sample 1M6.

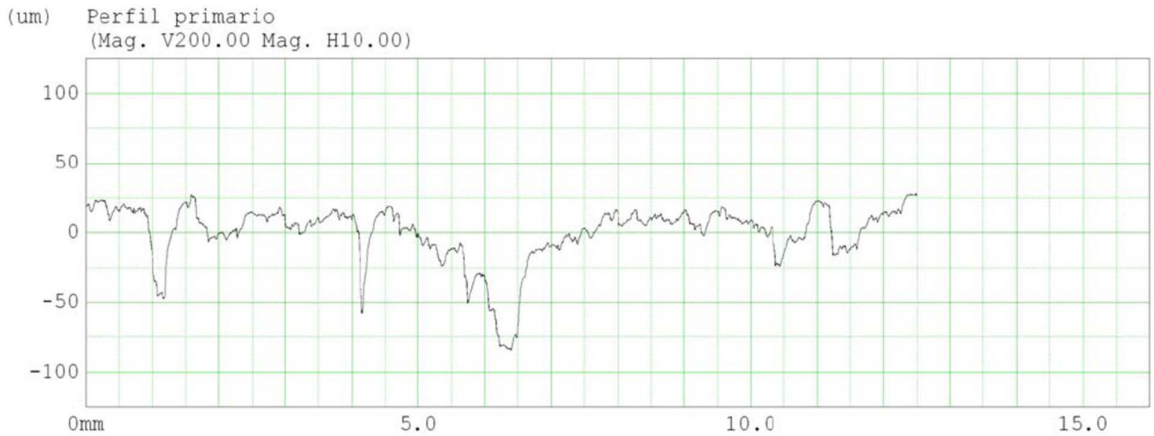

Figure A128. Primary profile; diagonal 2 after wear in sample 1M6.

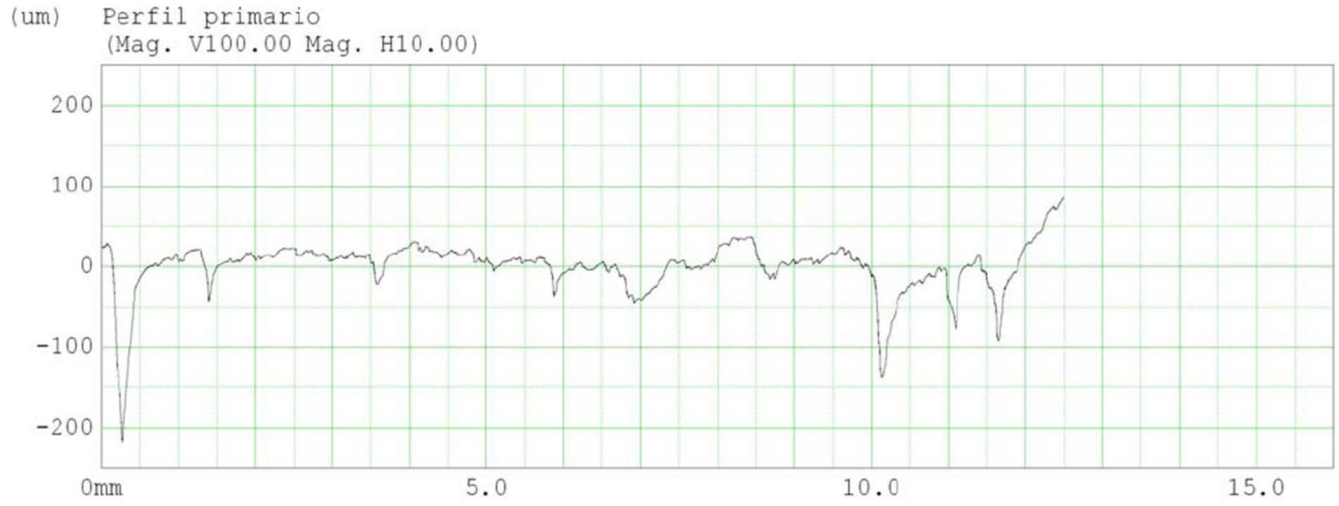

Figure A129. Primary profile; diagonal 3 after wear in sample 1M6.

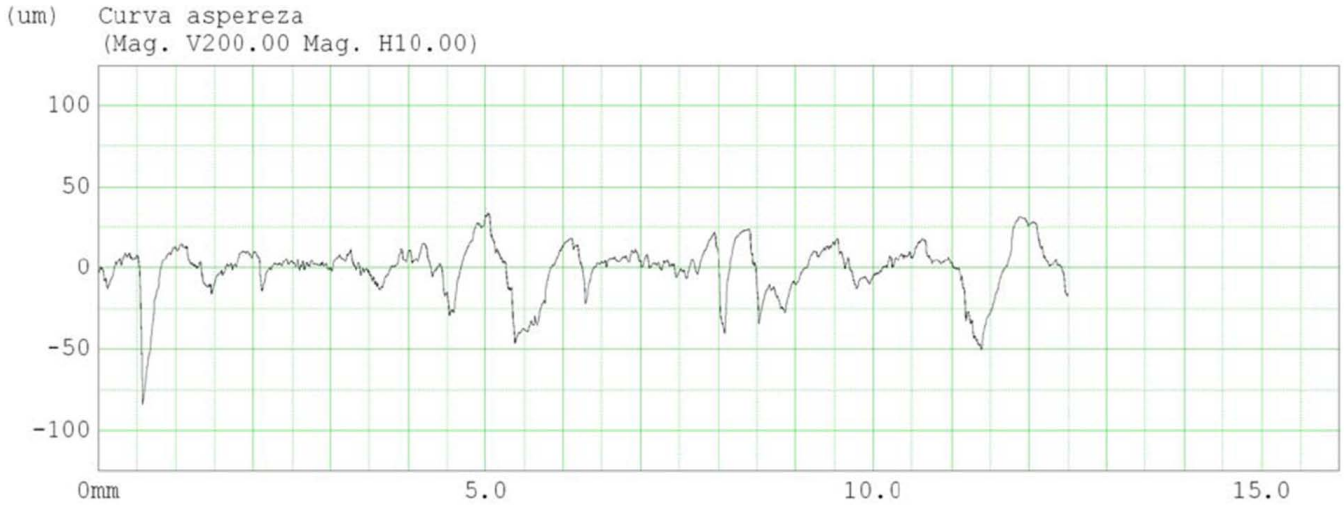

Figure A130. Roughness profile; diagonal 1 after wear in sample 1M6.

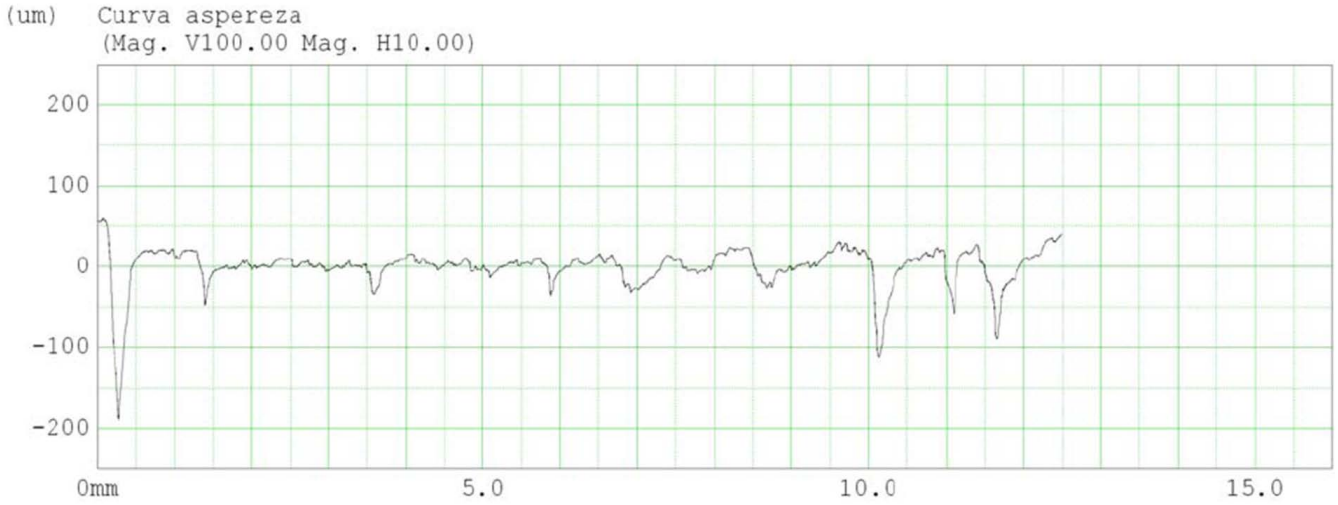

Figure A131. Roughness profile; diagonal 2 after wear in sample 1M6.

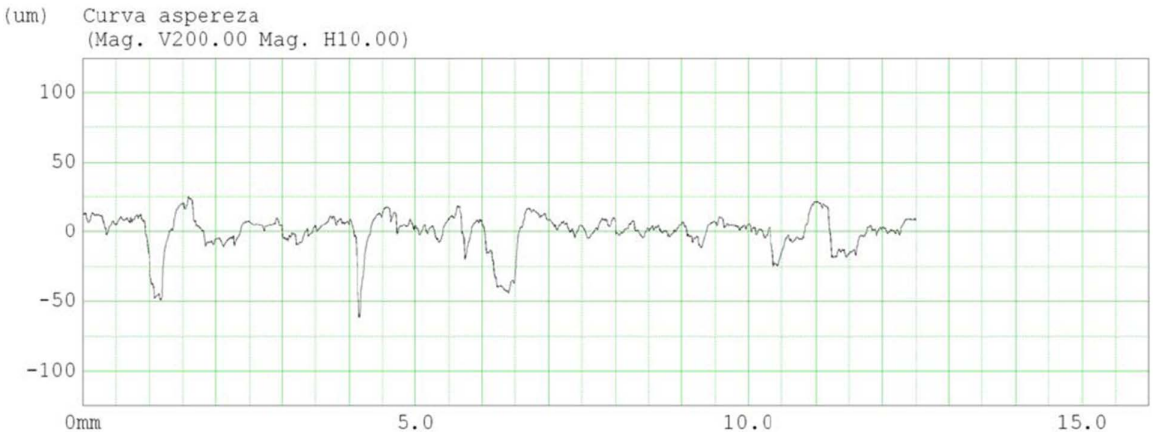

Figure A132. Roughness profile; diagonal 3 after wear in sample 1M6.

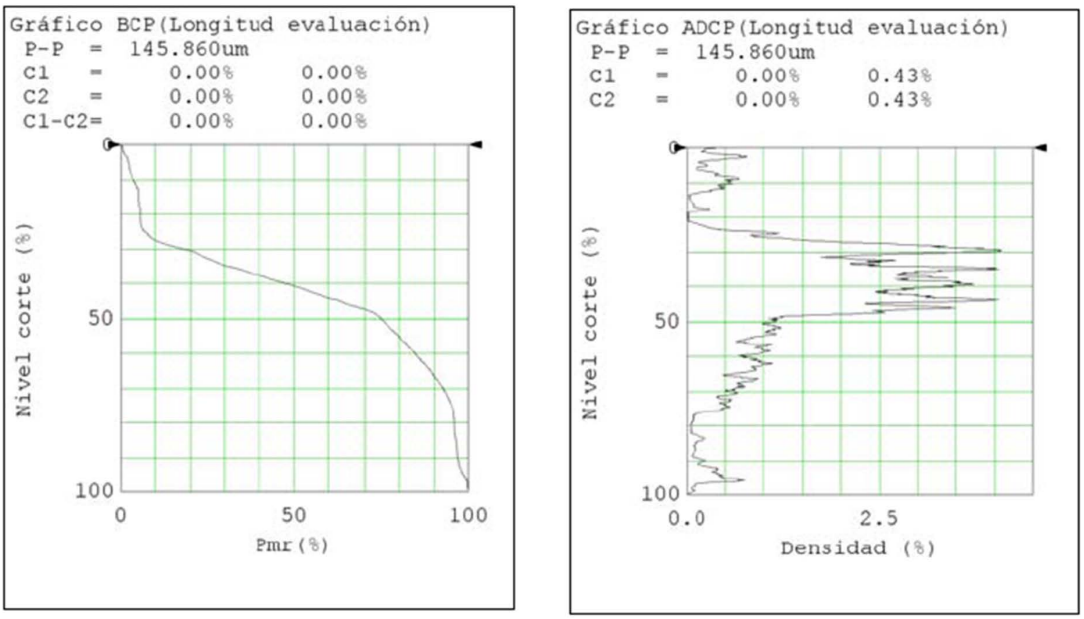

Figure A133. Material graphs along diagonal 1 after wear in sample 1M6.

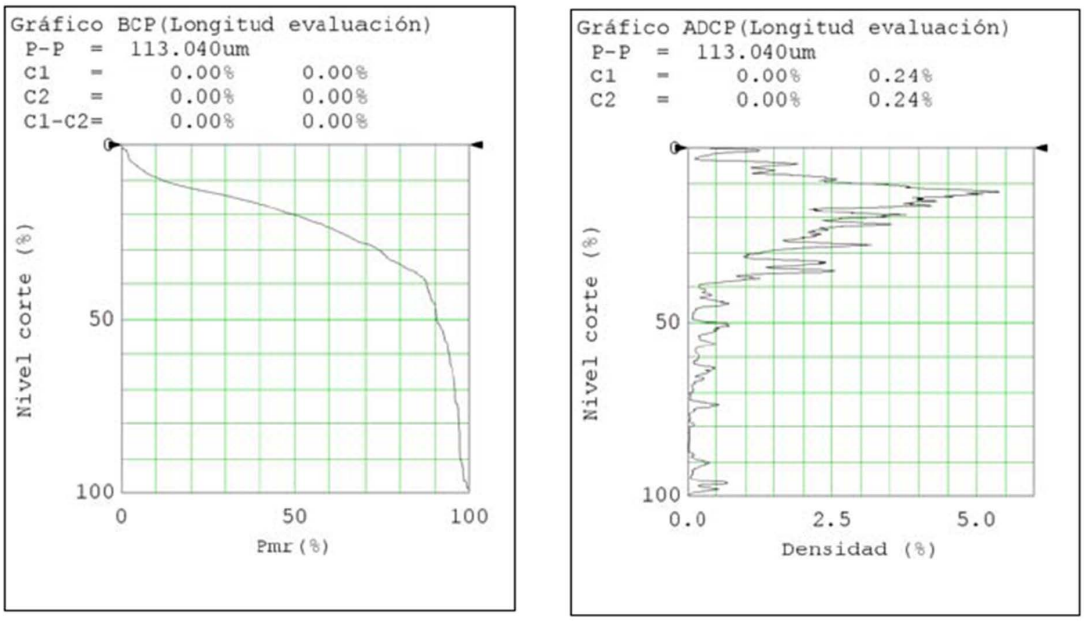

Figure A134. Material graphs along diagonal 2 after wear in sample 1M6.

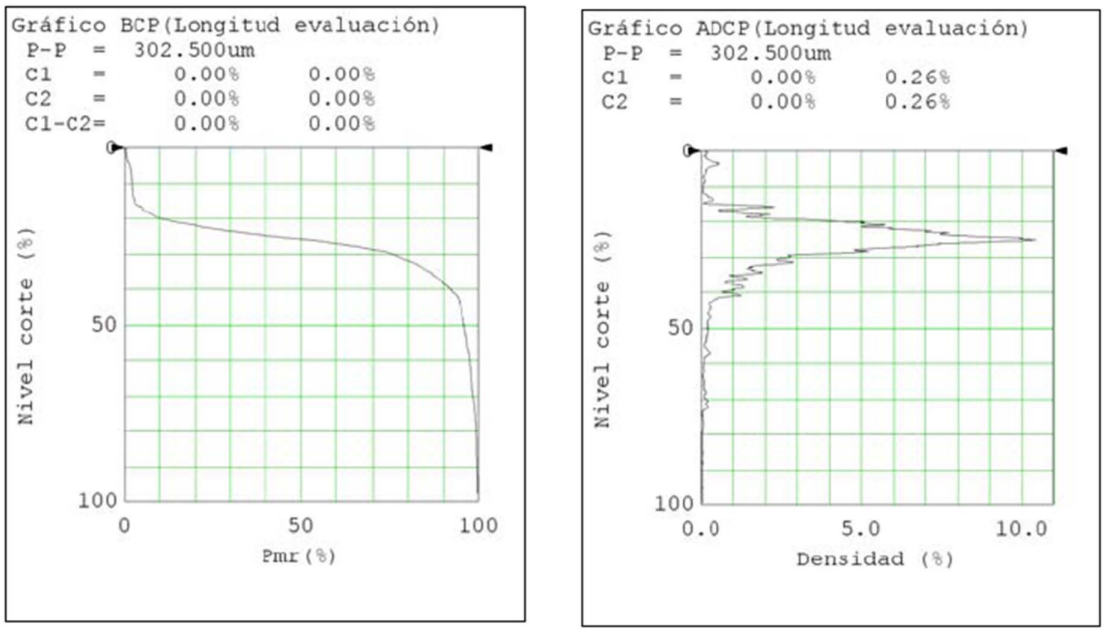

Figure A135. Material graphs along diagonal 3 after wear in sample 1M6.

Appendix B.4. Measurements After Wear in Sample 2M6

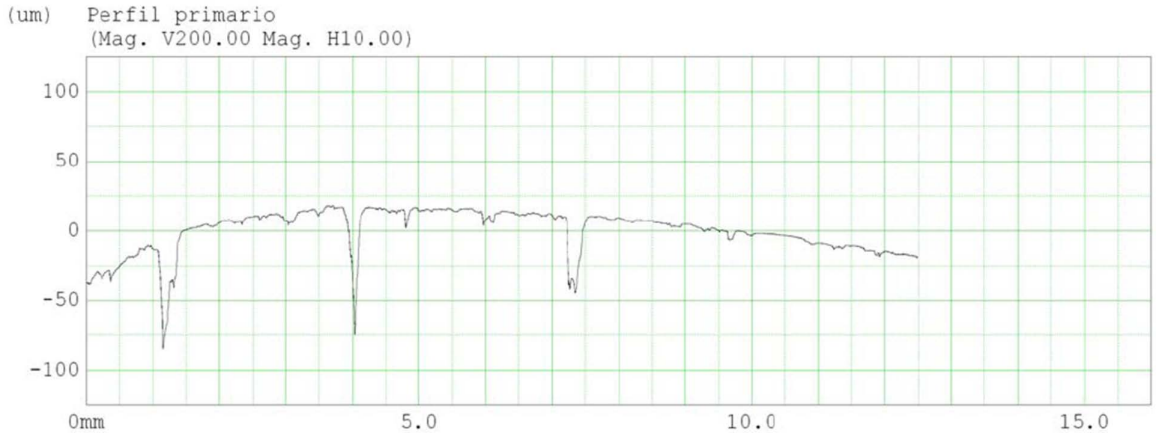

Figure A136. Primary profile; diagonal 1 after wear in sample 2M6.

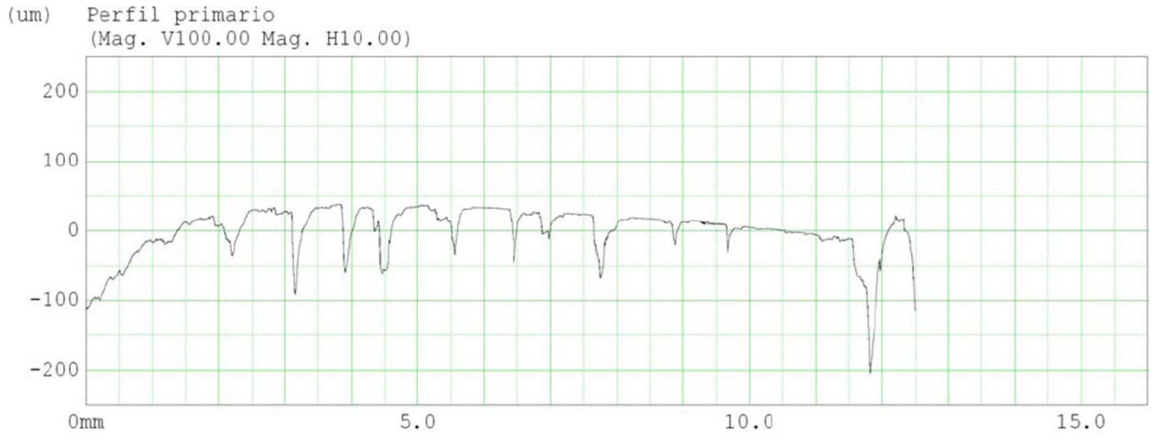

Figure A137. Primary profile; diagonal 2 after wear in sample 2M6.

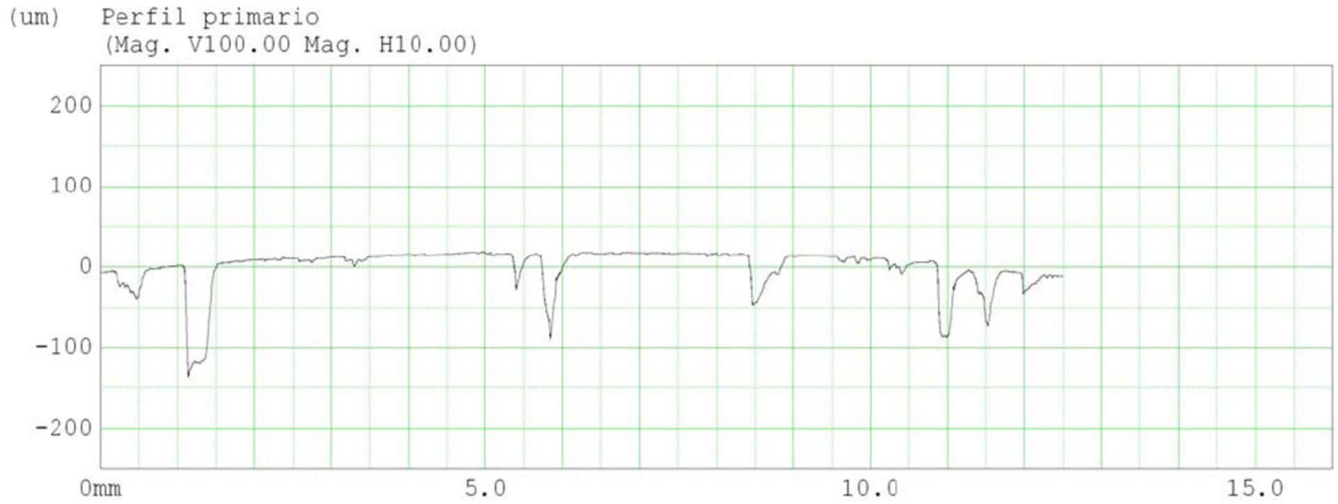

Figure A138. Primary profile; diagonal 3 after wear in sample 2M6.

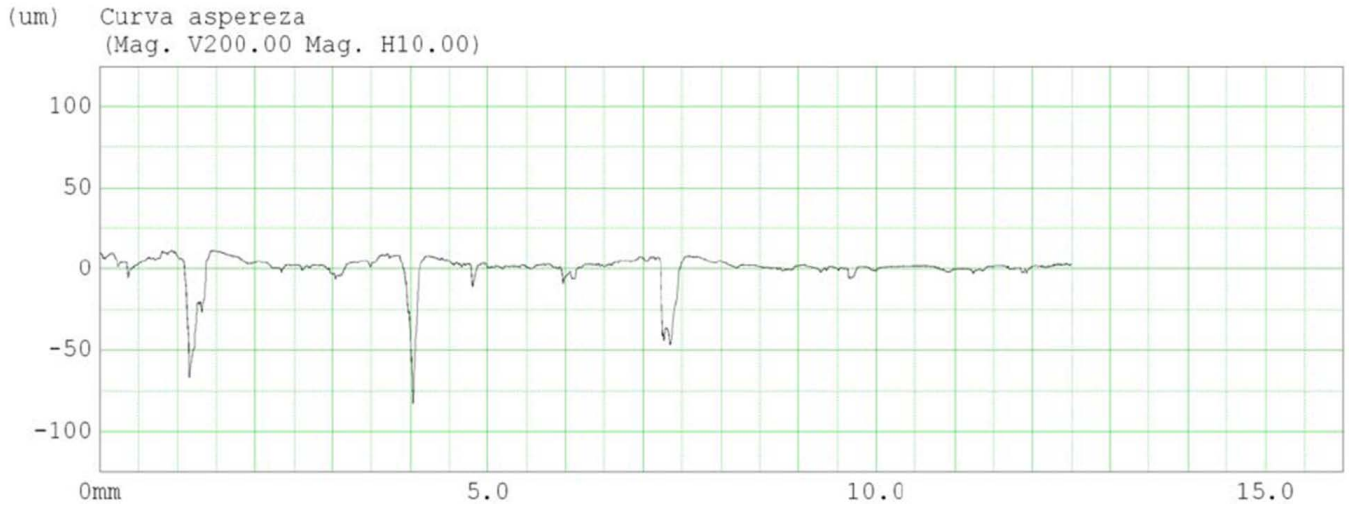

Figure A139. Roughness profile; diagonal 1 after wear in sample 2M6.

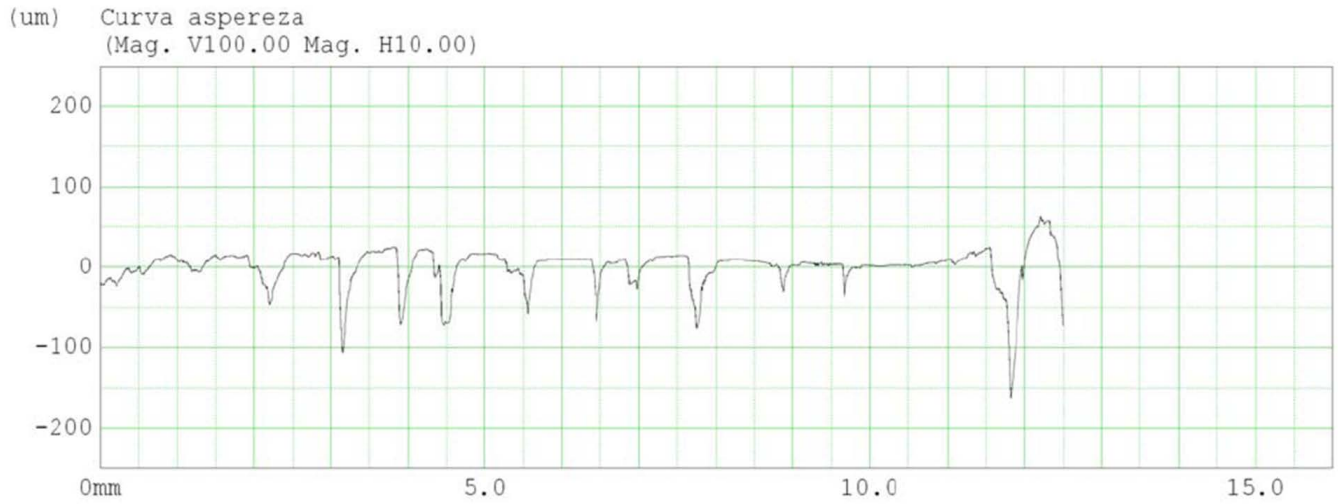

Figure A140. Roughness profile; diagonal 2 after wear in sample 2M6.

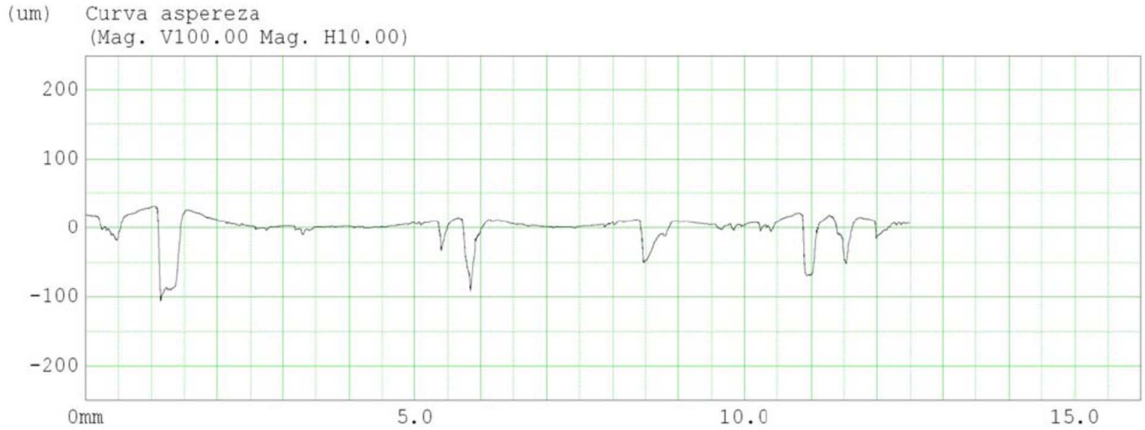

Figure A141. Roughness profile; diagonal 3 after wear in sample 2M6.

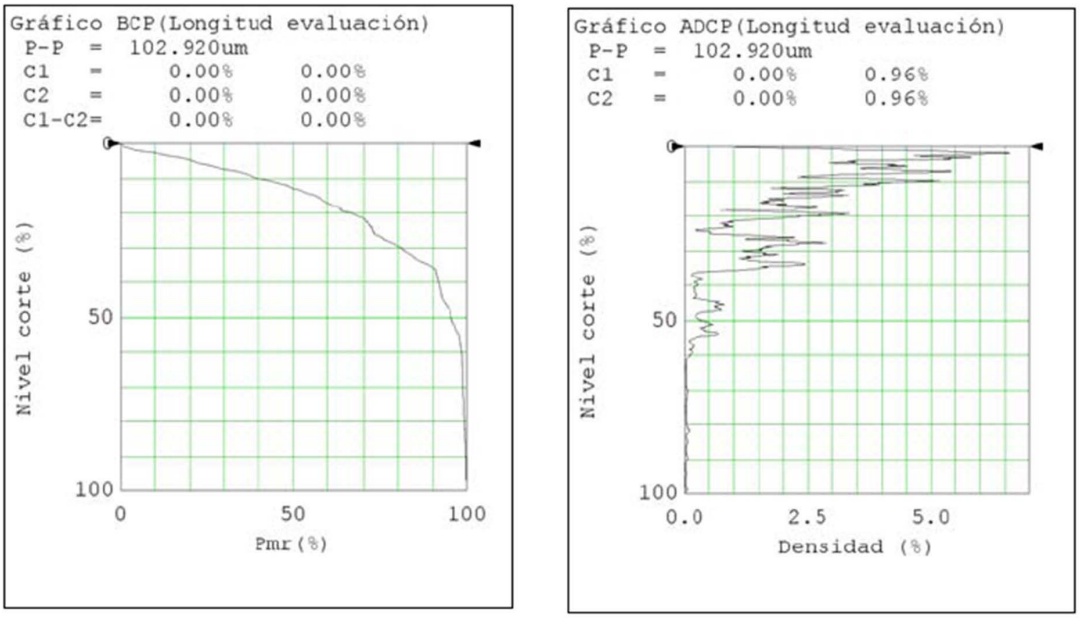

Figure A142. Material graphs along diagonal 1 after wear in sample 2M6.

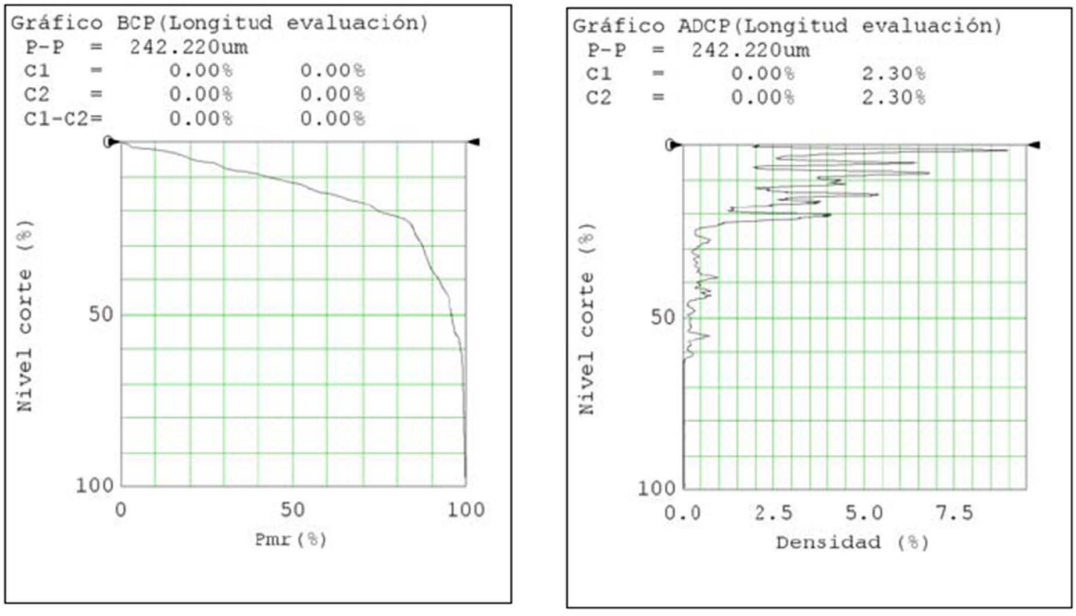

Figure A143. Material graphs along diagonal 2 after wear in sample 2M6.

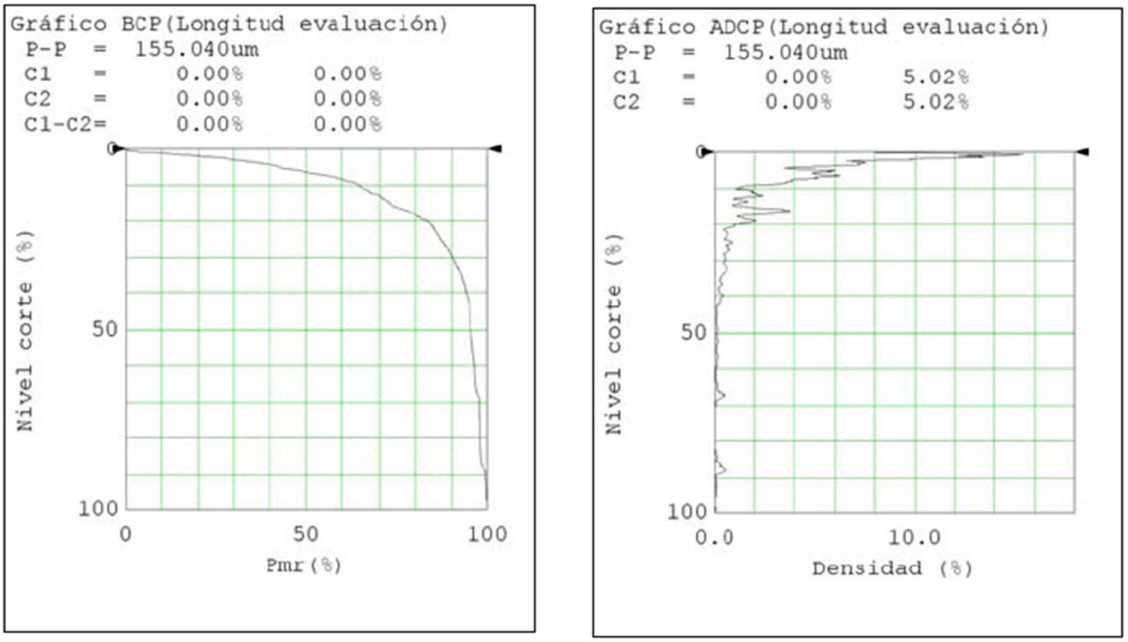

Figure A144. Material graphs along diagonal 3 after wear in sample 2M6.

Appendix B.5. Measurements After Wear in Sample 1M12

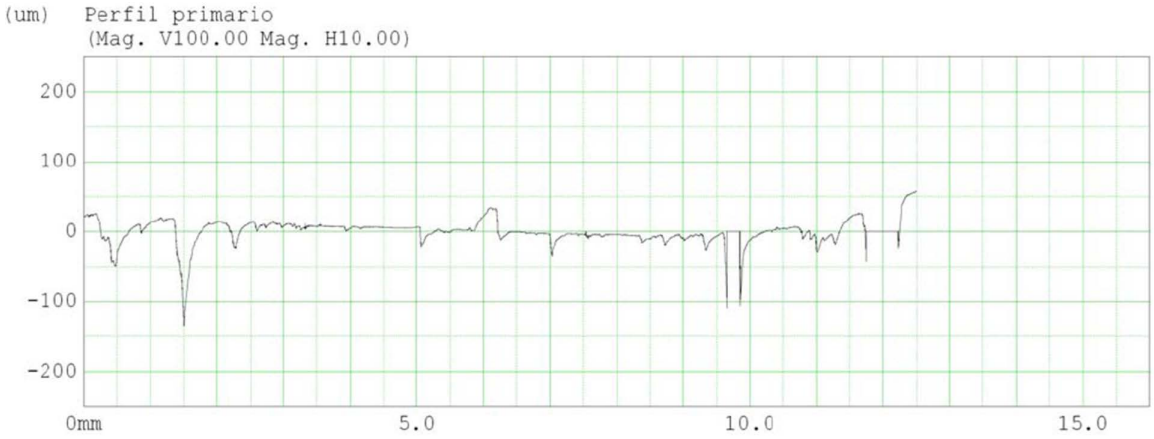

Figure A145. Primary profile; diagonal 1 after wear in sample 1M12.

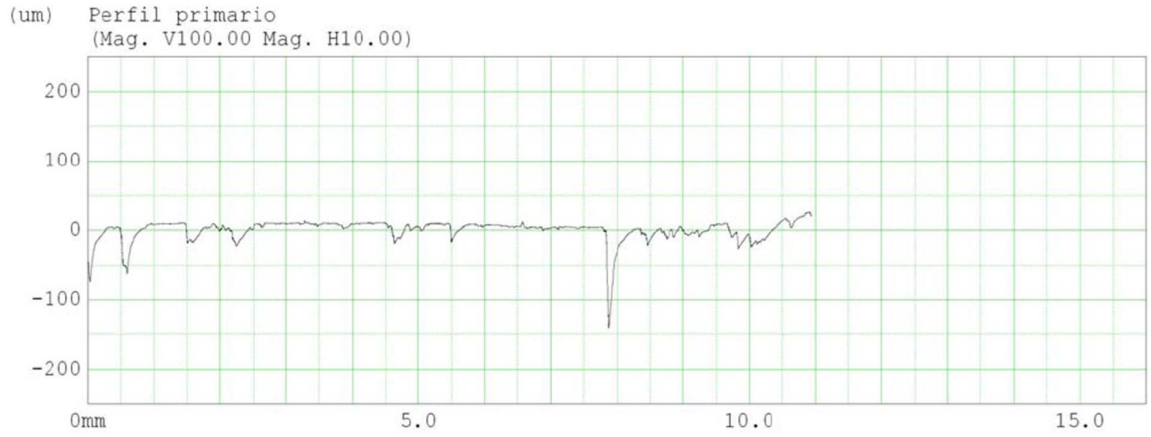

Figure A146. Primary profile; diagonal 2 after wear in sample 1M12.

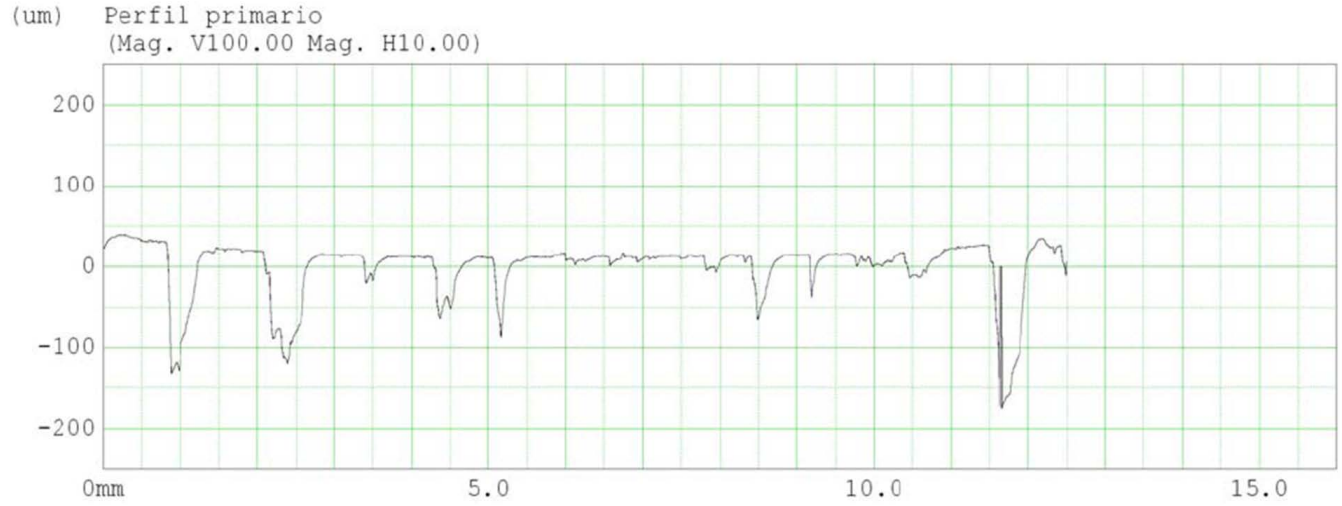

Figure A147. Primary profile; diagonal 3 after wear in sample 1M12.

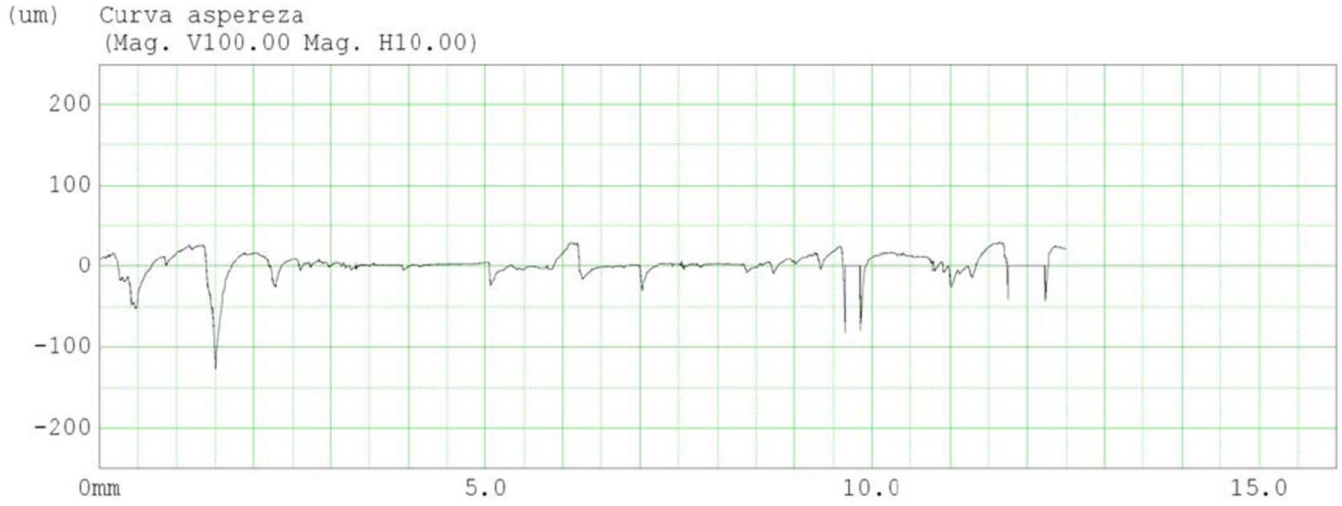

Figure A148. Roughness profile; diagonal 1 after wear in sample 1M12.

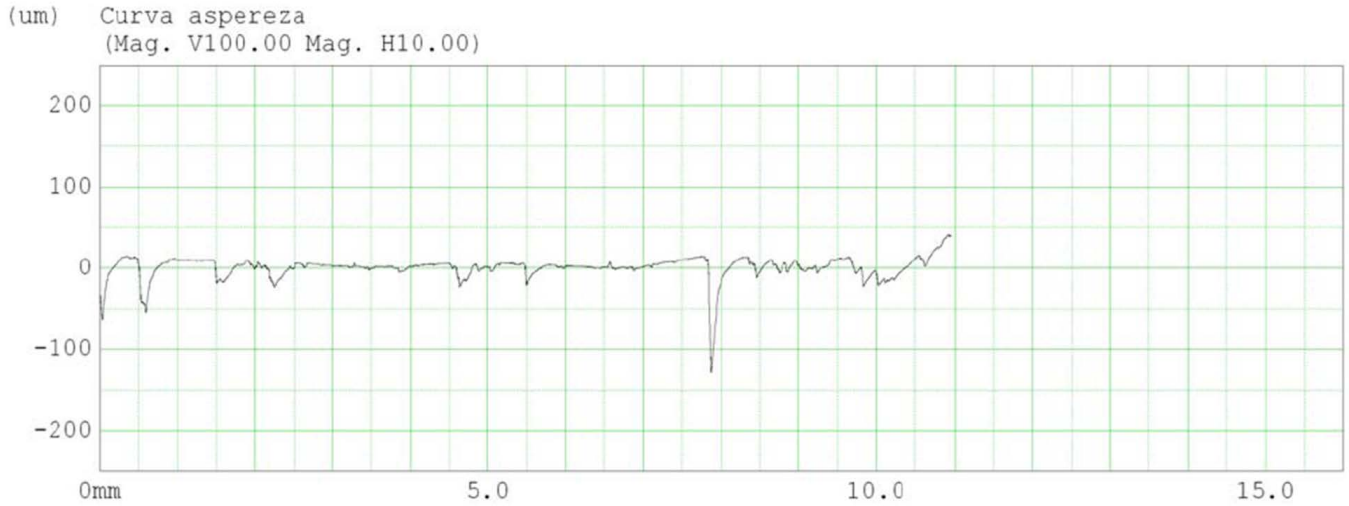

Figure A149. Roughness profile; diagonal 2 after wear in sample 1M12.

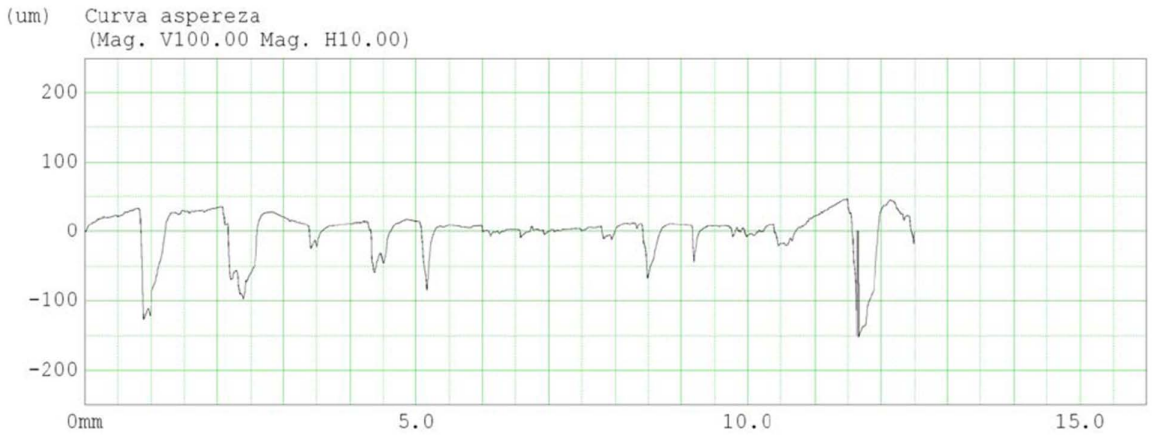

Figure A150. Roughness profile; diagonal 3 after wear in sample 1M12.

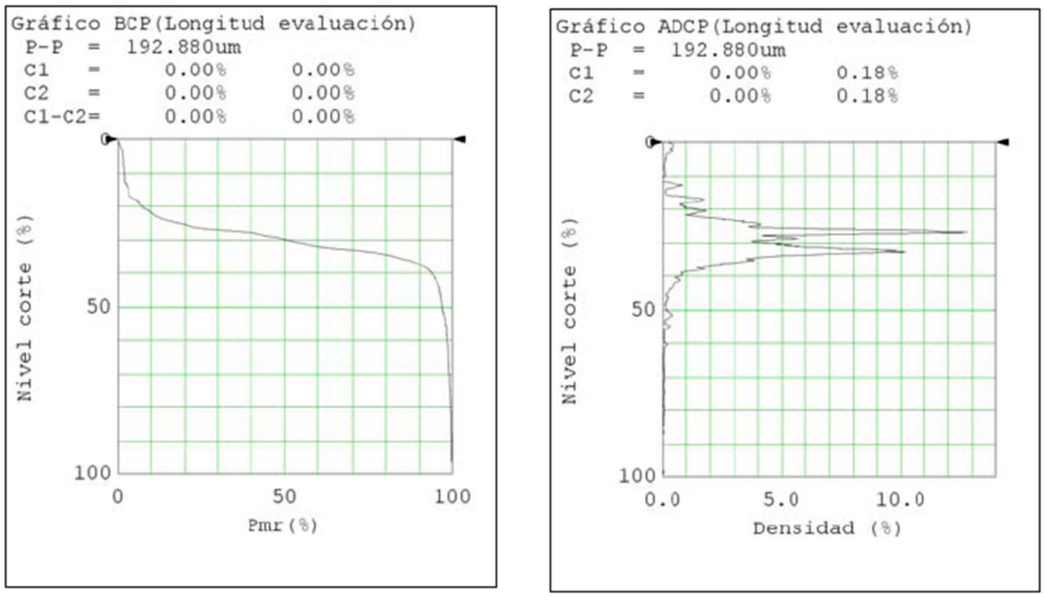

Figure A151. Material graphs along diagonal 1 after wear in sample 1M12.

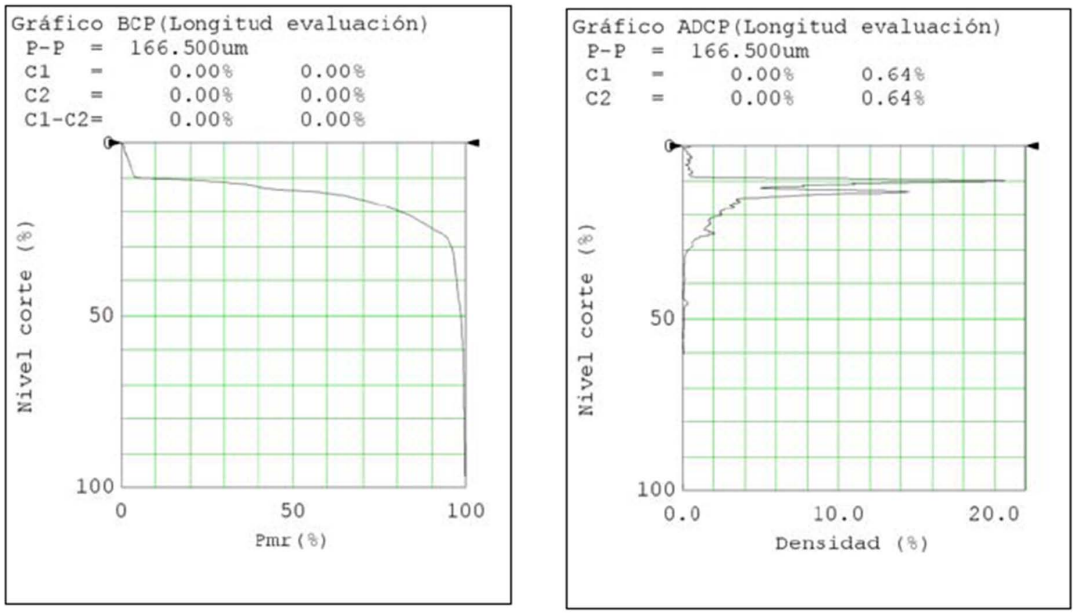

Figure A152. Material graphs along diagonal 2 after wear in sample 1M12.

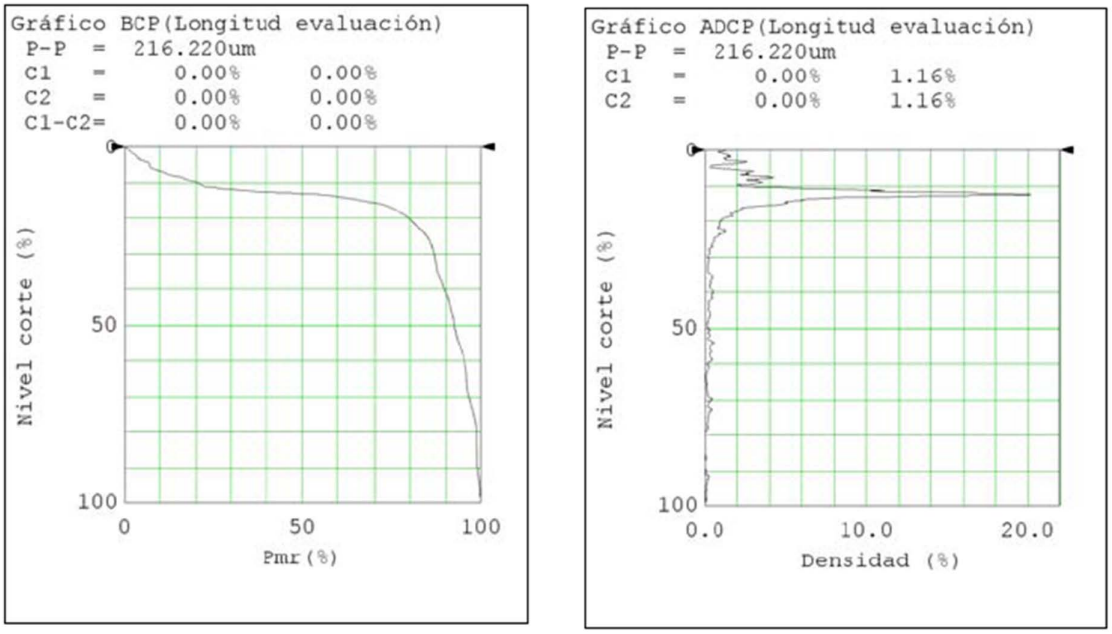

Figure A153. Material graphs along diagonal 3 after wear in sample 1M12.

Appendix B.6. Measurements After Wear in Sample 3M12

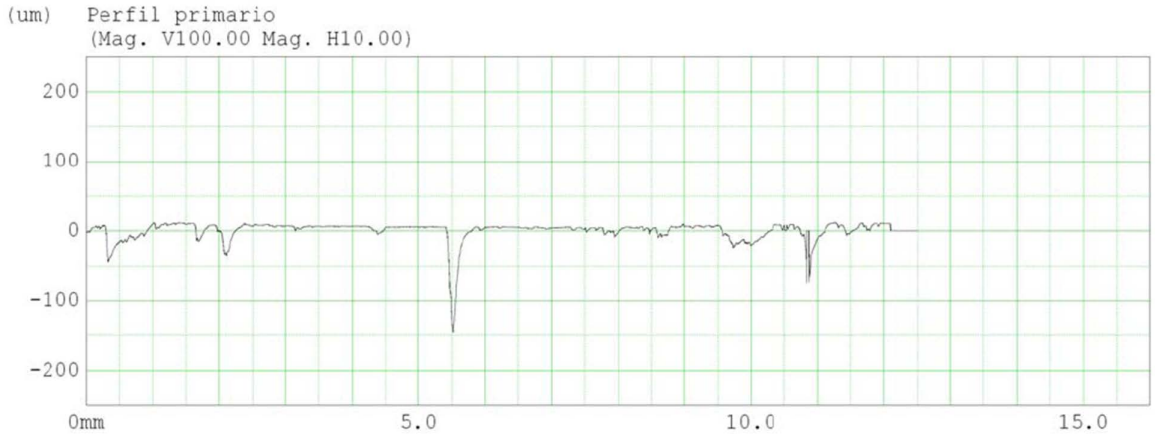

Figure A154. Primary profile; diagonal 1 after wear in sample 3M12.

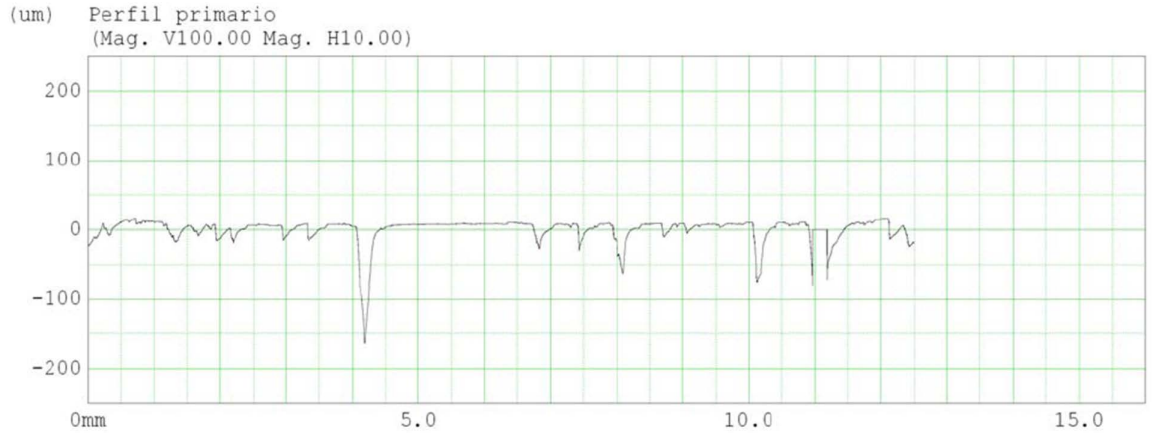

Figure A155. Primary profile; diagonal 2 after wear in sample 3M12.

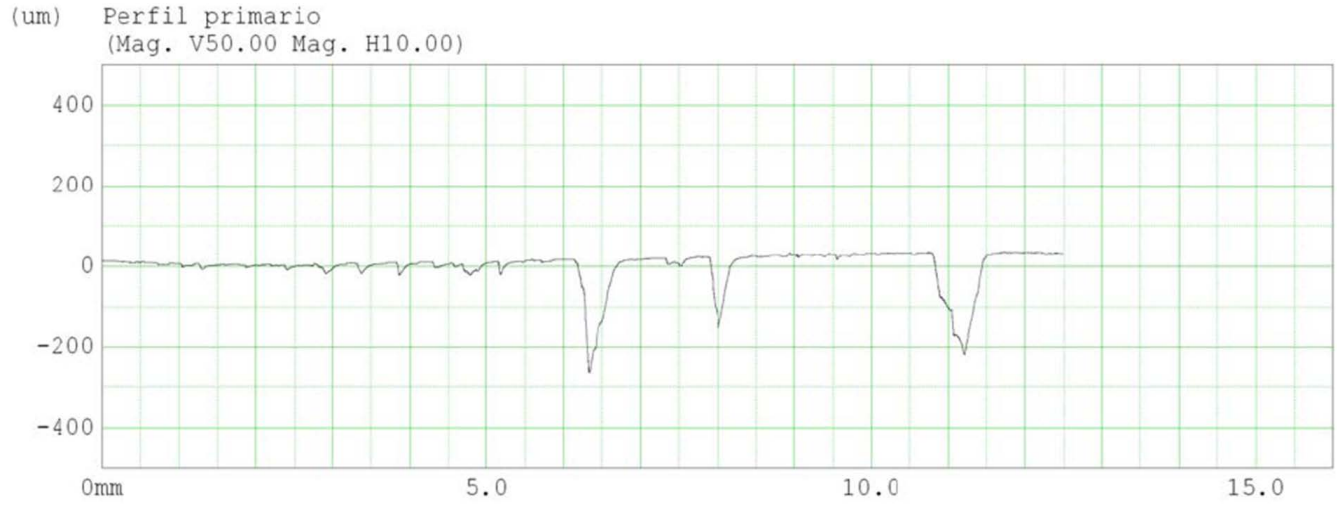

Figure A156. Primary profile; diagonal 3 after wear in sample 3M12.

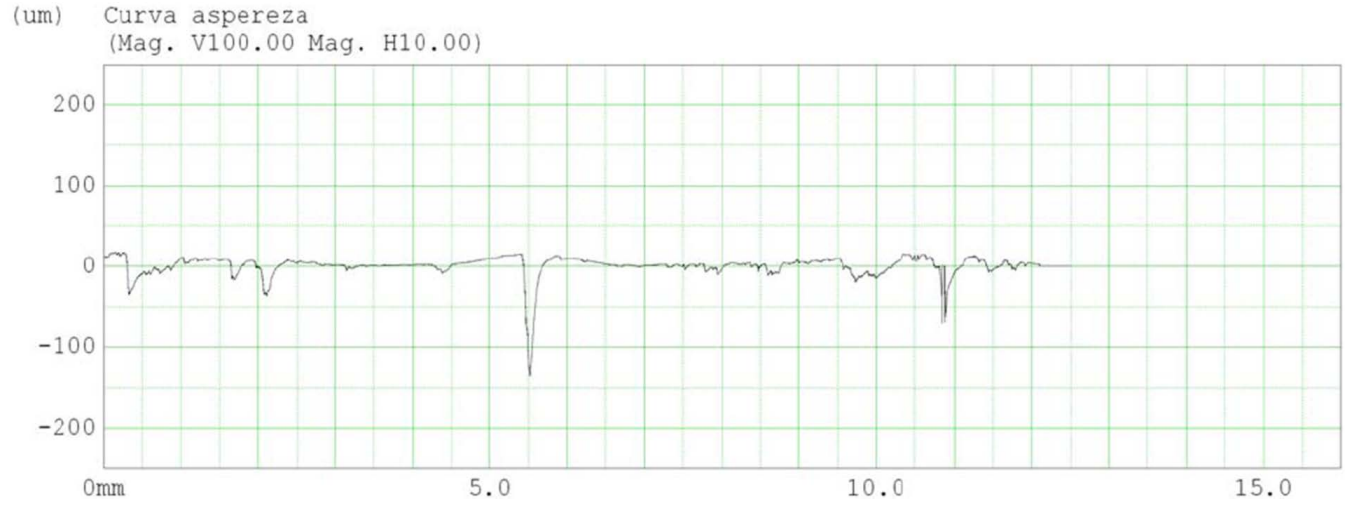

Figure A157. Roughness profile; diagonal 1 after wear in sample 3M12.

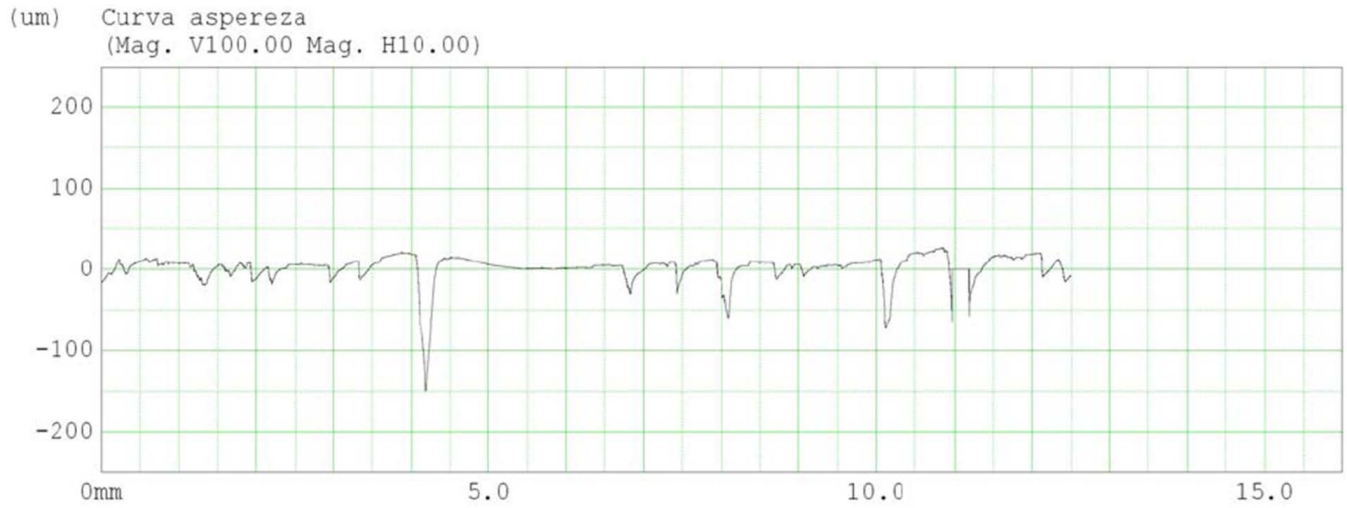

Figure A158. Roughness profile; diagonal 2 after wear in sample 3M12.

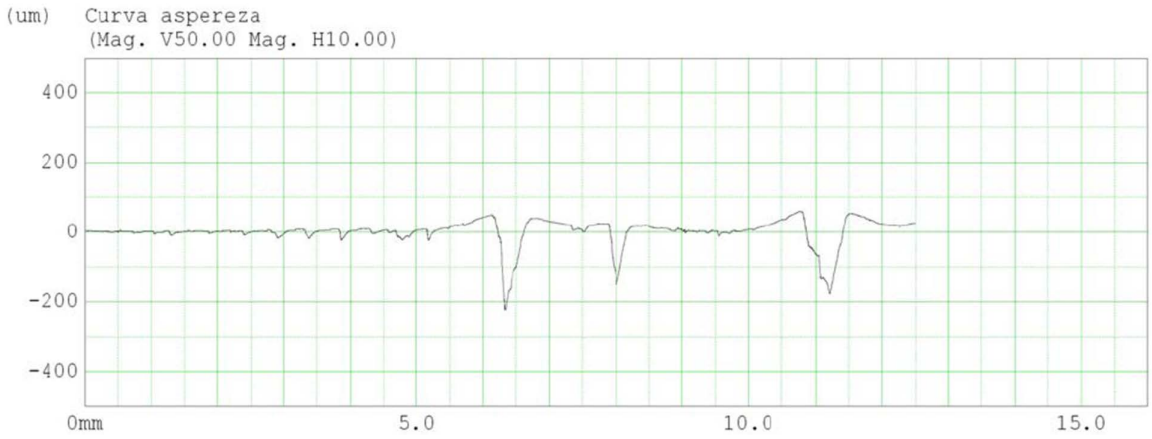

Figure A159. Roughness profile; diagonal 3 after wear in sample 3M12.

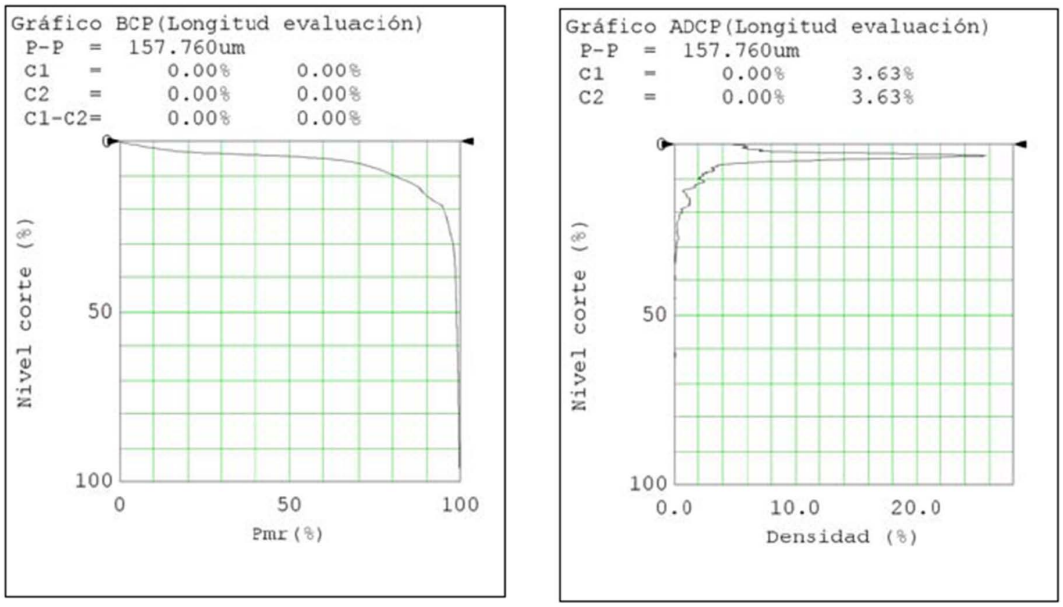

Figure A160. Material graphs along diagonal 1 after wear in sample 3M12.

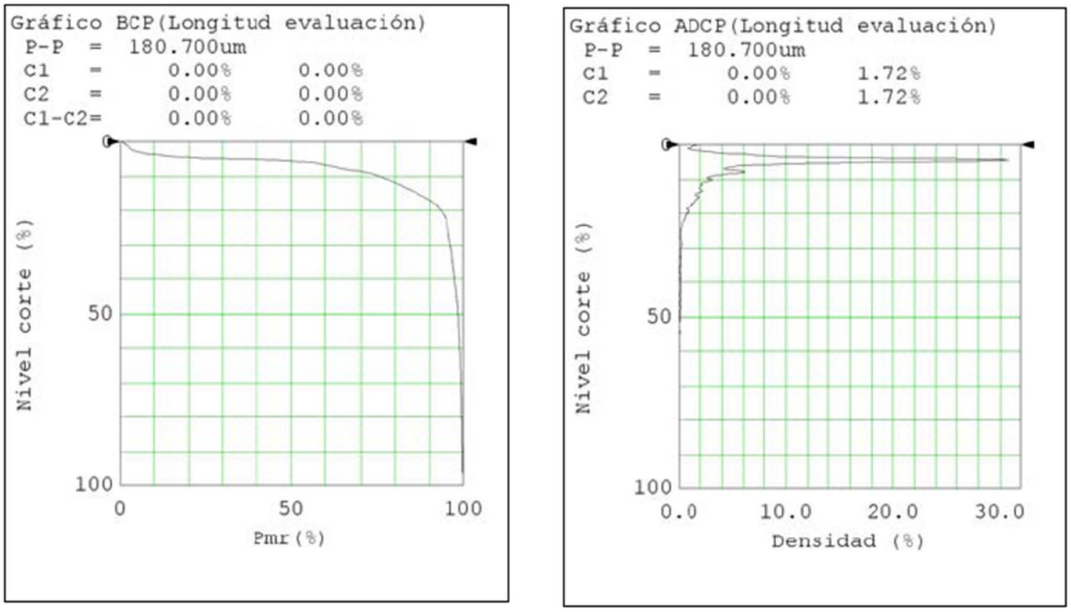

Figure A161. Material graphs along diagonal 2 after wear in sample 3M12.

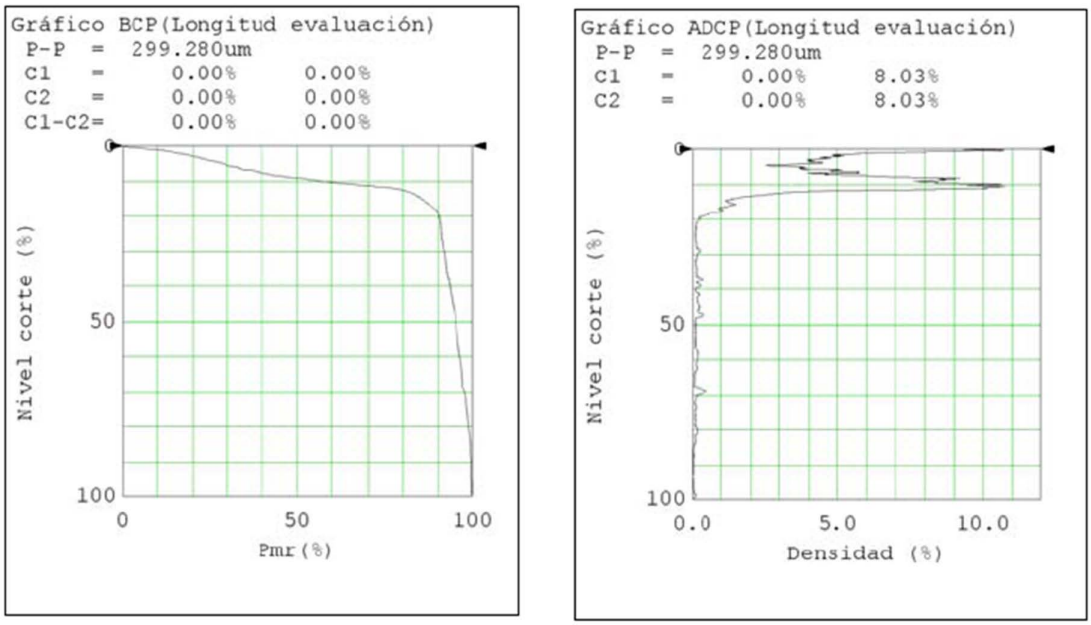

Figure A162. Material graphs along diagonal 3 after wear in sample 3M12.

Appendix B.7. Measurements After Friction in Sample 1N6

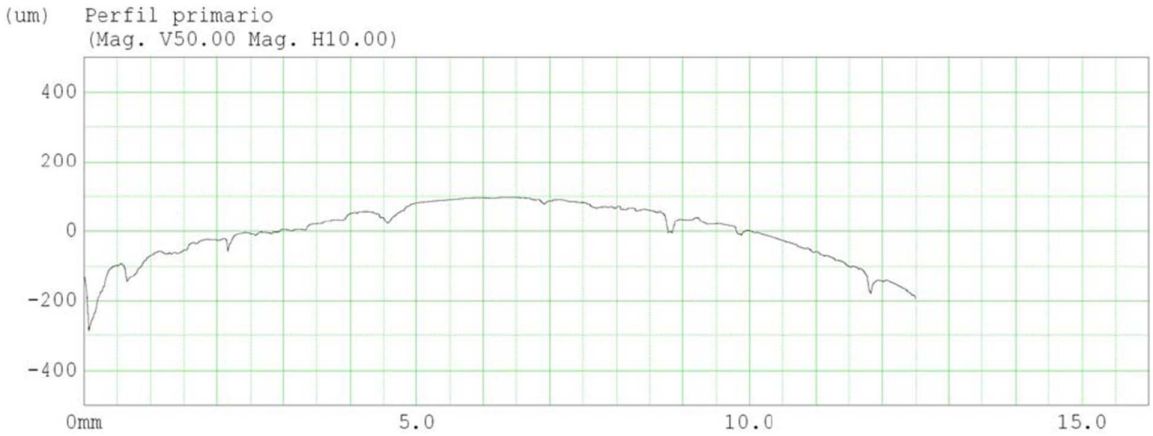

Figure A163. Primary profile; diagonal 1 after wear in sample 1N6.

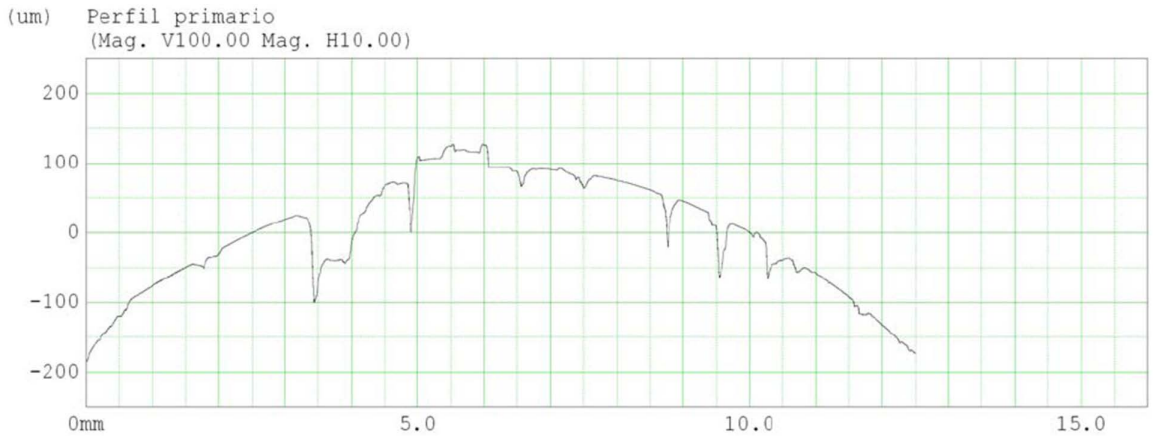

Figure A164. Primary profile; diagonal 2 after wear in sample 1N6.

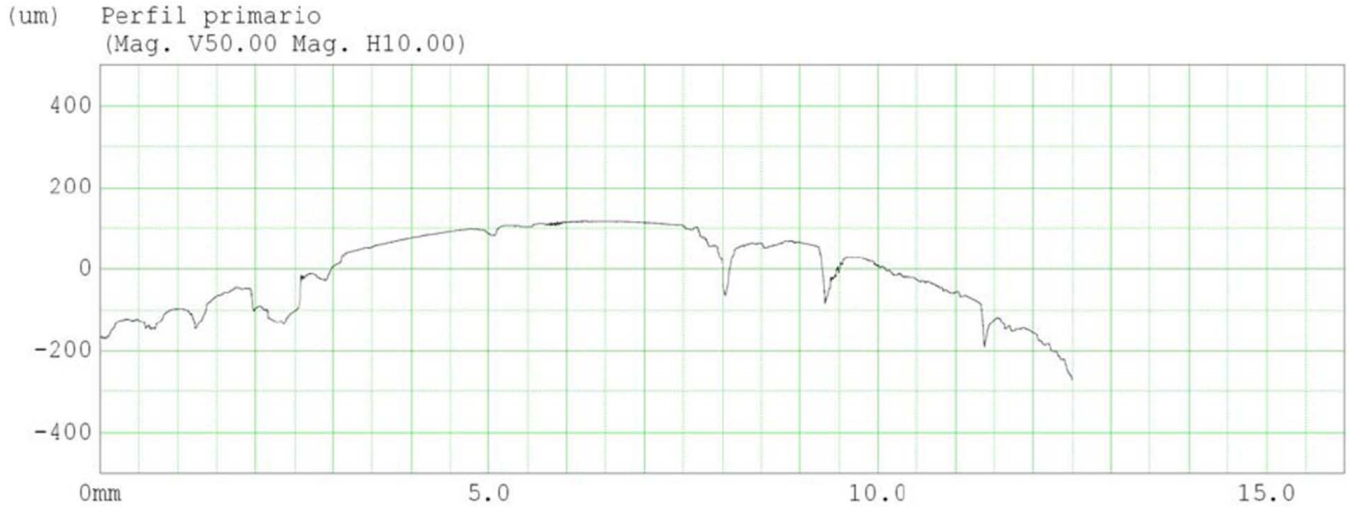

Figure A165. Primary profile; diagonal 3 after wear in sample 1N6.

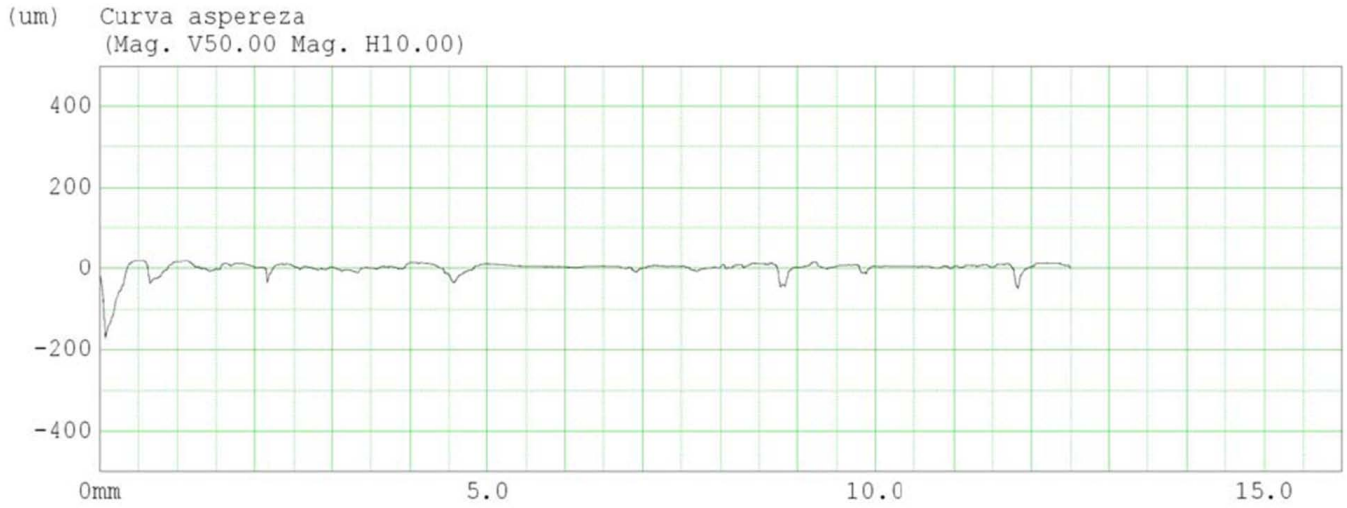

Figure A166. Roughness profile; diagonal 1 after wear in sample 1N6.

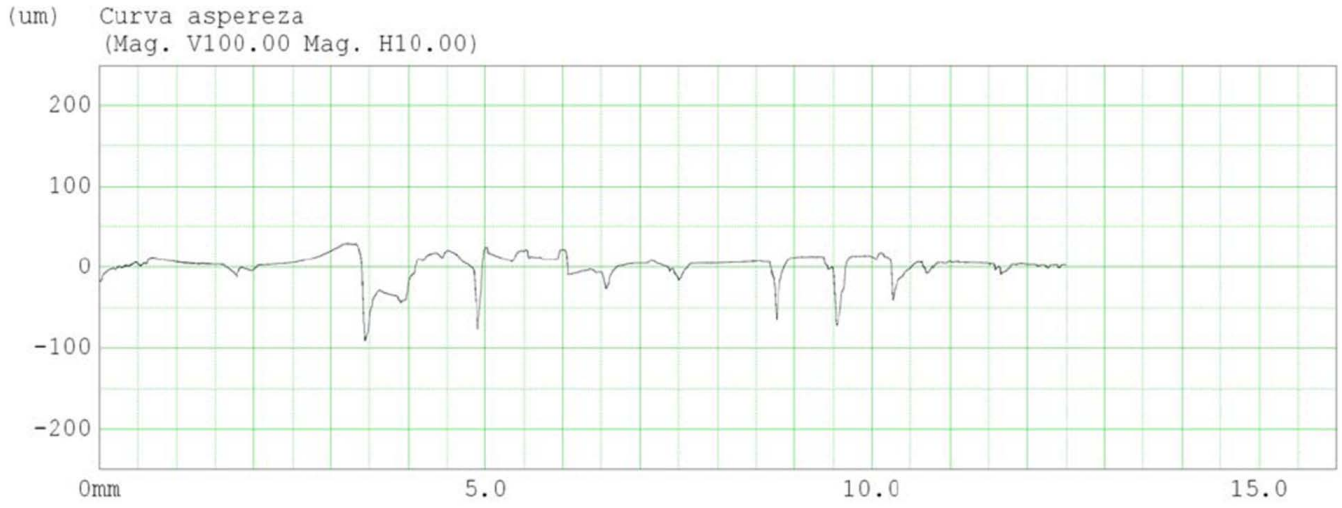

Figure A167. Roughness profile; diagonal 2 after wear in sample 1N6.

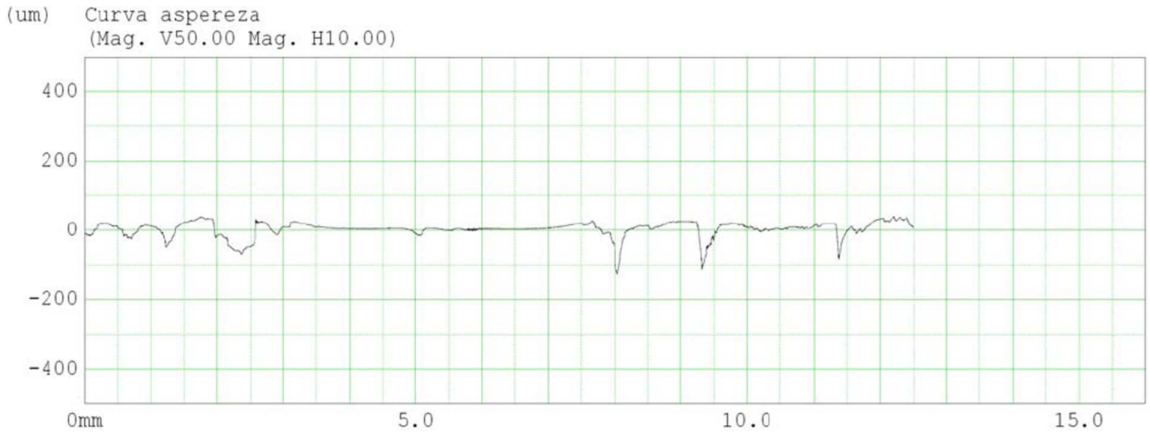

Figure A168. Roughness profile; diagonal 3 after wear in sample 1N6.

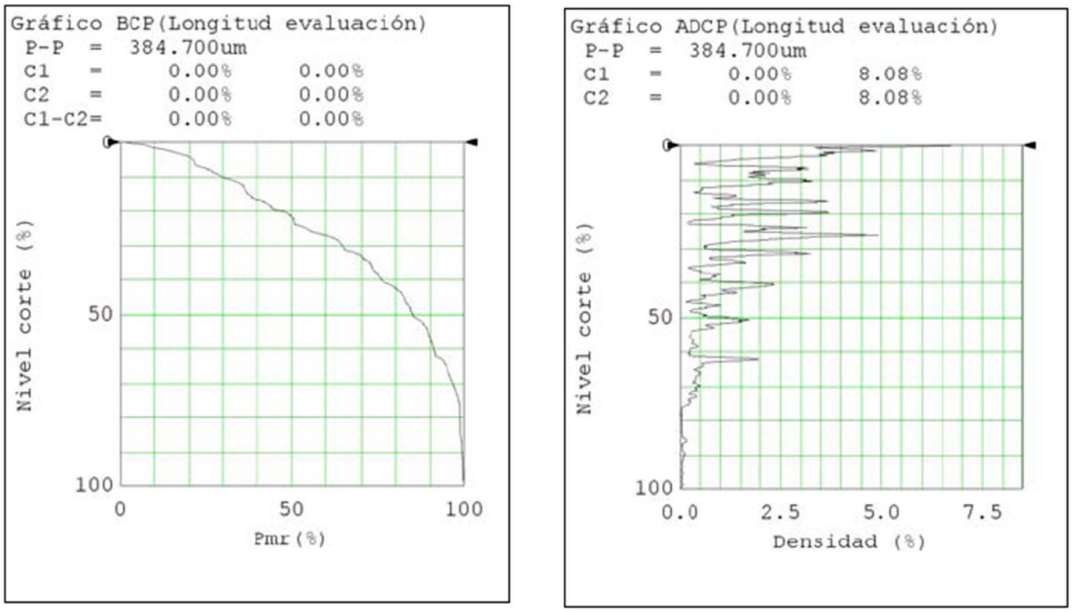

Figure A169. Material graphs along diagonal 1 after wear in sample 1N6.

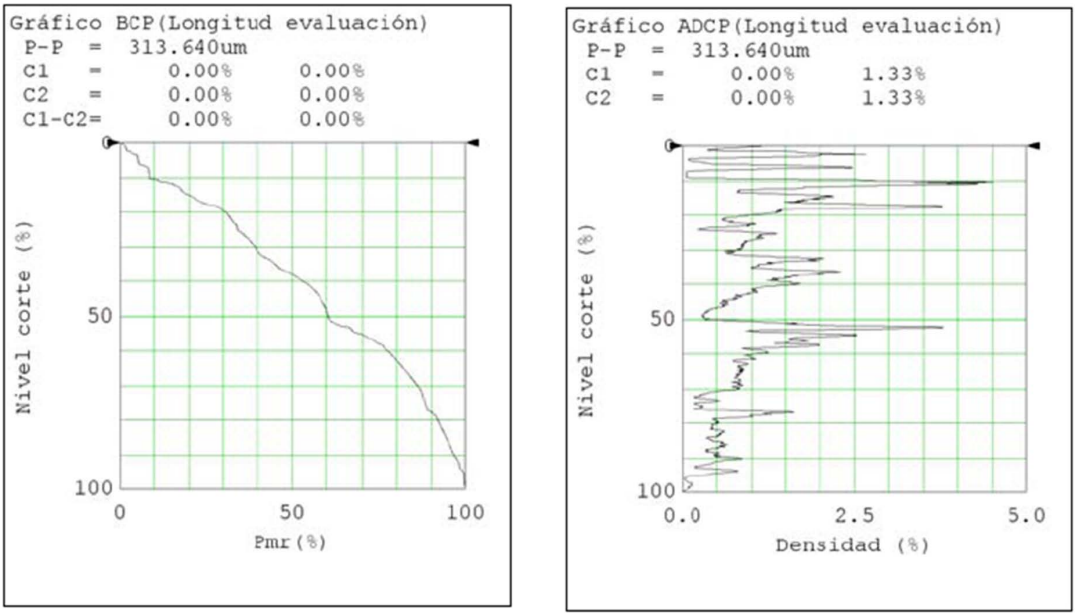

Figure A170. Material graphs along diagonal 2 after wear in sample 1N6.

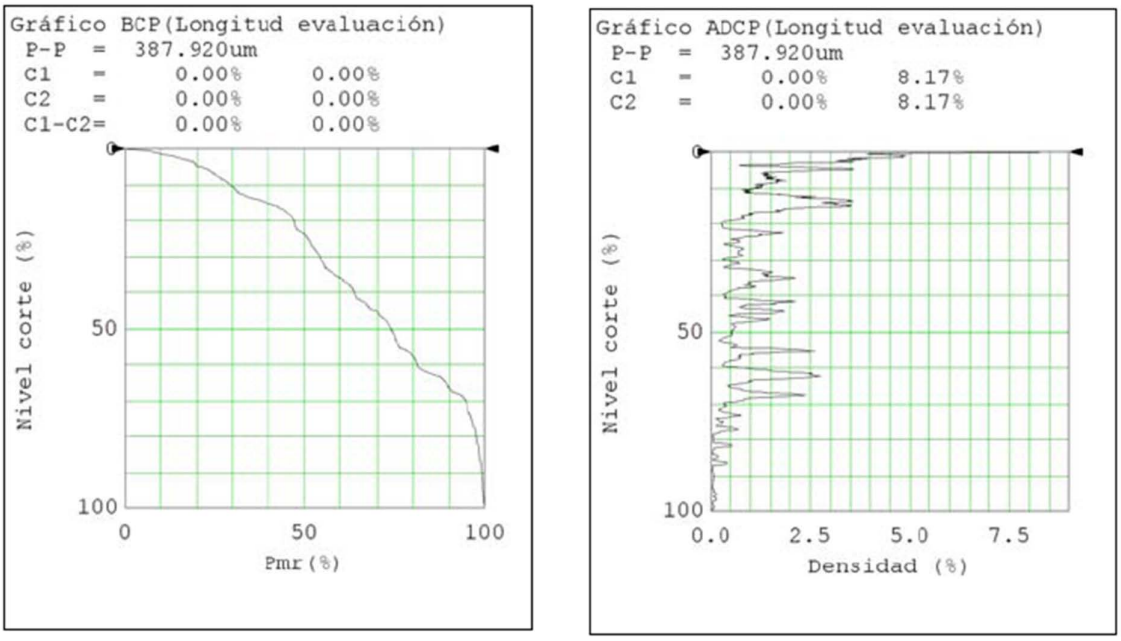

Figure A171. Material graphs along diagonal 3 after wear in sample 1N6.

Appendix B.8. Measurements After Friction in Sample 3N6

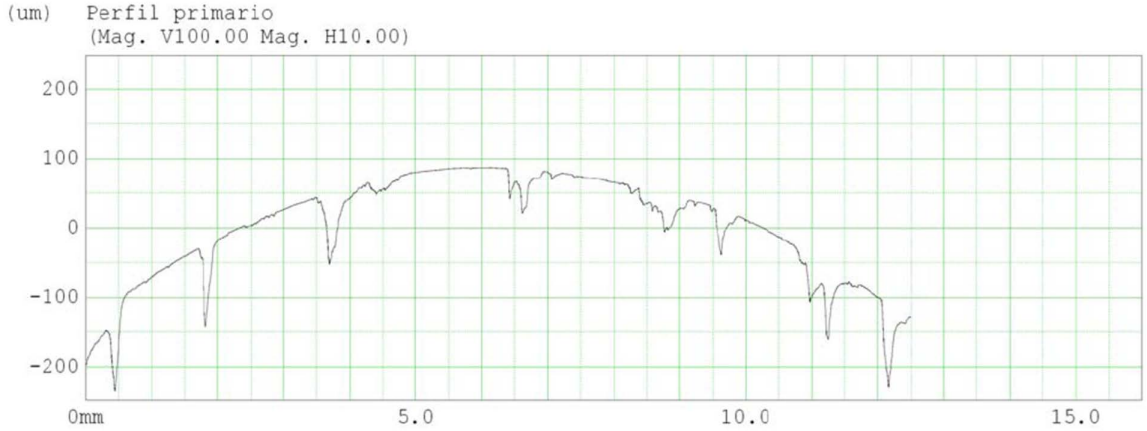

Figure A172. Primary profile; diagonal 1 after wear in sample 3N6.

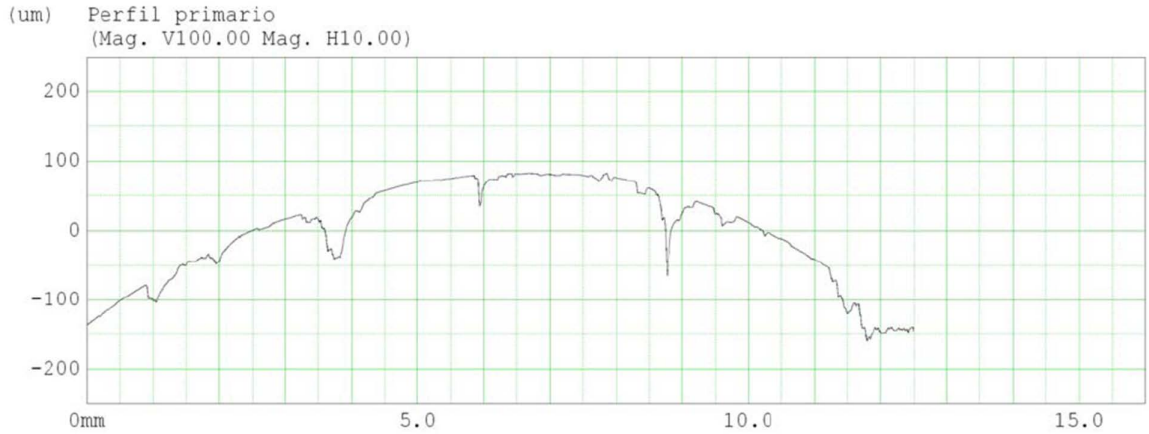

Figure A173. Primary profile; diagonal 2 after wear in sample 3N6.

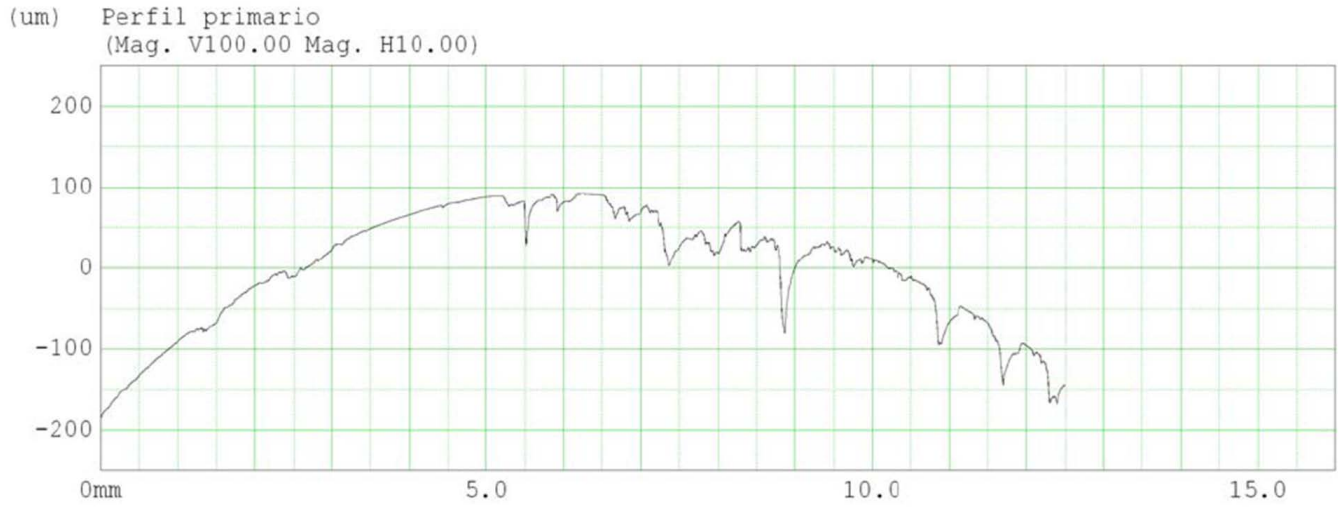

Figure A174. Primary profile; diagonal 3 after wear in sample 3N6.

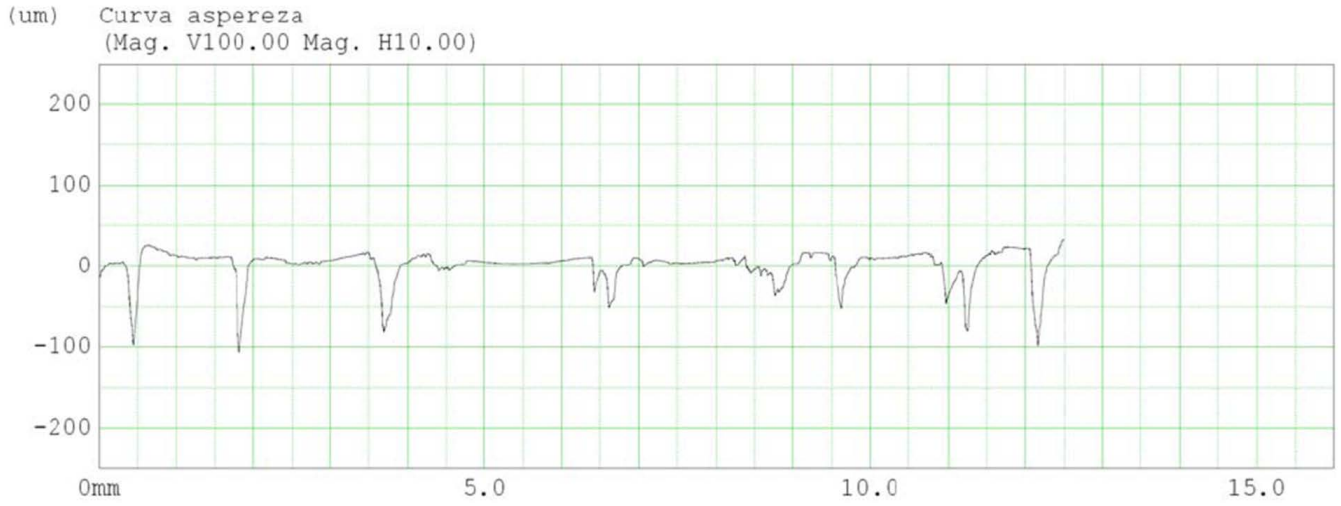

Figure A175. Roughness profile; diagonal 1 after wear in sample 3N6.

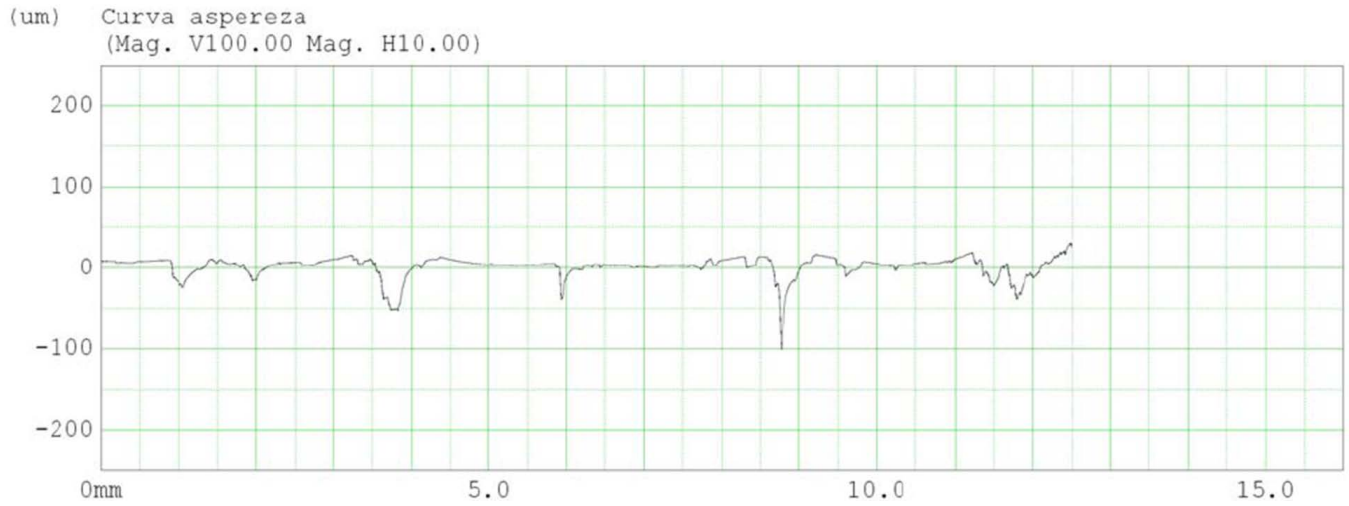

Figure A176. Roughness profile; diagonal 2 after wear in sample 3N6.

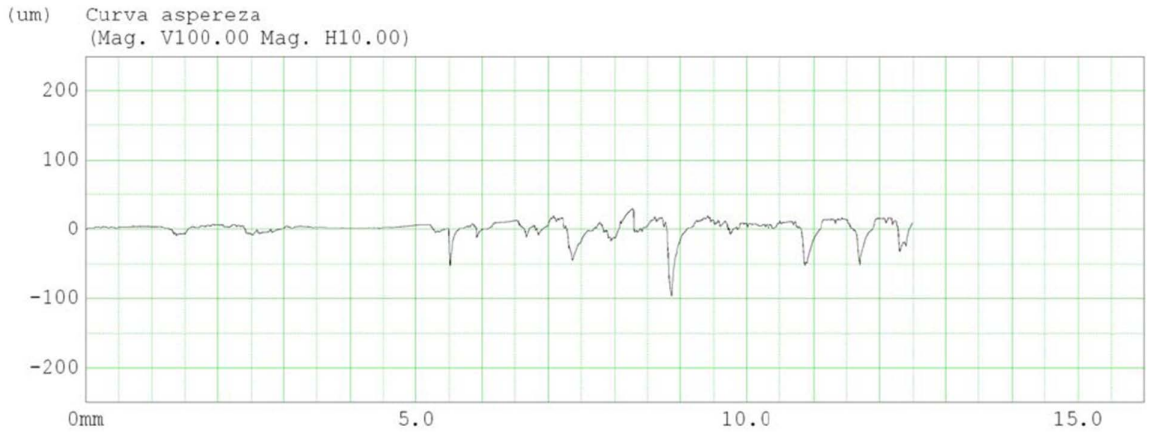

Figure A177. Roughness profile; diagonal 3 after wear in sample 3N6.

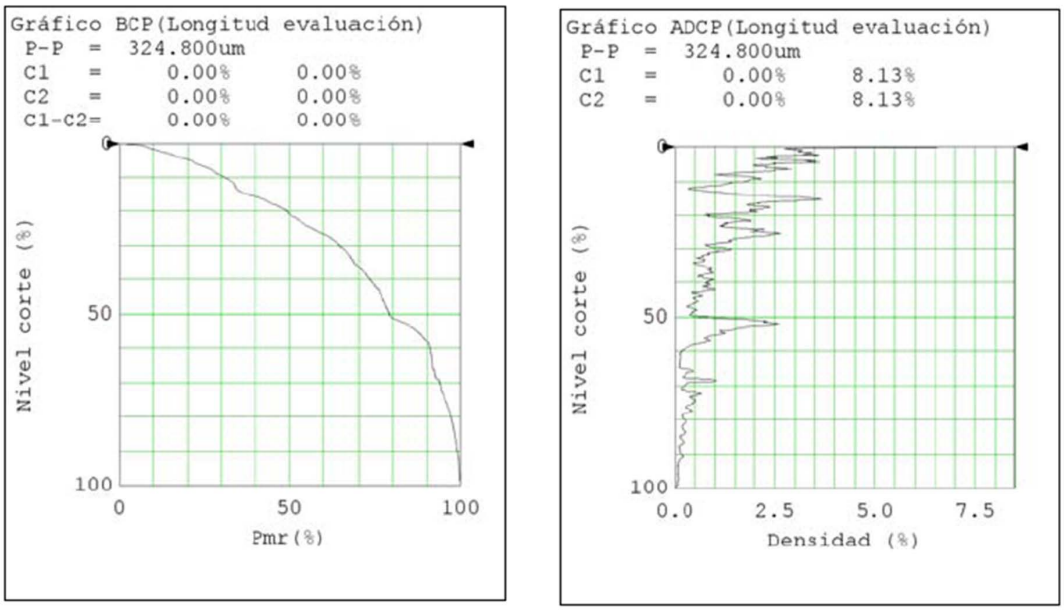

Figure A178. Material graphs along diagonal 1 after wear in sample 3N6.

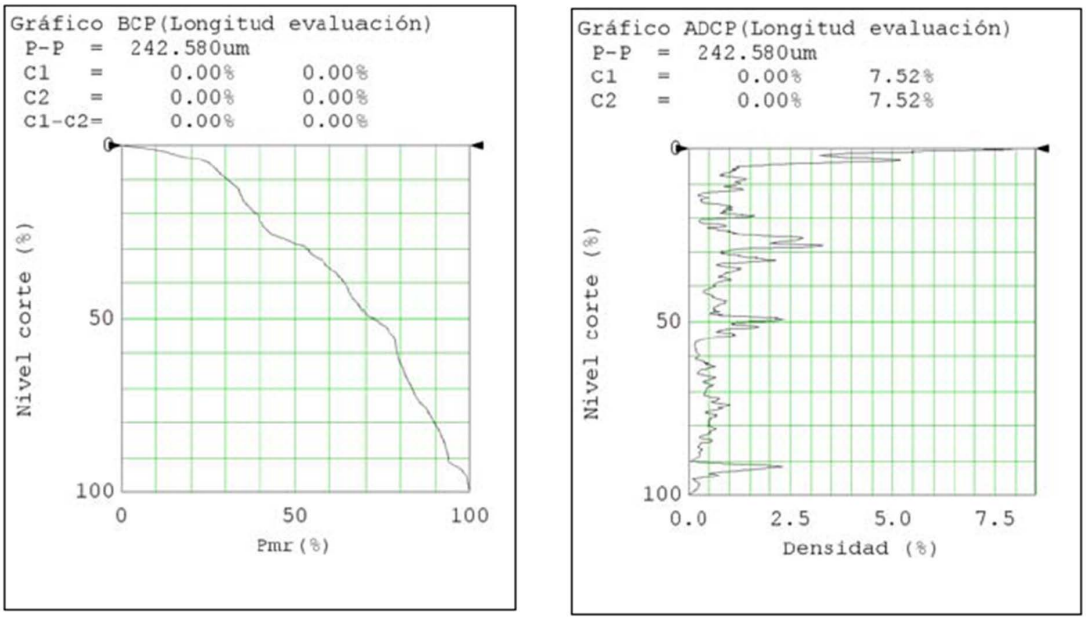

Figure A179. Material graphs along diagonal 2 after wear in sample 3N6.

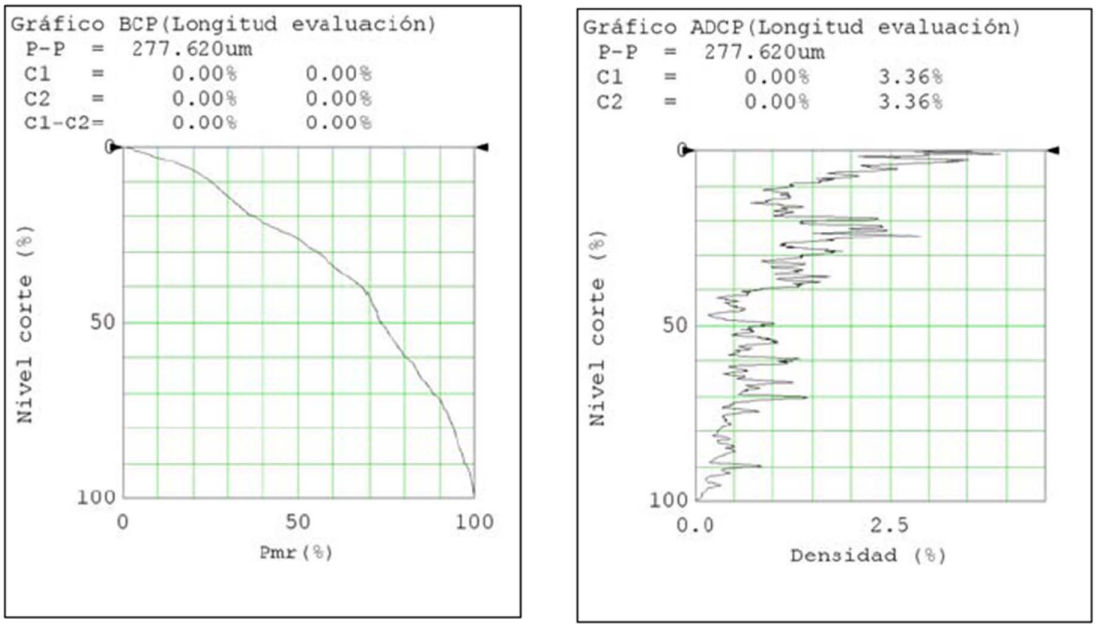

Figure A180. Material graphs along diagonal 3 after wear in sample 3N6.

Appendix B.9. Measurements After Friction in Sample 1N12

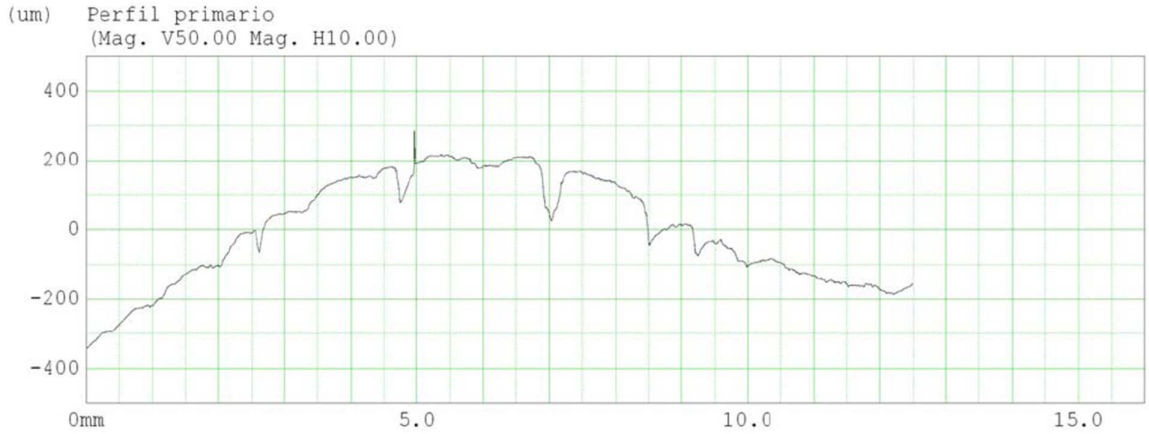

Figure A181. Primary profile; diagonal 1 after wear in sample 1N12.

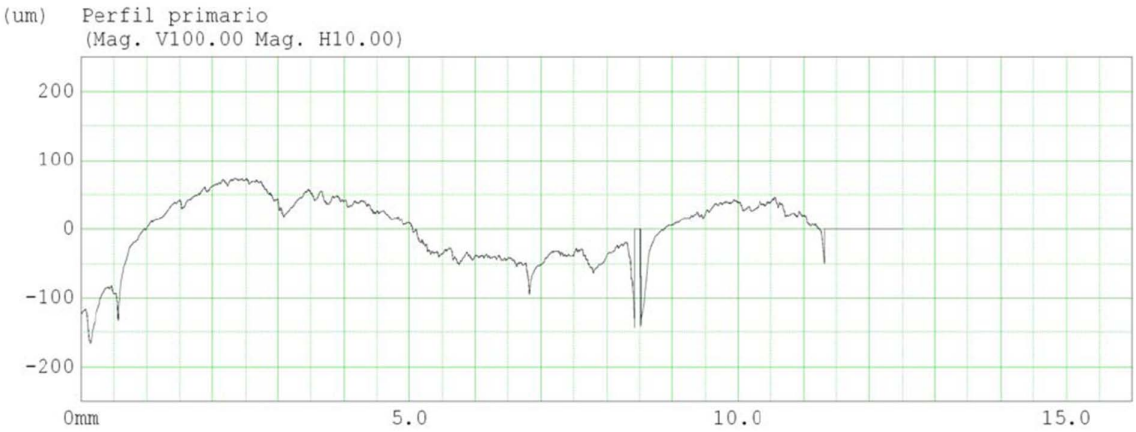

Figure A182. Primary profile; diagonal 2 after wear in sample 1N12.

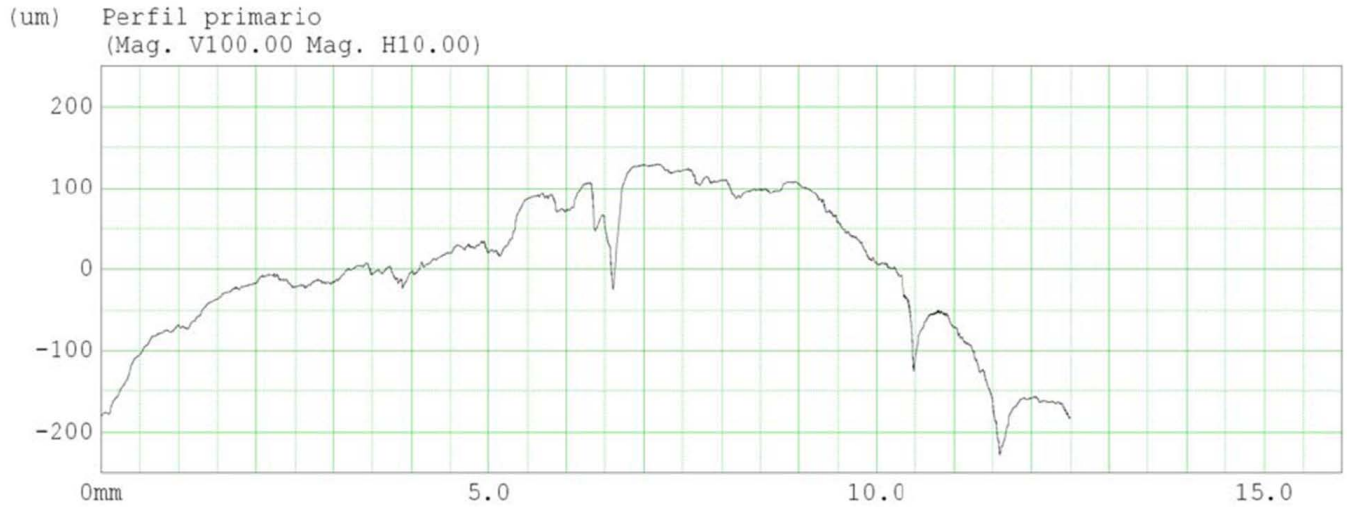

Figure A183. Primary profile; diagonal 3 after wear in sample 1N12.

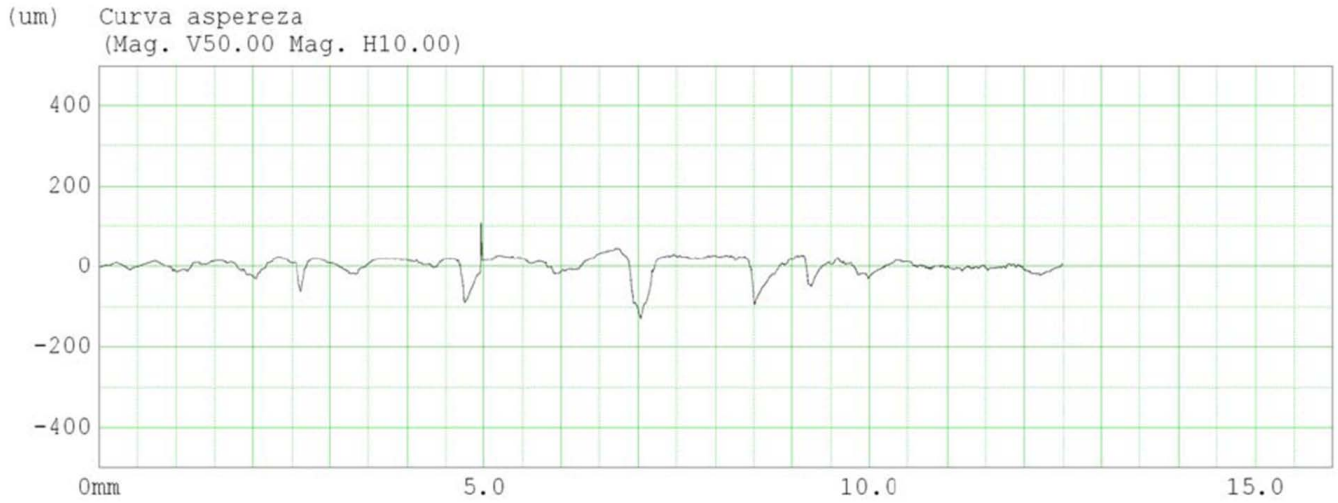

Figure A184. Roughness profile; diagonal 1 after wear in sample 1N12.

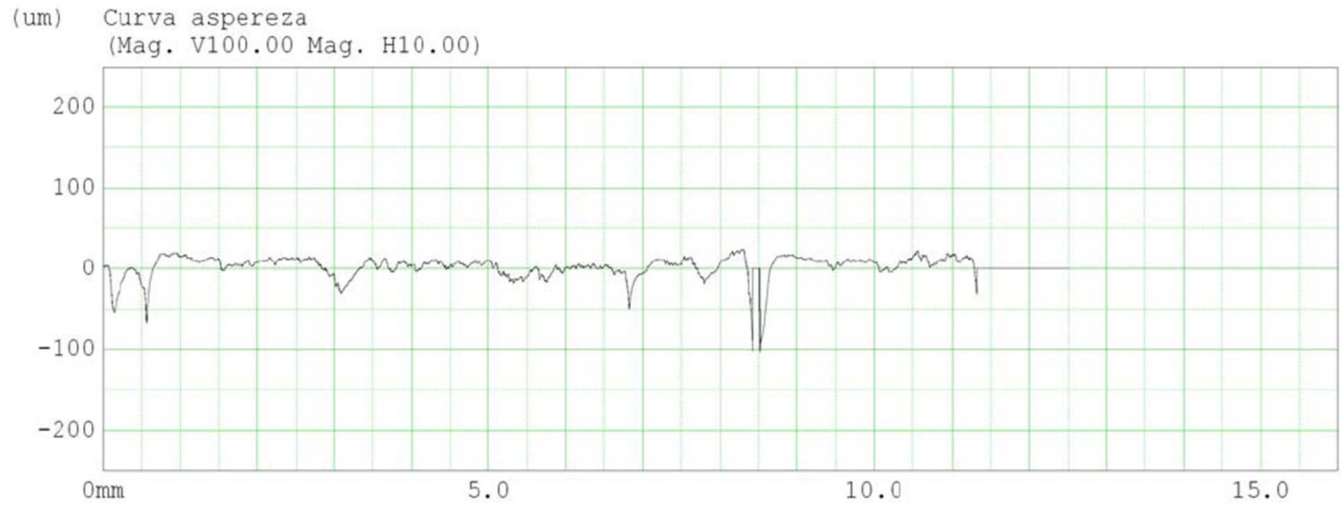

Figure A185. Roughness profile; diagonal 2 after wear in sample 1N12.

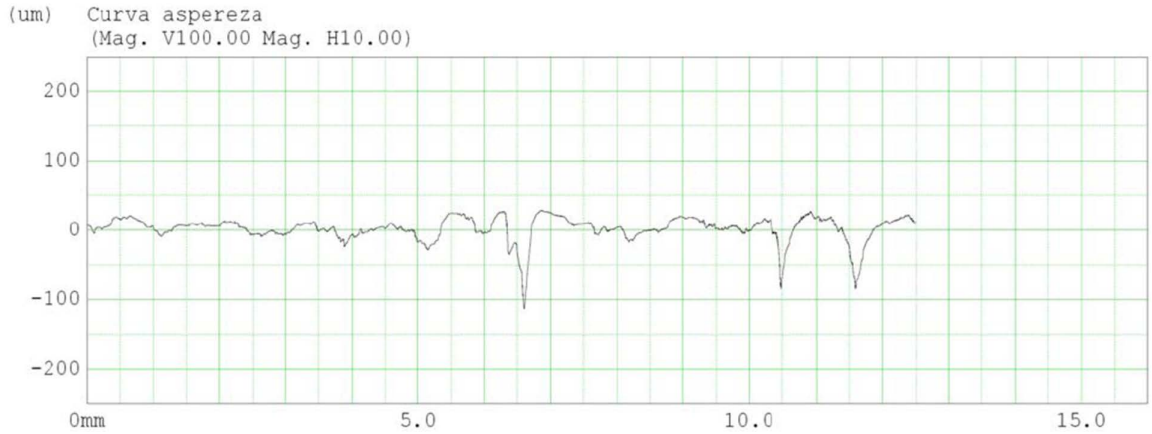

Figure A186. Roughness profile; diagonal 3 after wear in sample 1N12.

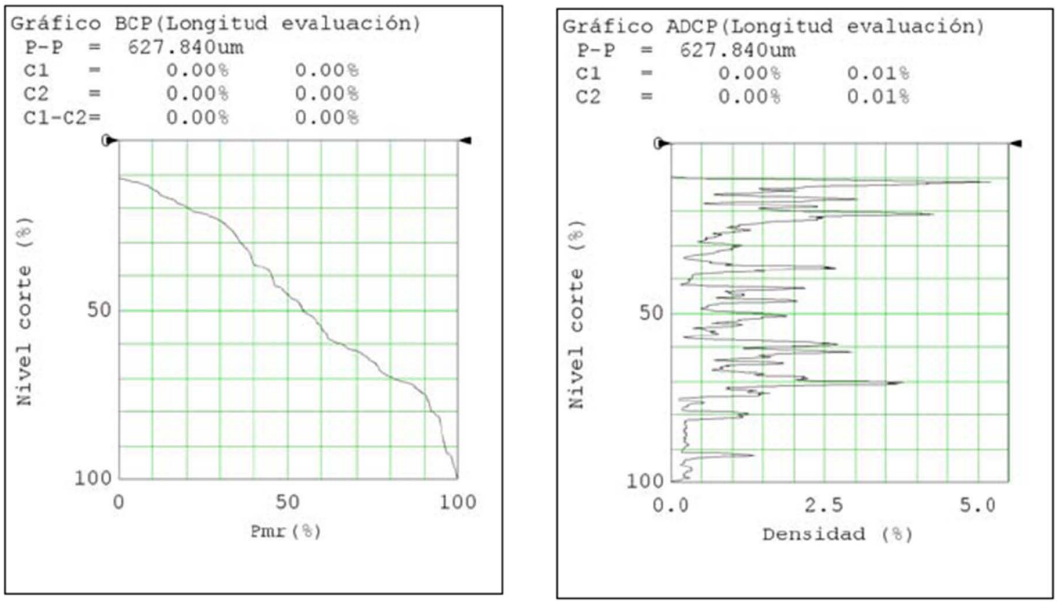

Figure A187. Material graphs along diagonal 1 after wear in sample 1N12.

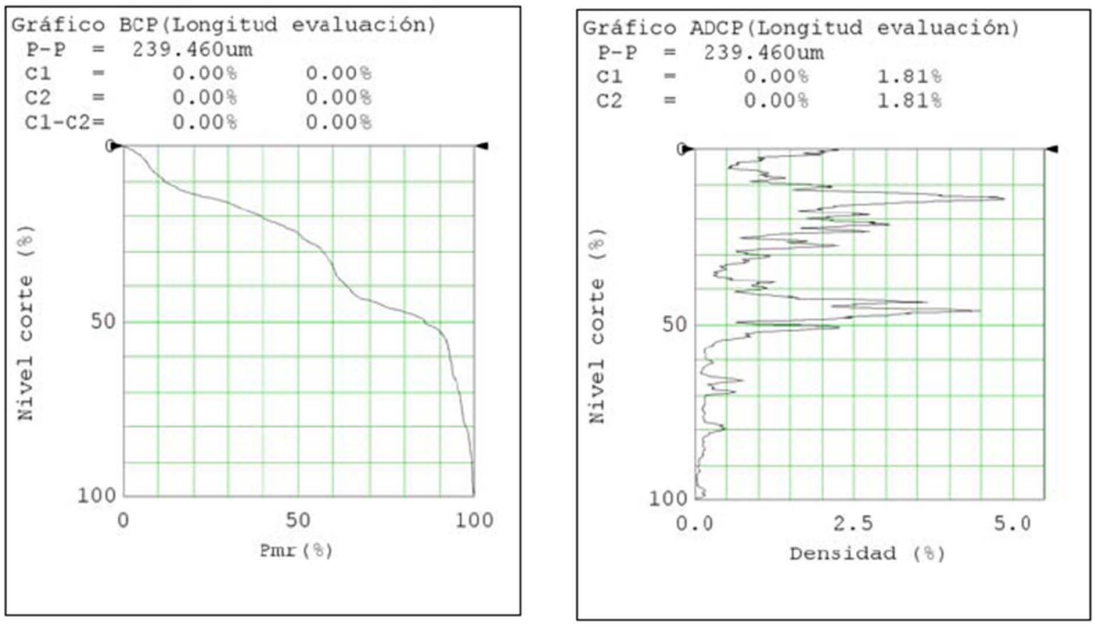

Figure A188. Material graphs along diagonal 2 after wear in sample 1N12.

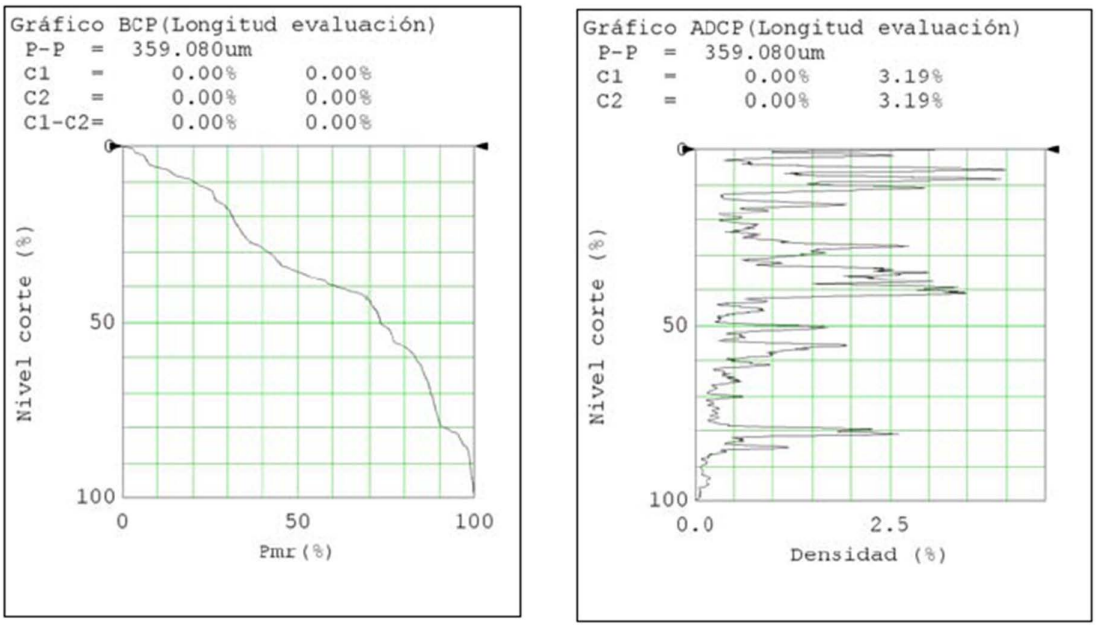

Figure A189. Material graphs along diagonal 3 after wear in sample 1N12.

Appendix B.10. Measurements After Friction in Sample 2N12

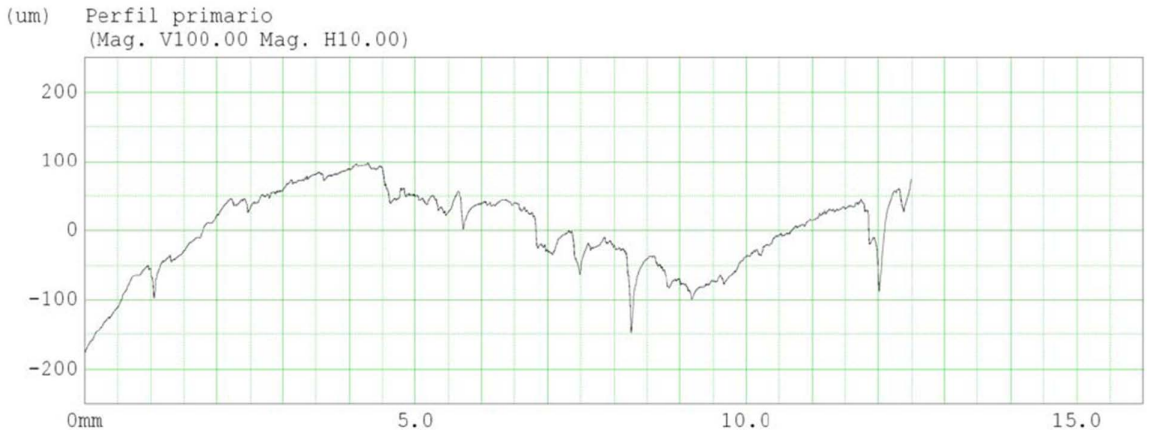

Figure A190. Primary profile; diagonal 1 after wear in sample 2N12.

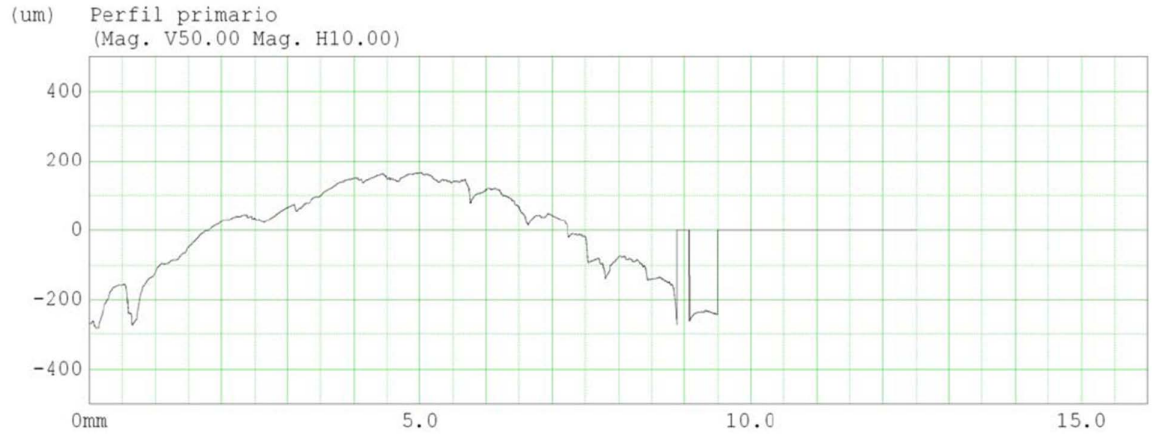

Figure A191. Primary profile; diagonal 2 after wear in sample 2N12.

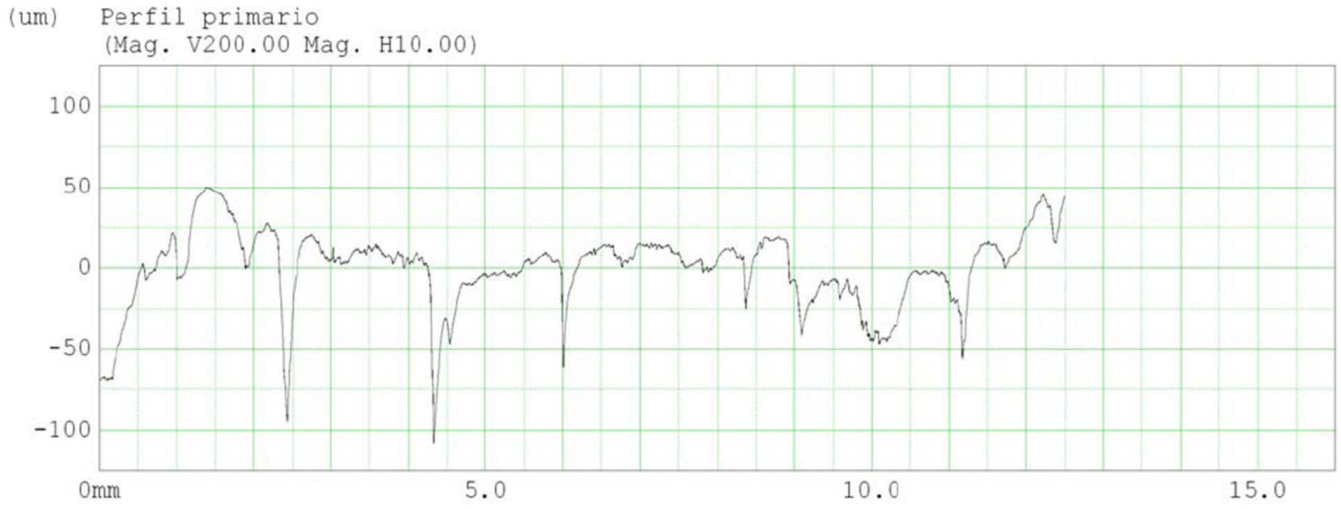

Figure A192. Primary profile; diagonal 3 after wear in sample 2N12.

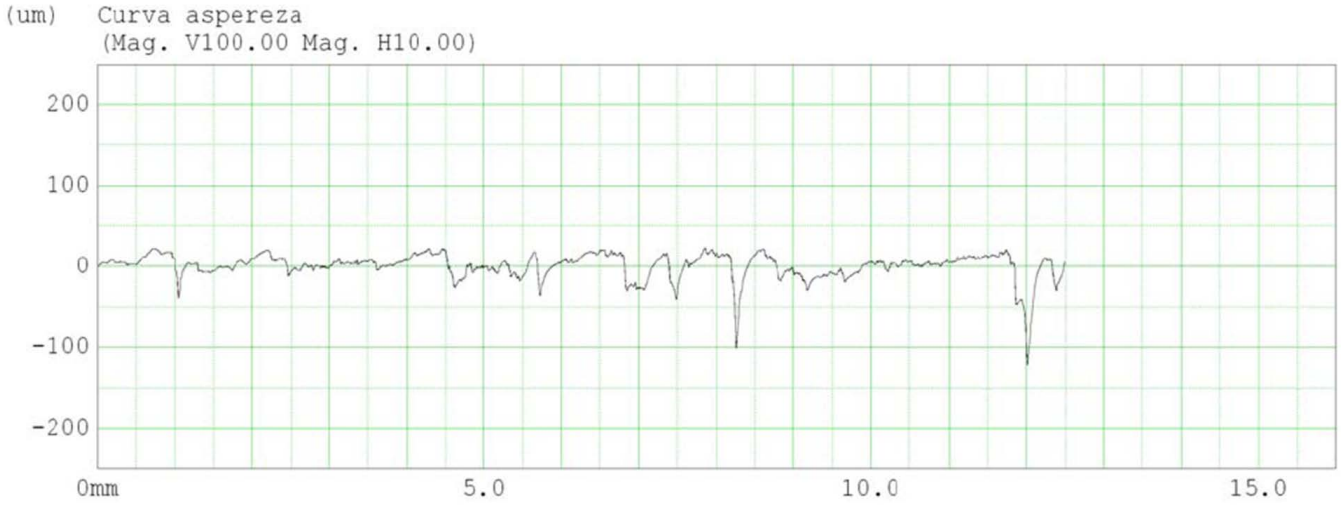

Figure A193. Roughness profile; diagonal 1 after wear in sample 2N12.

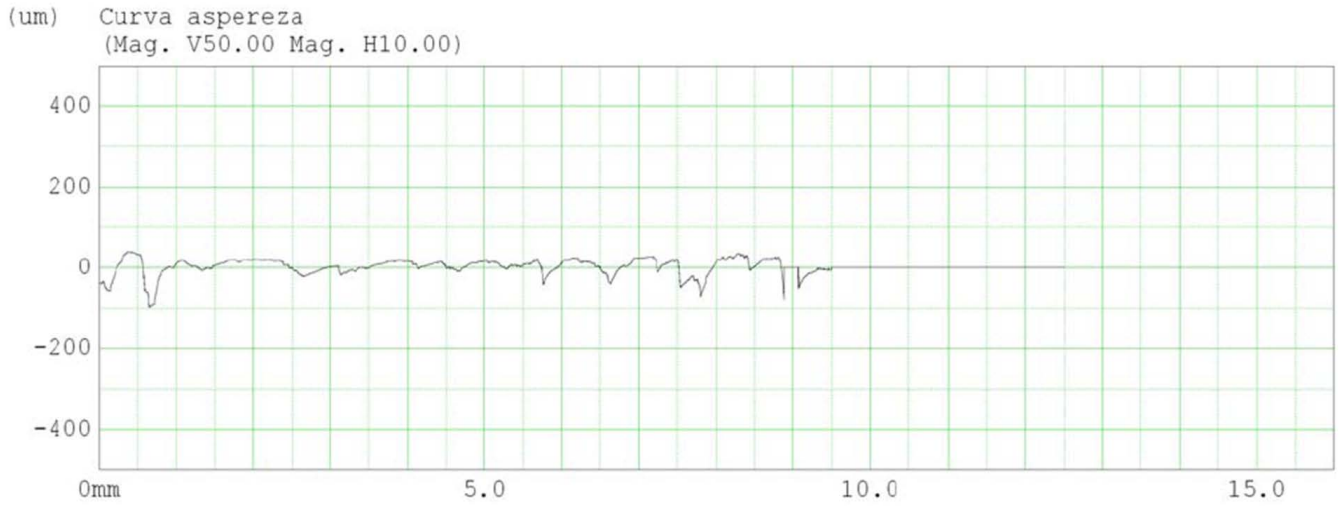

Figure A194. Roughness profile; diagonal 2 after wear in sample 2N12.

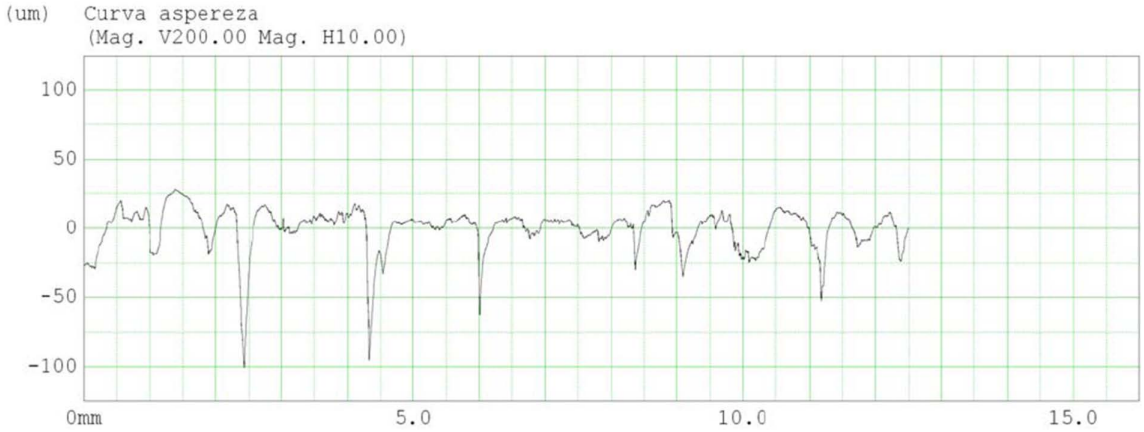

Figure A195. Roughness profile; diagonal 3 after wear in sample 2N12.

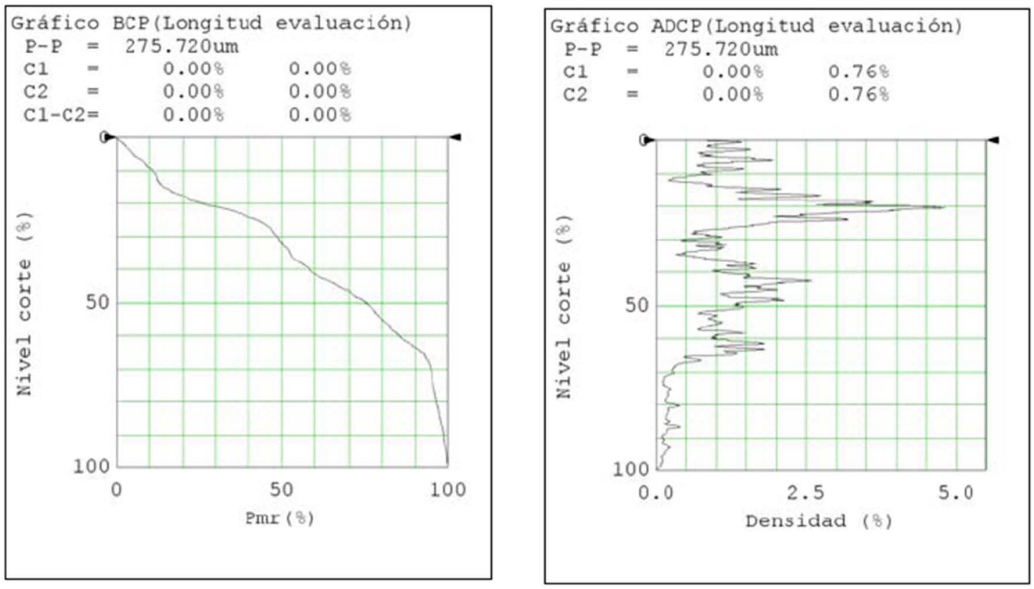

Figure A196. Material graphs along diagonal 1 after wear in sample 2N12.

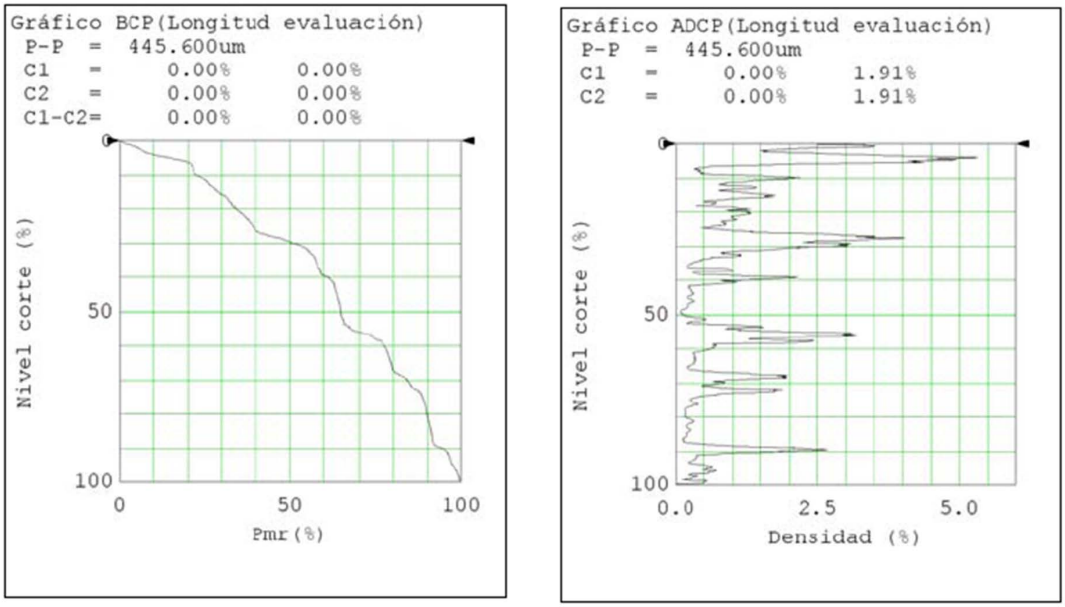

Figure A197. Material graphs along diagonal 2 after wear in sample 2N12.

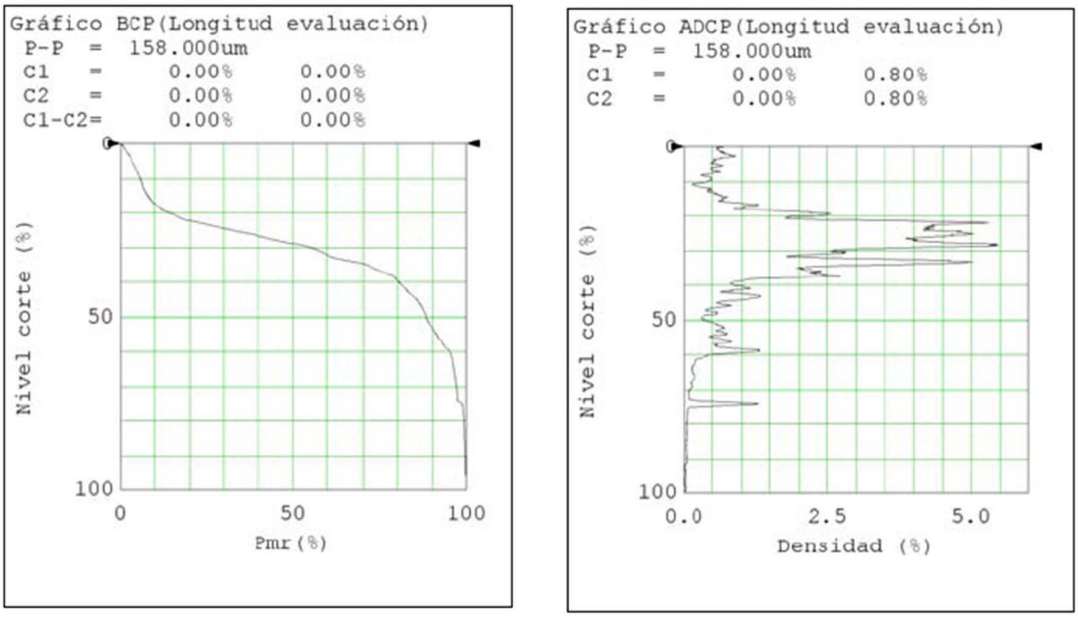

Figure A198. Material graphs along diagonal 3 after wear in sample 2N12.

Appendix B.11. Measurements After Friction in Sample 1B12

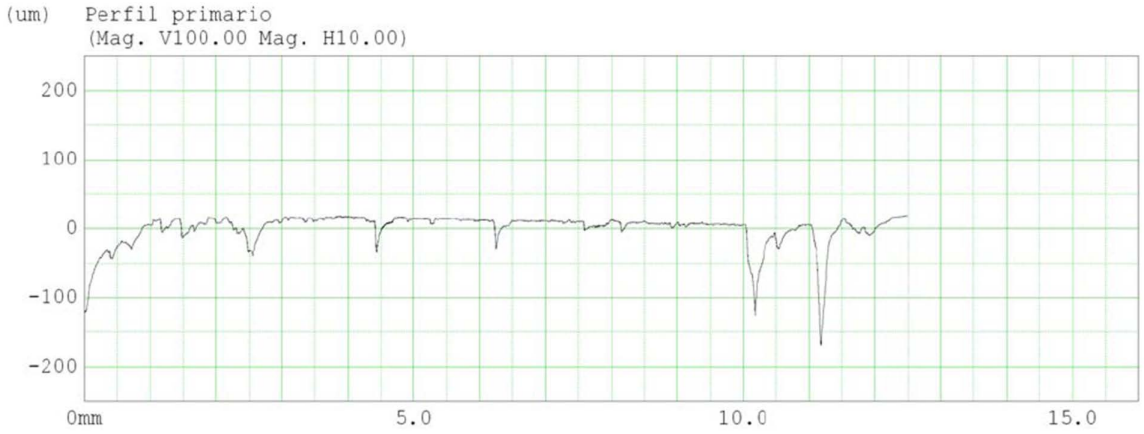

Figure A199. Primary profile; diagonal 1 after wear in sample 1B12.

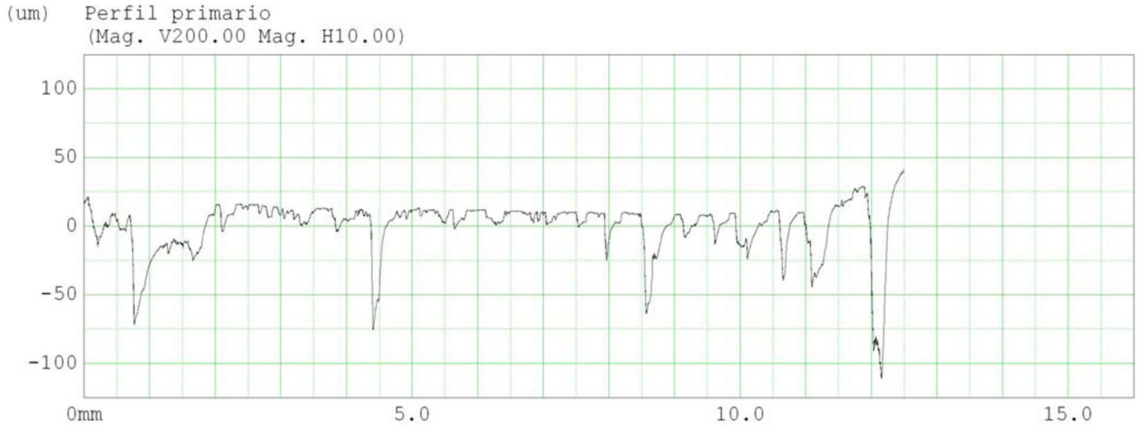

Figure A200. Primary profile; diagonal 2 after wear in sample 1B12.

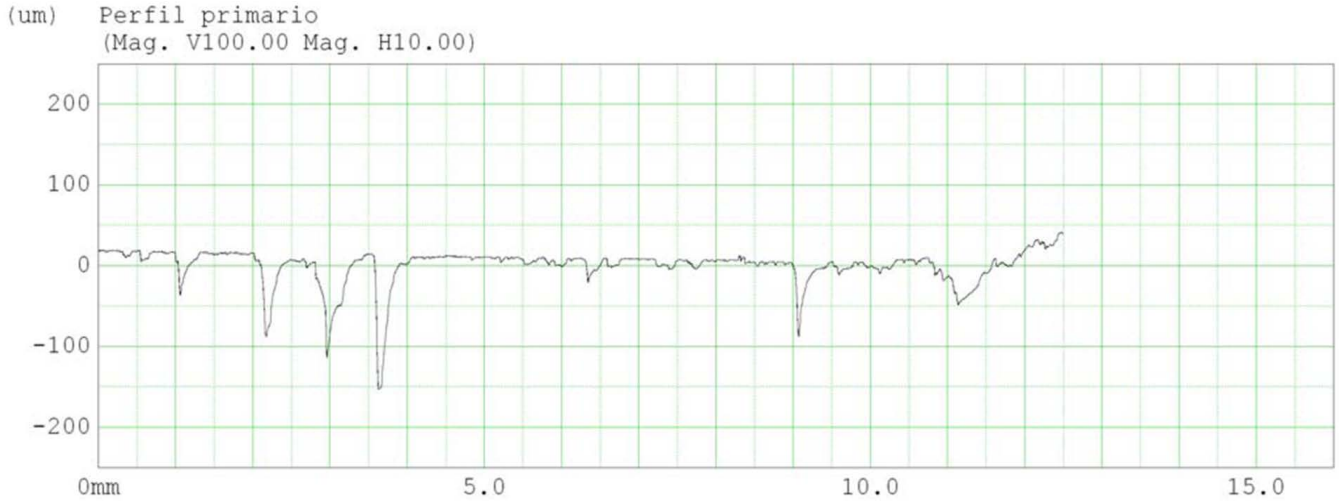

Figure A201. Primary profile; diagonal 3 after wear in sample 1B12.

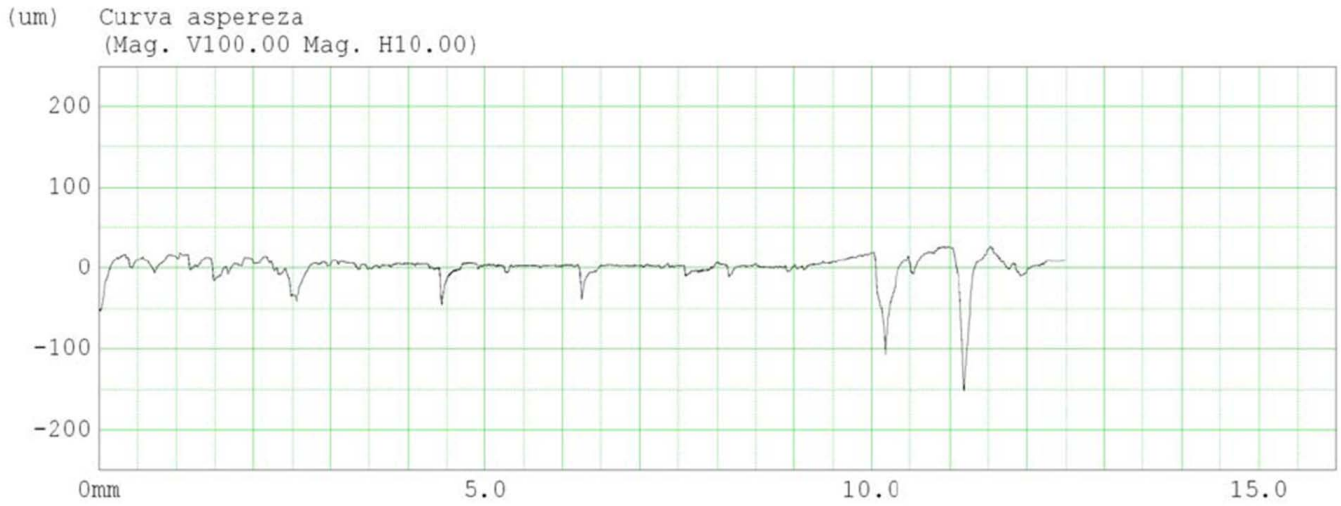

Figure A202. Roughness profile; diagonal 1 after wear in sample 1B12.

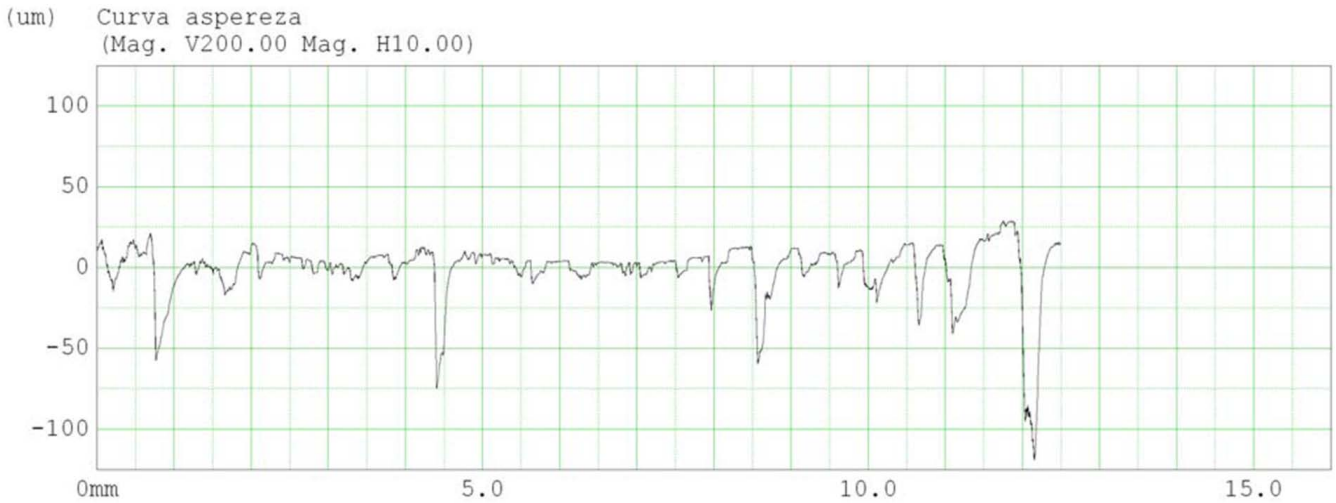

Figure A203. Roughness profile; diagonal 2 after wear in sample 1B12.

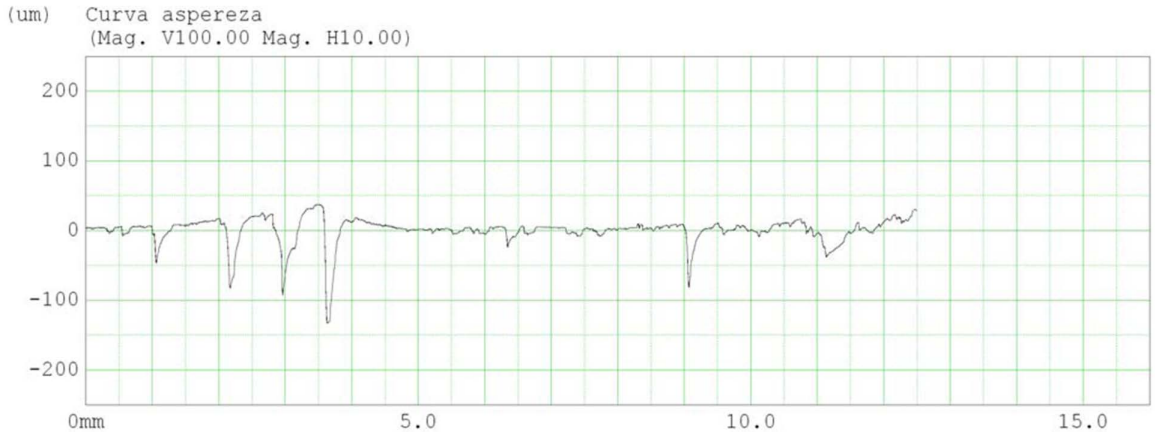

Figure A204. Roughness profile; diagonal 3 after wear in sample 1B12.

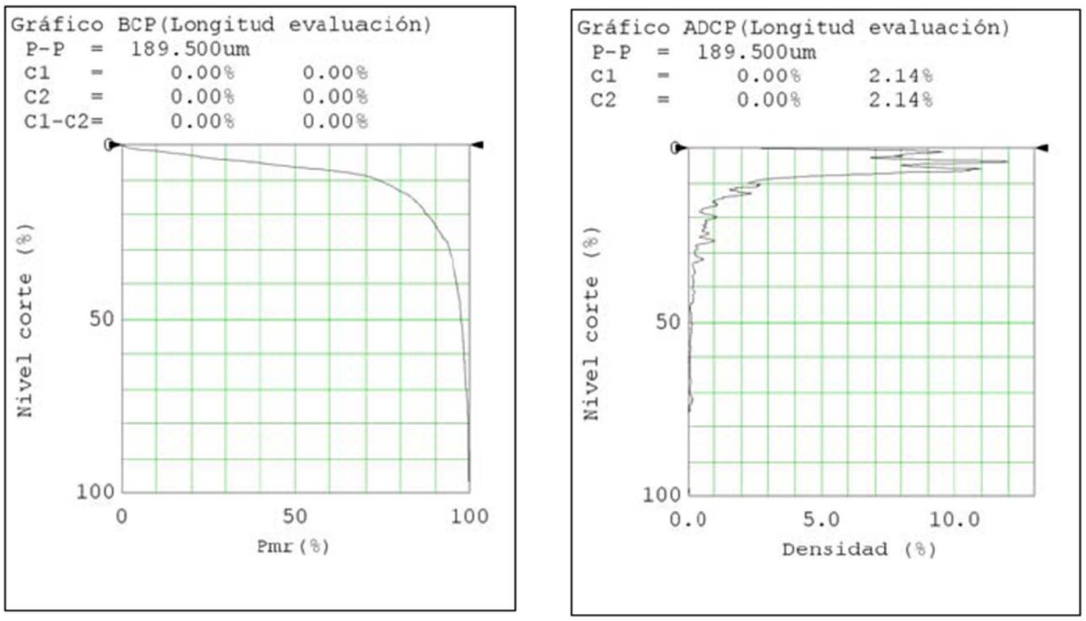

Figure A205. Material graphs along diagonal 1 after wear in sample 1B12.

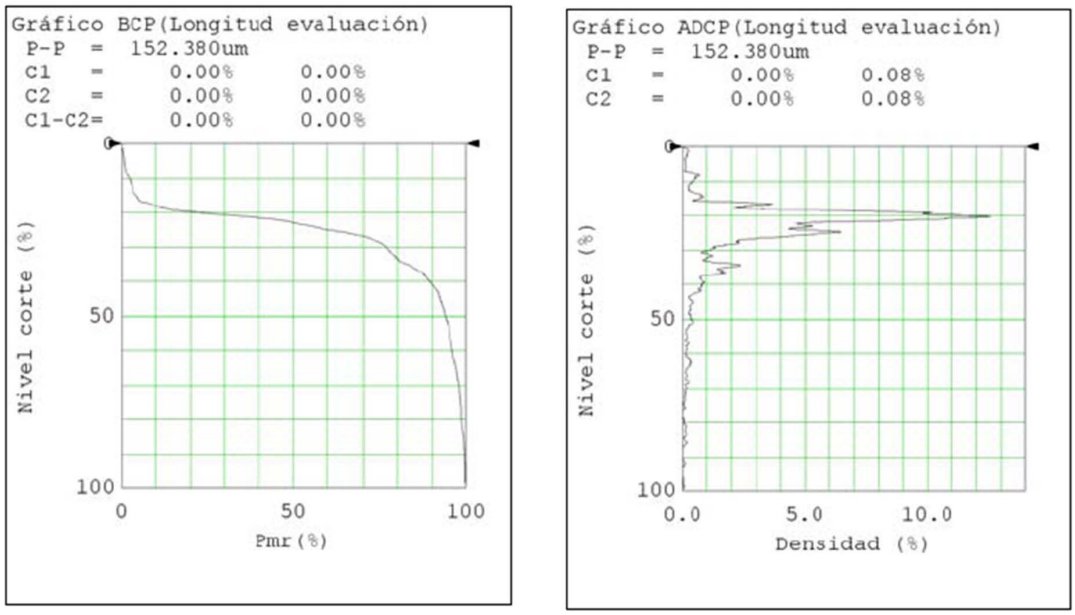

Figure A206. Material graphs along diagonal 2 after wear in sample 1B12.

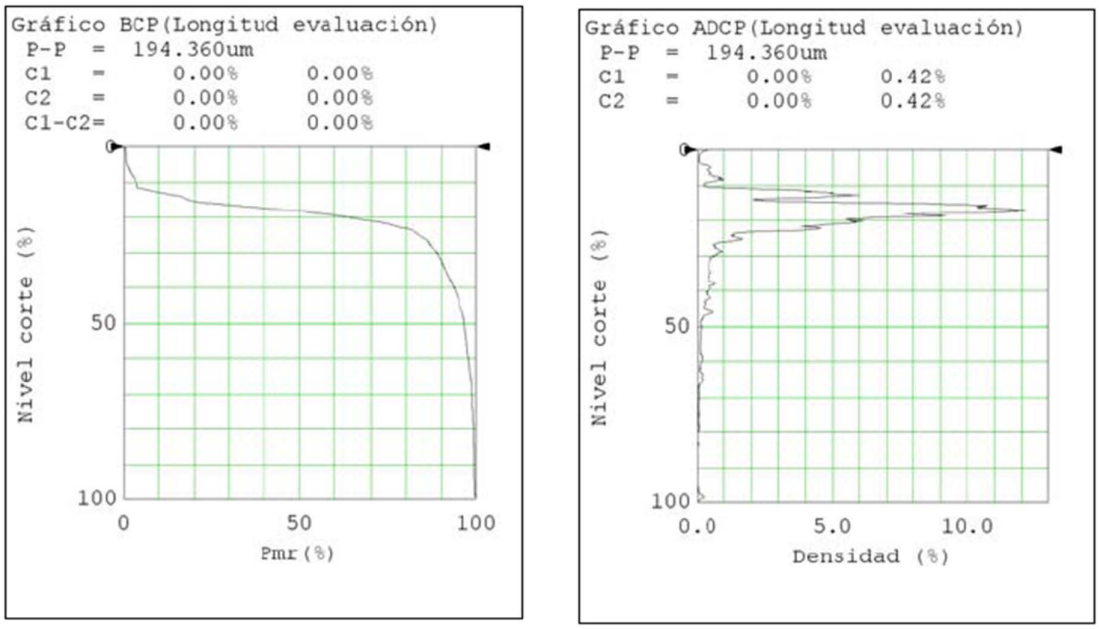

Figure A207. Material graphs along diagonal 3 after wear in sample 1B12.

Appendix B.12. Measurements After Wear in Sample 2B12

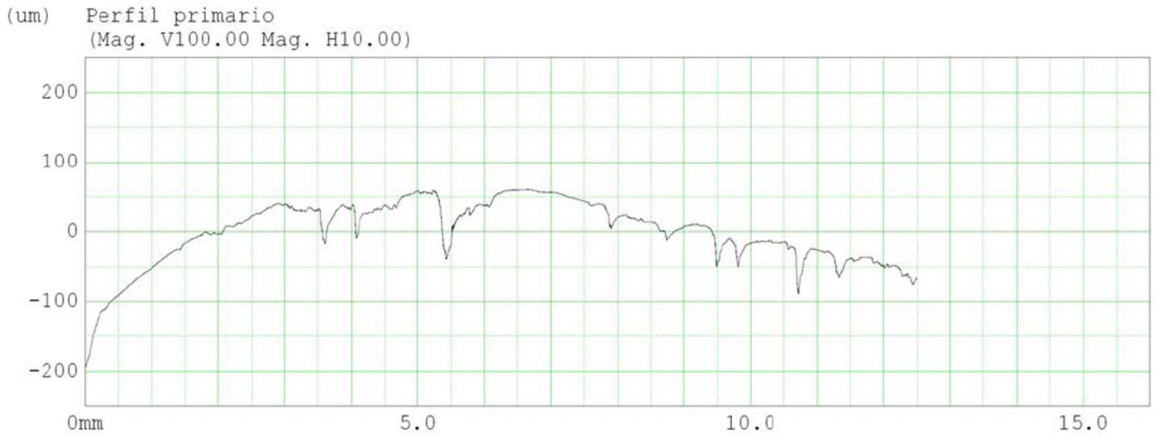

Figure A208. Primary profile; diagonal 1 after wear in sample 2B12.

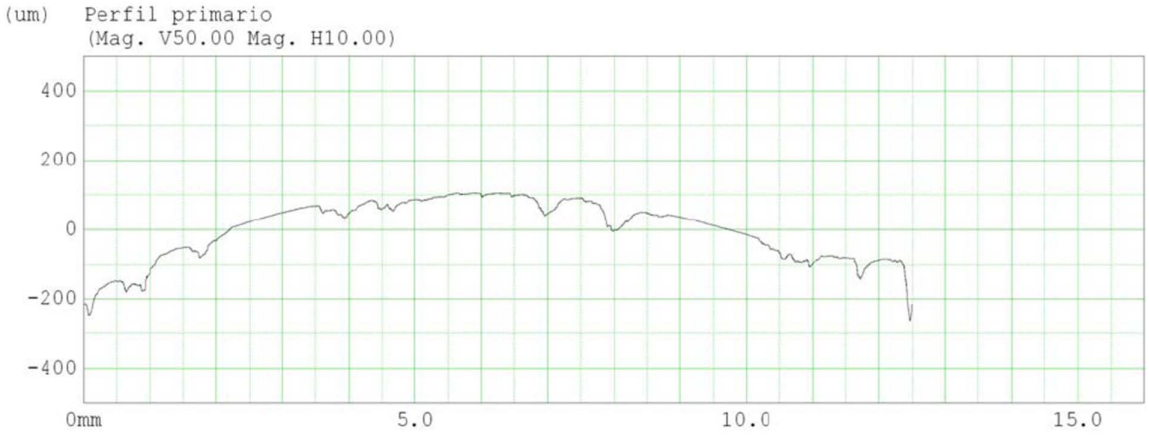

Figure A209. Primary profile; diagonal 2 after wear in sample 2B12.

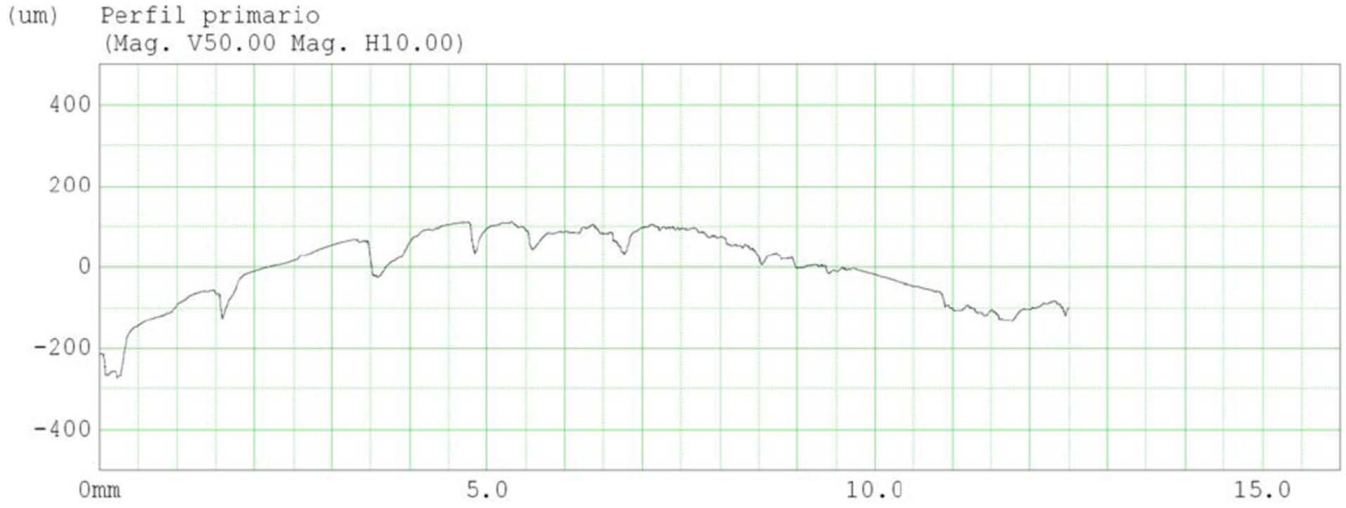

Figure A210. Primary profile; diagonal 3 after wear in sample 2B12.

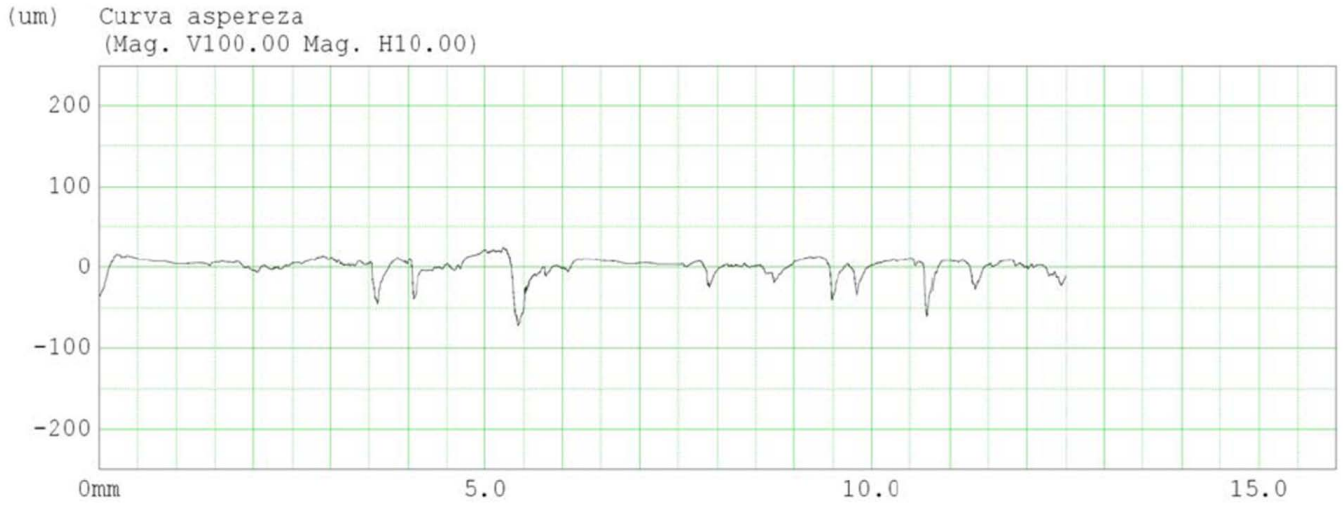

Figure A211. Roughness profile; diagonal 1 after wear in sample 2B12.

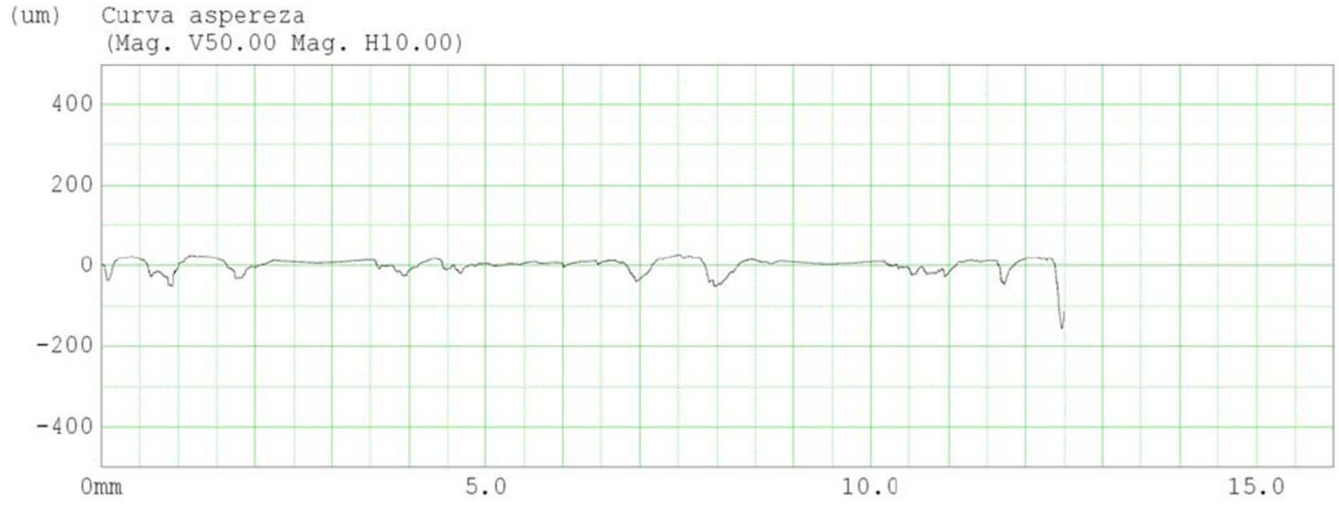

Figure A212. Roughness profile; diagonal 2 after wear in sample 2B12.

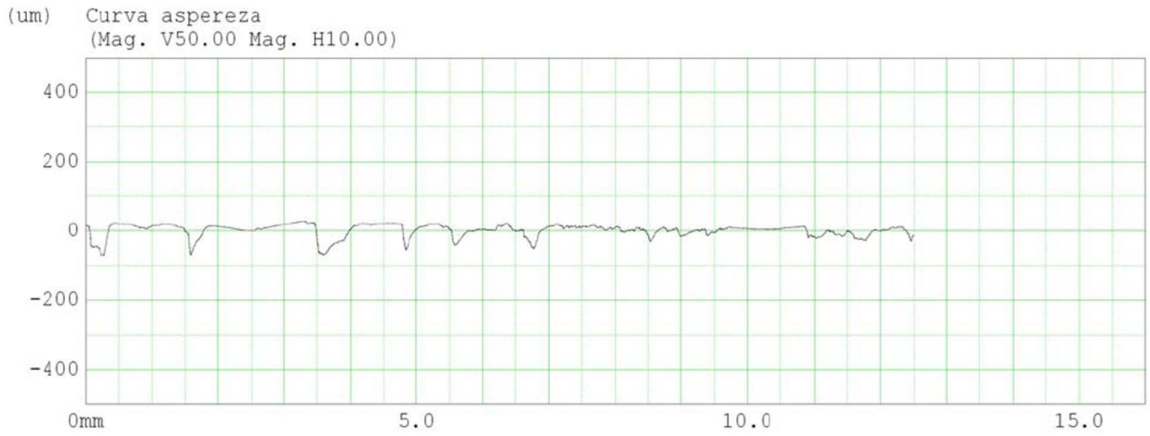

Figure A213. Roughness profile; diagonal 3 after wear in sample 2B12.

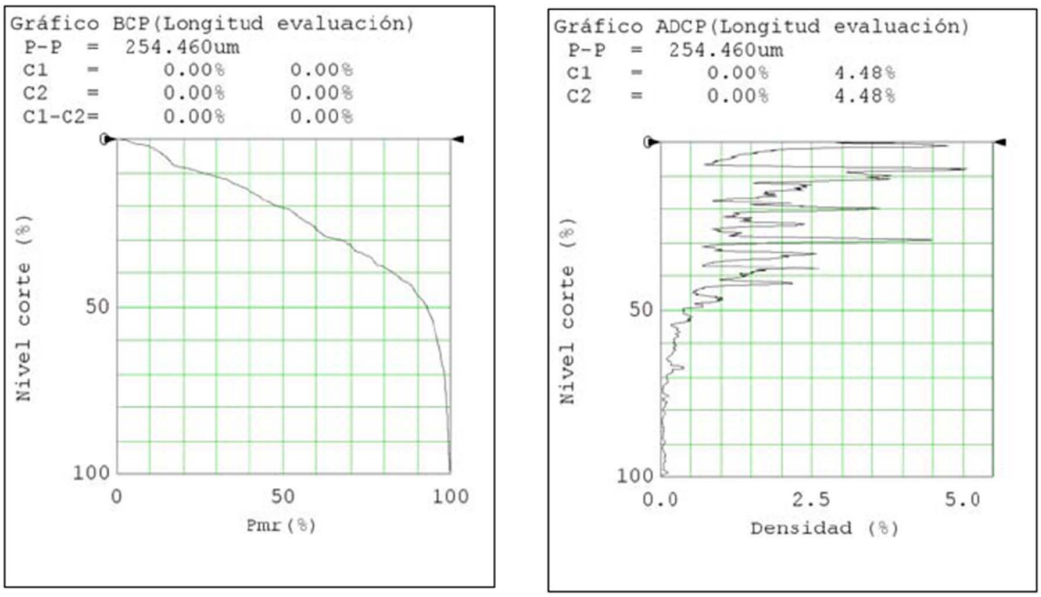

Figure A214. Material graphs along diagonal 1 after wear in sample 2B12.

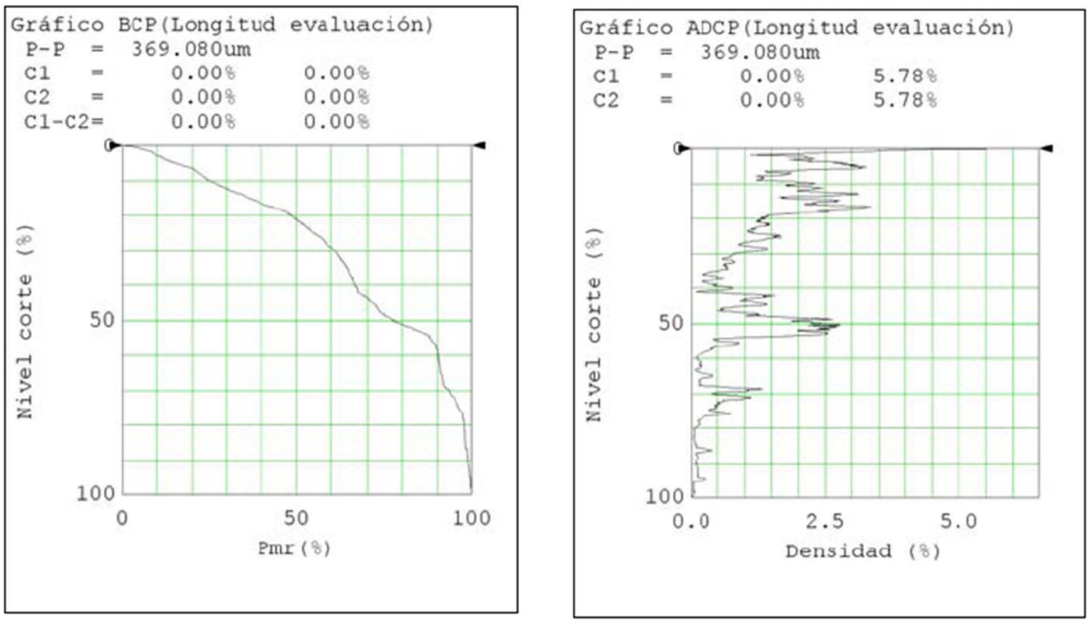

Figure A215. Material graphs along diagonal 2 after wear in sample 2B12.

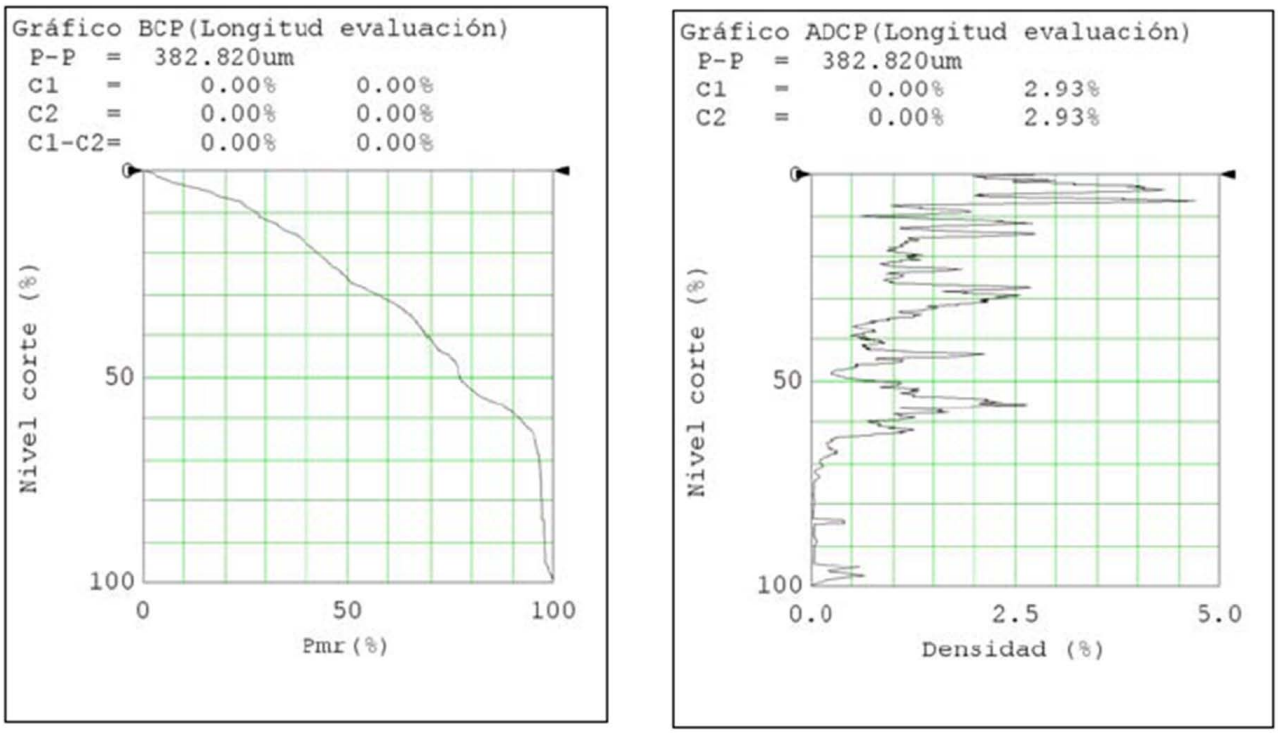

Figure A216. Material graphs along diagonal 3 after wear in sample 2B12.

Appendix C. Measurement Values for All the Profiles

Appendix C.1. Measurements Values in Epoxy Resin

Table A1. Measurement results before wear for sample E1.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	1.01	1.03	1.17	µm
Rq	1.21	1.23	1.28	µm
Rz	3.72	3.09	2.39	µm
Rsk	1.90	1.44	1.29	
Rku	5.98	2.41	1.86	
Rk	1.55	1.15	1.29	µm
Rpk	1.59	2.72	2.60	µm
Rvk	0.38	0.34	0.16	µm
Mr1	26.23	27.44	30.23	%
Mr2	94.32	93.28	96.42	%
Rmr (10%)	0.18	0.55	0.35	%
Rmr (20%)	0.33	1.93	2.51	%
Rmr (30%)	0.49	2.54	4.25	%
Rmr (40%)	1.12	6.00	6.64	%
Rmr (50%)	5.41	10.40	8.95	%
Rmr (60%)	17.35	14.78	12.12	%
Rmr (70%)	30.46	23.04	1.17	%
Rmr (80%)	58.55	40.29	1.28	%

Table A1. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Initial wear	0.00	0.00	2.39	%
Rmr2 (0.0%, 10.0%)	0.18	0.55	1.29	%
Rmr2 (0.0%, 20.0%)	0.33	1.93	1.86	%
Rmr2 (0.0%, 30.0%)	0.49	2.54	1.29	%
Rmr2 (0.0%, 40.0%)	1.12	6.00	2.60	%
Rmr2 (0.0%, 50.0%)	5.41	10.40	0.16	%
Rmr2 (0.0%, 60.0%)	17.35	14.78	30.23	%
Rmr2 (0.0%, 70.0%)	30.46	23.04	96.42	%

Table A2. Measurement results after wear for sample E1.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	17.58	15.00	13.54	µm
Rq	22.90	19.45	20.28	µm
Rz	104.06	89.69	117.64	µm
Rsk	−0.76	−0.67	−1.76	
Rku	3.77	3.90	9.22	
Rmr (10%)	6.30	8.41	7.16	%
Rmr (20%)	19.38	58.24	58.71	%
Rmr (30%)	60.56	81.19	86.99	%
Rmr (40%)	82.33	95.66	93.45	%
Rmr (50%)	89.00	96.70	95.39	%
Rmr (60%)	93.15	97.46	96.73	%
Rmr (70%)	95.16	98.32	98.29	%
Rmr (80%)	97.15	98.96	99.06	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	6.30	8.41	7.16	%
Rmr2 (0.0%, 20.0%)	19.38	58.24	58.71	%
Rmr2 (0.0%, 30.0%)	60.56	81.19	86.99	%
Rmr2 (0.0%, 40.0%)	82.33	95.66	93.45	%
Rmr2 (0.0%, 50.0%)	89.00	96.70	95.39	%
Rmr2 (0.0%, 60.0%)	93.15	97.46	96.73	%
Rmr2 (0.0%, 70.0%)	95.16	98.32	98.29	%

Table A3. Measurement results before wear for sample E2.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	0.39	0.82	0.45	µm
Rq	0.54	0.89	0.70	µm
Rz	3.22	2.41	4.33	µm
Rsk	0.73	1.07	2.62	

Table A3. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rku	4.40	5.29	14.50	
Rk	0.82	1.25	0.90	µm
Rpk	0.69	2.54	1.50	µm
Rvk	0.98	0.23	0.38	µm
Mr1	15.57	28.39	19.96	%
Mr2	91.38	94.75	91.21	%
Rmr (10%)	0.06	1.41	0.41	%
Rmr (20%)	0.10	6.20	0.62	%
Rmr (30%)	0.25	10.17	0.81	%
Rmr (40%)	0.39	14.93	0.86	%
Rmr (50%)	7.60	18.32	1.12	%
Rmr (60%)	86.54	22.37	1.44	%
Rmr (70%)	98.95	32.28	4.26	%
Rmr (80%)	99.11	56.68	18.67	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	0.06	1.41	0.41	%
Rmr2 (0.0%, 20.0%)	0.10	6.20	0.62	%
Rmr2 (0.0%, 30.0%)	0.25	10.17	0.81	%
Rmr2 (0.0%, 40.0%)	0.39	14.93	0.86	%
Rmr2 (0.0%, 50.0%)	7.60	18.32	1.12	%
Rmr2 (0.0%, 60.0%)	86.54	22.37	1.44	%
Rmr2 (0.0%, 70.0%)	98.95	32.28	4.26	%

Table A4. Measurement results after wear for sample E2.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	17.04	17.71	14.80	µm
Rq	22.97	25.08	19.01	µm
Rz	121.74	138.01	88.89	µm
Rsk	−1.58	−1.63	−0.84	
Rku	7.27	6.86	3.76	
Rmr (10%)	12.47	11.17	2.91	%
Rmr (20%)	41.69	57.00	12.35	%
Rmr (30%)	76.24	85.40	47.88	%
Rmr (40%)	90.08	93.19	77.76	%
Rmr (50%)	94.18	96.24	91.02	%
Rmr (60%)	97.79	97.39	95.36	%
Rmr (70%)	99.35	98.39	97.61	%
Rmr (80%)	99.57	99.08	98.76	%
Initial wear	0.00	0.00	0.00	%

Table A4. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rmr2 (0.0%, 10.0%)	12.47	11.17	2.91	%
Rmr2 (0.0%, 20.0%)	41.69	57.00	12.35	%
Rmr2 (0.0%, 30.0%)	76.24	85.40	47.88	%
Rmr2 (0.0%, 40.0%)	90.08	93.19	77.76	%
Rmr2 (0.0%, 50.0%)	94.18	96.24	91.02	%
Rmr2 (0.0%, 60.0%)	97.79	97.39	95.36	%
Rmr2 (0.0%, 70.0%)	99.35	98.39	97.61	%

Appendix C.2. Measured Values in Micron-Sized SiC Particles

Table A5. Measurement results before wear for sample 1M6.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	1.08	0.77	0.58	µm
Rq	1.22	0.89	0.69	µm
Rz	3.88	2.04	1.66	µm
Rsk	−1.33	−1.32	−0.94	
Rku	2.60	2.79	2.50	
Rk	1.12	0.84	0.54	µm
Rpk	1.58	0.17	0.20	µm
Rvk	4.08	2.15	2.97	µm
Mr1	4.37	4.31	7.09	%
Mr2	72.32	64.67	75.61	%
Rmr (10%)	0.15	13.60	33.20	%
Rmr (20%)	0.35	54.26	80.54	%
Rmr (30%)	0.70	68.34	86.51	%
Rmr (40%)	0.80	74.89	89.71	%
Rmr (50%)	12.23	85.33	92.65	%
Rmr (60%)	76.63	89.12	94.49	%
Rmr (70%)	88.20	92.98	95.47	%
Rmr (80%)	91.57	0.77	97.01	%
Initial wear	0.00	0.89	0.00	%
Rmr2 (0.0%, 10.0%)	0.15	2.04	33.20	%
Rmr2 (0.0%, 20.0%)	0.35	−1.32	80.54	%
Rmr2 (0.0%, 30.0%)	0.70	2.79	86.51	%
Rmr2 (0.0%, 40.0%)	0.80	0.84	89.71	%
Rmr2 (0.0%, 50.0%)	12.23	0.17	92.65	%
Rmr2 (0.0%, 60.0%)	76.63	2.15	94.49	%
Rmr2 (0.0%, 70.0%)	88.20	4.31	95.47	%

Table A6. Measurement results after wear for sample 1M6.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	10.98	8.80	14.77	µm
Rq	15.65	12.11	21.94	µm
Rz	77.14	57.23	112.06	µm
Rsk	−1.01	−0.95	−1.32	
Rku	5.31	5.14	5.92	
Rmr (10%)	5.46	5.53	1.89	%
Rmr (20%)	19.91	24.67	29.38	%
Rmr (30%)	67.96	65.04	85.45	%
Rmr (40%)	85.82	86.79	95.41	%
Rmr (50%)	91.50	93.12	97.01	%
Rmr (60%)	96.06	94.87	98.13	%
Rmr (70%)	98.98	96.02	99.11	%
Rmr (80%)	99.48	98.69	99.46	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	5.46	5.53	1.89	%
Rmr2 (0.0%, 20.0%)	19.91	24.67	29.38	%
Rmr2 (0.0%, 30.0%)	67.96	65.04	85.45	%
Rmr2 (0.0%, 40.0%)	85.82	86.79	95.41	%
Rmr2 (0.0%, 50.0%)	91.50	93.12	97.01	%
Rmr2 (0.0%, 60.0%)	96.06	94.87	98.13	%
Rmr2 (0.0%, 70.0%)	98.98	96.02	99.11	%

Table A7. Measurement results before wear for sample 2M6.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	0.26	0.48	0.29	µm
Rq	0.32	0.55	0.34	µm
Rz	1.26	1.66	1.08	µm
Rsk	1.26	1.42	1.15	µm
Rku	2.53	3.21	2.29	
Rk	0.67	0.82	0.57	µm
Rpk	0.29	1.27	0.34	µm
Rvk	0.21	0.33	0.29	µm
Mr1	13.13	20.47	16.88	%
Mr2	92.50	92.60	91.85	%
Rmr (10%)	0.57	2.83	0.61	%
Rmr (20%)	4.23	9.74	3.81	%
Rmr (30%)	11.43	12.09	13.04	%
Rmr (40%)	24.77	15.13	26.84	%
Rmr (50%)	44.66	26.45	56.70	%
Rmr (60%)	69.39	56.09	86.09	%

Table A7. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rmr (70%)	89.31	89.95	96.90	%
Rmr (80%)	97.55	98.49	99.00	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	0.57	2.83	0.61	%
Rmr2 (0.0%, 20.0%)	4.23	9.74	3.81	%
Rmr2 (0.0%, 30.0%)	11.43	12.09	13.04	%
Rmr2 (0.0%, 40.0%)	24.77	15.13	26.84	%
Rmr2 (0.0%, 50.0%)	44.66	26.45	56.70	%
Rmr2 (0.0%, 60.0%)	69.39	56.09	86.09	%
Rmr2 (0.0%, 70.0%)	89.31	89.95	96.90	%

Table A8. Measurement results after wear for sample 2M6.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	4.75	15.02	11.41	µm
Rq	8.27	21.70	17.36	µm
Rz	49.19	119.18	83.04	µm
Rsk	−1.56	−1.79	−1.89	
Rku	10.08	6.91	7.79	
Rmr (10%)	39.99	1.97	9.21	%
Rmr (20%)	94.55	10.94	48.03	%
Rmr (30%)	95.42	77.48	88.37	%
Rmr (40%)	96.89	91.66	92.68	%
Rmr (50%)	97.45	95.66	94.11	%
Rmr (60%)	98.76	98.45	95.94	%
Rmr (70%)	99.36	99.06	96.79	%
Rmr (80%)	99.71	99.50	97.83	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	0.00	1.97	9.21	%
Rmr2 (0.0%, 20.0%)	39.99	10.94	48.03	%
Rmr2 (0.0%, 30.0%)	94.55	77.48	88.37	%
Rmr2 (0.0%, 40.0%)	95.42	91.66	92.68	%
Rmr2 (0.0%, 50.0%)	96.89	95.66	94.11	%
Rmr2 (0.0%, 60.0%)	97.45	98.45	95.94	%
Rmr2 (0.0%, 70.0%)	98.76	99.06	96.79	%

Table A9. Measurement results before wear for sample 1M12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	0.59	0.72	0.35	µm
Rq	0.66	0.84	0.39	µm
Rz	1.38	2.18	1.00	µm

Table A9. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rsk	−0.44	0.03	−0.77	
Rku	2.49	3.24	2.05	
Rk	0.78	1.30	0.63	µm
Rpk	0.23	1.00	0.33	µm
Rvk	2.27	2.32	0.52	µm
Mr1	8.44	8.78	12.44	%
Mr2	74.07	75.72	85.54	%
Rmr (10%)	4.40	0.24	0.92	%
Rmr (20%)	46.63	0.29	3.95	%
Rmr (30%)	74.84	2.24	12.46	%
Rmr (40%)	83.49	12.36	31.18	%
Rmr (50%)	87.65	61.68	63.23	%
Rmr (60%)	90.87	80.87	83.85	%
Rmr (70%)	93.99	89.48	90.84	%
Rmr (80%)	96.15	92.46	96.44	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	4.40	0.24	0.92	%
Rmr2 (0.0%, 20.0%)	46.63	0.29	3.95	%
Rmr2 (0.0%, 30.0%)	74.84	2.24	12.46	%
Rmr2 (0.0%, 40.0%)	83.49	12.36	31.18	%
Rmr2 (0.0%, 50.0%)	87.65	61.68	63.23	%
Rmr2 (0.0%, 60.0%)	90.87	80.87	83.85	%
Rmr2 (0.0%, 70.0%)	93.99	89.48	90.84	%

Table A10. Measurement results after wear for sample 1M12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	9.41	7.81	20.83	µm
Rq	13.34	12.72	29.23	µm
Rz	88.39	78.40	136.39	µm
Rsk	−0.99	−1.80	−2.04	
Rku	9.16	11.29	7.22	
Rmr (10%)	17.45	1.60	14.43	%
Rmr (20%)	72.49	20.97	49.26	%
Rmr (30%)	93.89	87.44	83.16	%
Rmr (40%)	97.17	97.23	88.19	%
Rmr (50%)	98.40	98.44	91.78	%
Rmr (60%)	99.13	99.18	95.14	%
Rmr (70%)	99.47	99.47	97.05	%

Table A10. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rmr (80%)	99.67	99.63	98.15	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	17.45	0.00	14.43	%
Rmr2 (0.0%, 20.0%)	72.49	1.60	49.26	%
Rmr2 (0.0%, 30.0%)	93.89	20.97	83.16	%
Rmr2 (0.0%, 40.0%)	97.17	87.44	83.16	%
Rmr2 (0.0%, 50.0%)	98.40	97.23	88.19	%
Rmr2 (0.0%, 60.0%)	99.13	98.44	91.78	%
Rmr2 (0.0%, 70.0%)	99.47	99.18	95.14	%

Table A11. Measurement results before wear for sample 3M12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	0.28	0.26	0.28	µm
Rq	0.33	0.34	0.32	µm
Rz	1.07	1.06	1.08	µm
Rsk	−0.29	−0.86	−0.05	
Rku	2.35	2.61	2.25	
Rk	0.63	0.61	0.79	µm
Rpk	0.67	0.13	0.50	µm
Rvk	0.46	0.80	0.32	µm
Mr1	19.85	4.24	16.74	%
Mr2	88.75	82.10	94.17	%
Rmr (10%)	1.86	4.32	1.00	%
Rmr (20%)	4.90	40.27	7.21	%
Rmr (30%)	11.38	76.75	15.39	%
Rmr (40%)	17.93	88.30	22.60	%
Rmr (50%)	27.62	94.24	41.69	%
Rmr (60%)	60.60	95.84	62.07	%
Rmr (70%)	85.57	96.87	87.88	%
Rmr (80%)	93.29	97.80	96.76	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	1.86	4.32	1.00	%
Rmr2 (0.0%, 20.0%)	4.90	40.27	7.21	%
Rmr2 (0.0%, 30.0%)	11.38	76.75	15.39	%
Rmr2 (0.0%, 40.0%)	17.93	88.30	22.60	%
Rmr2 (0.0%, 50.0%)	27.62	94.24	41.69	%
Rmr2 (0.0%, 60.0%)	60.60	95.84	62.07	%
Rmr2 (0.0%, 70.0%)	85.57	96.87	87.88	%

Table A12. Measurement results after wear for sample 3M12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	7.05	10.22	20.60	µm
Rq	11.63	15.82	30.53	µm
Rz	77.96	93.89	147.06	µm
Rsk	−1.78	−1.88	−2.01	
Rku	9.99	8.72	7.01	
Rk	12.04			
Rpk	6.98			
Rvk	26.37			
Mr1	16.56			
Mr2	81.63			
Rmr (10%)	45.77	25.13	11.42	%
Rmr (20%)	93.68	87.21	54.08	%
Rmr (30%)	97.38	95.84	91.63	%
Rmr (40%)	98.68	97.30	93.33	%
Rmr (50%)	99.00	98.28	94.92	%
Rmr (60%)	99.23	99.09	96.26	%
Rmr (70%)	99.47	99.36	97.94	%
Rmr (80%)	99.63	99.59	99.10	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	45.77	25.13	11.42	%
Rmr2 (0.0%, 20.0%)	93.68	87.21	54.08	%
Rmr2 (0.0%, 30.0%)	97.38	95.84	91.63	%
Rmr2 (0.0%, 40.0%)	98.68	97.30	93.33	%
Rmr2 (0.0%, 50.0%)	99.00	98.28	94.92	%
Rmr2 (0.0%, 60.0%)	99.23	99.09	96.26	%
Rmr2 (0.0%, 70.0%)	99.47	99.36	97.94	%

Appendix C.3. Measured Values in Nano-Sized SiC Particles

Table A13. Measurement results before wear for sample 1N6.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	1.34	1.47	1.62	µm
Rq	1.38	1.52	1.73	µm
Rz	1.42	1.87	2.46	µm
Rsk	1.09	1.00	1.22	
Rku	1.24	1.27	1.76	
Rk	1.05	1.05	1.33	µm
Rpk	0.20	0.18	1.18	µm
Rvk	0.81	1.97	1.18	µm
Mr1	4.35	4.99	28.10	%

Table A13. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Mr2	84.30	73.82	88.97	%
Rmr (10%)	0.65	5.43	0.43	%
Rmr (20%)	11.26	32.48	0.74	%
Rmr (30%)	36.67	59.89	7.58	%
Rmr (40%)	66.98	73.73	19.47	%
Rmr (50%)	81.65	78.53	33.83	%
Rmr (60%)	88.99	86.40	65.37	%
Rmr (70%)	95.35	87.81	90.07	%
Rmr (80%)	97.78	89.70	95.76	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	0.65	5.43	0.43	%
Rmr2 (0.0%, 20.0%)	11.26	32.48	0.74	%
Rmr2 (0.0%, 30.0%)	36.67	59.89	7.58	%
Rmr2 (0.0%, 40.0%)	66.98	73.73	19.47	%
Rmr2 (0.0%, 50.0%)	81.65	78.53	33.83	%
Rmr2 (0.0%, 60.0%)	88.99	86.40	65.37	%
Rmr2 (0.0%, 70.0%)	95.35	87.81	90.07	%

Table A14. Measurement results after wear for sample 1N6.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	8.76	10.66	14.70	um
Rq	14.22	13.88	19.84	um
Rz	77.14	69.98	99.25	um
Rsk	−1.60	−0.75	−0.37	
Rku	8.15	5.21	4.76	
Rmr (10%)	61.69	7.55	12.26	%
Rmr (20%)	93.10	39.70	42.12	%
Rmr (30%)	96.61	85.11	84.85	%
Rmr (40%)	98.18	91.72	92.12	%
Rmr (50%)	98.73	94.01	94.08	%
Rmr (60%)	98.91	97.52	97.22	%
Rmr (70%)	99.09	98.38	98.77	%
Rmr (80%)	99.48	99.06	99.17	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	61.69	7.55	12.26	%
Rmr2 (0.0%, 20.0%)	93.10	39.70	42.12	%
Rmr2 (0.0%, 30.0%)	96.61	85.11	84.85	%
Rmr2 (0.0%, 40.0%)	98.18	91.72	92.12	%
Rmr2 (0.0%, 50.0%)	98.73	94.01	94.08	%

Table A14. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rmr2 (0.0%, 60.0%)	98.91	97.52	97.22	%
Rmr2 (0.0%, 70.0%)	99.09	98.38	98.77	%

Table A15. Measurement results before wear for sample 3N6.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	1.07	1.12	1.45	µm
Rq	1.14	1.21	1.50	µm
Rz	1.87	2.40	1.58	µm
Rsk	1.11	1.17	1.10	
Rku	1.42	1.47	1.28	
Rk	1.29	1.22	1.24	µm
Rpk	0.44	0.74	1.14	µm
Rvk	0.84	0.63	0.38	µm
Mr1	9.95	12.72	18.53	%
Mr2	76.04	89.19	85.67	%
Rmr (10%)	0.04	0.16	1.02	%
Rmr (20%)	1.69	0.27	8.30	%
Rmr (30%)	9.76	2.49	10.23	%
Rmr (40%)	25.12	6.73	14.38	%
Rmr (50%)	51.83	16.12	23.35	%
Rmr (60%)	64.50	38.83	38.54	%
Rmr (70%)	79.46	68.44	65.89	%
Rmr (80%)	88.10	88.68	81.16	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	0.04	0.16	1.02	%
Rmr2 (0.0%, 20.0%)	1.69	0.27	8.30	%
Rmr2 (0.0%, 30.0%)	9.76	2.49	10.23	%
Rmr2 (0.0%, 40.0%)	25.12	6.73	14.38	%
Rmr2 (0.0%, 50.0%)	51.83	16.12	23.35	%
Rmr2 (0.0%, 60.0%)	64.50	38.83	38.54	%
Rmr2 (0.0%, 70.0%)	79.46	68.44	65.89	%

Table A16. Measurement results after wear for sample 3N6.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	13.06	8.66	8.28	um
Rq	18.78	12.13	11.21	um
Rz	99.21	66.98	60.17	um
Rsk	−2.06	−1.99	−0.94	
Rku	7.69	10.35	4.98	

Table A16. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rmr (10%)	5.82	1.65	1.74	%
Rmr (20%)	54.90	49.91	38.75	%
Rmr (30%)	85.17	87.50	89.40	%
Rmr (40%)	90.53	94.77	94.66	%
Rmr (50%)	94.08	97.13	97.20	%
Rmr (60%)	96.28	98.59	98.74	%
Rmr (70%)	97.48	99.58	99.43	%
Rmr (80%)	98.87	99.71	99.55	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	5.82	1.65	1.74	%
Rmr2 (0.0%, 20.0%)	54.90	49.91	38.75	%
Rmr2 (0.0%, 30.0%)	85.17	87.50	89.40	%
Rmr2 (0.0%, 40.0%)	90.53	94.77	94.66	%
Rmr2 (0.0%, 50.0%)	94.08	97.13	97.20	%
Rmr2 (0.0%, 60.0%)	96.28	98.59	98.74	%
Rmr2 (0.0%, 70.0%)	97.48	99.58	99.43	%

Table A17. Measurement results before wear for sample 1N12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	2.28	3.70	2.98	µm
Rq	2.42	3.94	3.27	µm
Rz	3.31	5.84	5.61	µm
Rsk	0.33	0.47	0.50	
Rku	1.43	1.40	1.65	
Rk	2.93	5.47	6.33	µm
Rpk	0.94	1.24	5.04	µm
Rvk	4.73	7.46	3.98	µm
Mr1	7.64	5.61	11.55	%
Mr2	71.02	69.40	84.52	%
Rmr (10%)	4.24	6.92	5.80	%
Rmr (20%)	14.67	25.05	9.14	%
Rmr (30%)	43.48	52.04	11.85	%
Rmr (40%)	63.47	62.99	23.28	%
Rmr (50%)	71.18	69.43	46.47	%
Rmr (60%)	76.33	75.72	64.09	%
Rmr (70%)	82.24	79.83	78.14	%
Rmr (80%)	84.87	84.03	88.86	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	4.24	6.92	5.80	%

Table A17. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rmr2 (0.0%, 20.0%)	14.67	25.05	9.14	%
Rmr2 (0.0%, 30.0%)	43.48	52.04	11.85	%
Rmr2 (0.0%, 40.0%)	63.47	62.99	23.28	%
Rmr2 (0.0%, 50.0%)	71.18	69.43	46.47	%
Rmr2 (0.0%, 60.0%)	76.33	75.72	64.09	%
Rmr2 (0.0%, 70.0%)	82.24	79.83	78.14	%

Table A18. Measurement results after wear for sample 1N12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	16.40	10.07	11.86	um
Rq	21.42	13.79	15.36	um
Rz	118.26	91.95	71.66	um
Rsk	−1.12	−1.64	−0.33	
Rku	4.35	8.08	4.00	
Rmr (10%)	0.03	21.31	21.40	%
Rmr (20%)	0.04	73.80	63.90	%
Rmr (30%)	1.59	91.32	89.20	%
Rmr (40%)	30.56	96.33	95.52	%
Rmr (50%)	80.18	97.99	96.82	%
Rmr (60%)	93.92	98.90	97.90	%
Rmr (70%)	96.49	99.30	99.00	%
Rmr (80%)	97.95	99.55	99.60	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	0.03	21.31	21.40	%
Rmr2 (0.0%, 20.0%)	0.04	73.80	63.90	%
Rmr2 (0.0%, 30.0%)	1.59	91.32	89.20	%
Rmr2 (0.0%, 40.0%)	30.56	96.33	95.52	%
Rmr2 (0.0%, 50.0%)	80.18	96.33	96.82	%
Rmr2 (0.0%, 60.0%)	93.92	97.99	97.90	%
Rmr2 (0.0%, 70.0%)	96.49	98.90	99.00	%

Table A19. Measurement results before wear for sample 2N12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	2.65	2.27	1.25	µm
Rq	2.85	2.50	1.45	µm
Rz	4.49	3.94	4.64	µm
Rsk	−0.02	0.14	−0.06	
Rku	1.53	1.75	2.10	
Rk	5.74	--	3.83	µm
Rpk	0.36	--	1.31	µm

Table A19. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rvk	3.24	4.37	1.06	µm
Mr1	2.96	--	5.46	%
Mr2	64.05	77.29	86.60	%
Rmr (10%)	9.39	18.72	1.24	%
Rmr (20%)	21.19	34.74	4.36	%
Rmr (30%)	40.28	50.16	10.82	%
Rmr (40%)	44.60	68.84	36.12	%
Rmr (50%)	50.64	74.46	54.44	%
Rmr (60%)	58.86	78.01	64.90	%
Rmr (70%)	69.47	80.35	84.90	%
Rmr (80%)	75.31	84.42	95.95	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	9.39	18.72	1.24	%
Rmr2 (0.0%, 20.0%)	21.19	34.74	4.36	%
Rmr2 (0.0%, 30.0%)	40.28	50.16	10.82	%
Rmr2 (0.0%, 40.0%)	44.60	68.84	36.12	%
Rmr2 (0.0%, 50.0%)	50.64	74.46	54.44	%
Rmr2 (0.0%, 60.0%)	58.86	78.01	64.90	%
Rmr2 (0.0%, 70.0%)	69.47	80.35	84.90	%

Table A20. Measurement results after wear for sample 2N12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	10.81	15.69	10.79	um
Rq	15.17	20.26	14.81	um
Rz	87.61	106.33	87.66	um
Rsk	−0.92	−0.60	−1.90	
Rku	6.22	3.80	8.94	
Rmr (10%)	28.03	6.33	8.99	%
Rmr (20%)	76.60	37.30	57.79	%
Rmr (30%)	92.03	67.93	81.81	%
Rmr (40%)	97.08	86.00	93.96	%
Rmr (50%)	98.62	91.33	97.38	%
Rmr (60%)	99.01	95.80	98.25	%
Rmr (70%)	99.37	97.75	98.86	%
Rmr (80%)	99.61	98.96	99.33	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	28.03	6.33	8.99	%
Rmr2 (0.0%, 20.0%)	76.60	37.30	57.79	%
Rmr2 (0.0%, 30.0%)	92.03	67.93	81.81	%

Table A20. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rmr2 (0.0%, 40.0%)	97.08	86.00	93.96	%
Rmr2 (0.0%, 50.0%)	98.62	91.33	97.38	%
Rmr2 (0.0%, 60.0%)	99.01	95.80	98.25	%
Rmr2 (0.0%, 70.0%)	99.37	97.75	98.86	%

Appendix C.4. Measured Values in Nano-Sized B4C Particles

Table A21. Measurement results before wear for sample 1B12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	1.78	2.16	1.57	µm
Rq	1.98	2.34	1.95	µm
Rz	3.41	3.58	5.50	µm
Rsk	1.37	1.25	1.57	
Rku	2.15	1.70	3.29	
Rk	3.75	2.97	3.98	µm
Rpk	2.78	3.54	2.67	µm
Rvk	0.33	0.65	0.43	µm
Mr1	16.98	20.45	15.34	%
Mr2	97.64	96.53	96.73	%
Rmr (10%)	1.10	3.06	0.51	%
Rmr (20%)	5.40	4.02	2.73	%
Rmr (30%)	10.29	5.36	5.70	%
Rmr (40%)	14.21	7.94	10.97	%
Rmr (50%)	21.57	12.74	17.32	%
Rmr (60%)	31.41	21.01	32.02	%
Rmr (70%)	53.08	32.55	49.50	%
Rmr (80%)	69.88	64.07	70.37	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	1.10	3.06	0.51	%
Rmr2 (0.0%, 20.0%)	5.40	4.02	2.73	%
Rmr2 (0.0%, 30.0%)	10.29	5.36	5.70	%
Rmr2 (0.0%, 40.0%)	14.21	7.94	10.97	%
Rmr2 (0.0%, 50.0%)	21.57	12.74	17.32	%
Rmr2 (0.0%, 60.0%)	31.41	21.01	32.02	%
Rmr2 (0.0%, 70.0%)	53.08	32.55	49.50	%

Table A22. Measurement results after wear for sample 1B12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	8.79	10.33	10.89	um
Rq	13.38	15.56	16.51	um
Rz	75.85	80.92	93.07	um
Rsk	−1.73	−1.95	−2.17	
Rku	10.44	8.07	10.24	
Rmr (10%)	18.86	7.70	5.53	%
Rmr (20%)	90.42	67.30	50.44	%
Rmr (30%)	95.08	90.54	89.94	%
Rmr (40%)	97.69	94.07	94.81	%
Rmr (50%)	98.65	96.23	97.17	%
Rmr (60%)	99.04	98.07	97.92	%
Rmr (70%)	99.39	98.59	99.02	%
Rmr (80%)	99.64	98.96	99.37	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	18.86	7.70	5.53	%
Rmr2 (0.0%, 20.0%)	90.42	67.30	50.44	%
Rmr2 (0.0%, 30.0%)	95.08	90.54	89.94	%
Rmr2 (0.0%, 40.0%)	97.69	94.07	94.81	%
Rmr2 (0.0%, 50.0%)	98.65	96.23	97.17	%
Rmr2 (0.0%, 60.0%)	99.04	98.07	97.92	%
Rmr2 (0.0%, 70.0%)	99.39	98.59	99.02	%

Table A23. Measurement results before wear for sample 2B12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra		1.83	1.43	µm
Rq		2.14	1.67	µm
Rz		7.46	3.94	µm
Rsk	0.77	0.59	1.13	
Rku	2.59	2.37	2.31	
Rk	3.32	4.22	3.20	µm
Rpk	2.42	3.63	1.39	µm
Rvk	1.00	3.97	0.85	µm
Mr1	22.19	23.08	12.09	%
Mr2	90.08	94.92	92.02	%
Rmr (10%)	1.59	1.41	1.30	%
Rmr (20%)	3.99	2.26	2.74	%
Rmr (30%)	10.13	8.37	7.92	%
Rmr (40%)	18.69	23.08	17.30	%

Table A23. *Cont.*

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Rmr (50%)	28.39	45.49	33.87	%
Rmr (60%)	42.78	84.73	50.79	%
Rmr (70%)	70.76	97.86	72.99	%
Rmr (80%)	86.52	98.46	89.44	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	1.59	1.41	1.30	%
Rmr2 (0.0%, 20.0%)	3.99	2.26	2.74	%
Rmr2 (0.0%, 30.0%)	10.13	8.37	7.92	%
Rmr2 (0.0%, 40.0%)	18.69	23.08	17.30	%
Rmr2 (0.0%, 50.0%)	28.39	45.49	33.87	%
Rmr2 (0.0%, 60.0%)	42.78	84.73	50.79	%
Rmr2 (0.0%, 70.0%)	70.76	97.86	72.99	%

Table A24. Measurement results after wear for sample 2B12.

Measured Parameters	Diagonal 1	Diagonal 2	Diagonal 3	Units
Ra	8.31	13.70	12.49	um
Rq	11.93	17.58	17.39	um
Rz	68.48	71.48	89.53	um
Rsk	−1.53	−1.18	−1.30	
Rku	6.82	3.64	6.16	
Rmr (10%)	4.18	13.44	29.36	%
Rmr (20%)	37.90	37.99	81.28	%
Rmr (30%)	81.79	71.57	93.39	%
Rmr (40%)	91.32	80.93	98.29	%
Rmr (50%)	95.38	87.78	99.30	%
Rmr (60%)	97.43	92.48	99.35	%
Rmr (70%)	98.63	94.61	99.43	%
Rmr (80%)	98.97	97.23	99.59	%
Initial wear	0.00	0.00	0.00	%
Rmr2 (0.0%, 10.0%)	4.18	13.44	29.36	%
Rmr2 (0.0%, 20.0%)	37.90	37.99	81.28	%
Rmr2 (0.0%, 30.0%)	81.79	71.57	93.39	%
Rmr2 (0.0%, 40.0%)	91.32	80.93	98.29	%
Rmr2 (0.0%, 50.0%)	95.38	87.78	99.30	%
Rmr2 (0.0%, 60.0%)	97.43	92.48	99.35	%
Rmr2 (0.0%, 70.0%)	98.63	94.61	99.43	%

Appendix D. Ra, Rq, Rz, Rsk, Rku, Rmr (10%), Rmr (20%), Rmr (30%), Rmr (40%), Rmr (50%), Rmr (60%), Rmr (70%), Rmr (80%), Rmr2 (0.0%, 10%), Rmr2 (0.0%, 20%), Rmr2 (0.0%, 30%), Rmr2 (0.0%, 40%), Rmr2 (0.0%, 50%), Rmr2 (0.0%, 60%), Rmr2 (0.0%, 70%)

Table A25. Measurement Ra parameter for every sample before and after wear.

Ra (μm)	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	1.01	1.03	1.17	17.58	15.00	13.54
E2	0.39	0.82	0.45	17.04	17.71	14.80
1M6	1.08	0.77	0.58	10.98	8.80	14.77
2M6	0.26	0.48	0.29	4.75	15.02	11.41
1M12	0.59	0.72	0.35	9.41	7.81	20.83
3M12	0.28	0.26	0.28	7.05	10.22	20.60
1N6	1.34	1.47	1.62	8.76	10.66	14.70
3N6	1.07	1.12	1.45	13.06	8.66	8.28
1N12	2.28	3.70	2.98	16.40	10.07	11.86
2N12	2.65	2.27	1.25	10.81	15.69	10.79
1B12	1.78	2.16	1.57	8.79	10.33	10.89
2B12		1.83	1.43	8.31	13.70	12.49

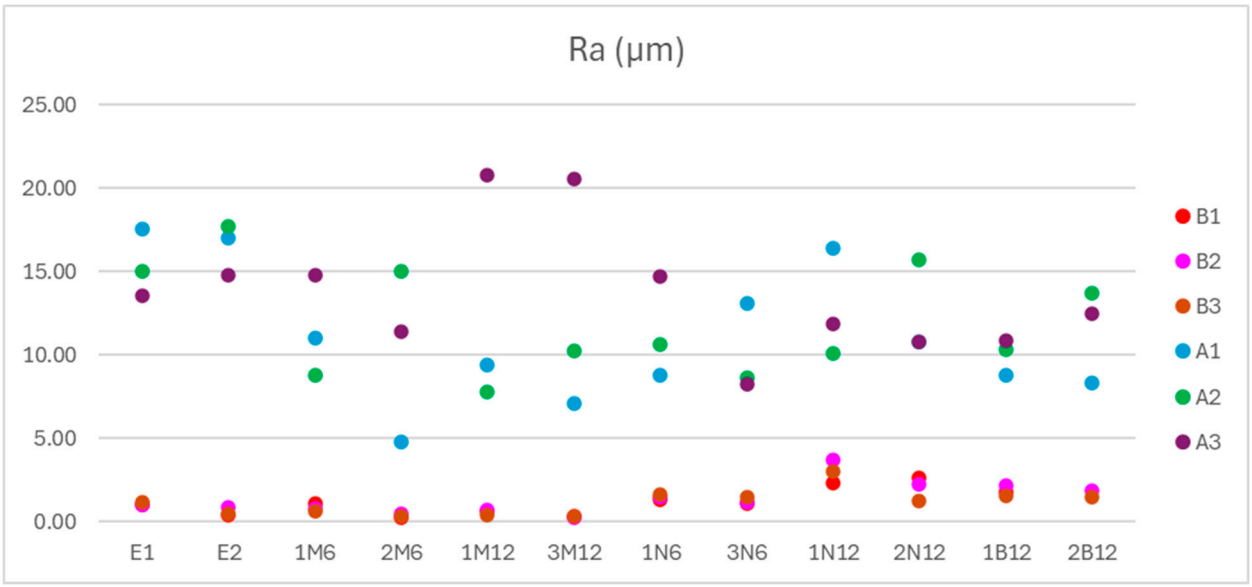

Figure A217. Plot for all the samples of Ra before and after wear.

Table A26. Measurement of Rq parameter for every sample before and after wear.

Rq (μm)	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	1.21	1.23	1.28	22.9	19.45	20.28
E2	0.54	0.89	0.7	22.97	25.08	19.01

Table A26. *Cont.*

Rq (µm)	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
1M6	1.22	0.89	0.69	15.65	12.11	21.94
2M6	0.32	0.55	0.34	8.27	21.7	17.36
1M12	0.66	0.84	0.39	13.34	12.72	29.23
3M12	0.33	0.34	0.32	11.63	15.82	30.53
1N6	1.38	1.52	1.73	14.22	13.88	19.84
3N6	1.14	1.21	1.5	18.78	12.13	11.21
1N12	2.42	3.94	3.27	21.42	13.79	15.36
2N12	2.85	2.5	1.45	15.17	20.26	14.81
1B12	1.98	2.34	1.95	13.38	15.56	16.51
2B12	0	2.14	1.67	11.93	17.58	17.39

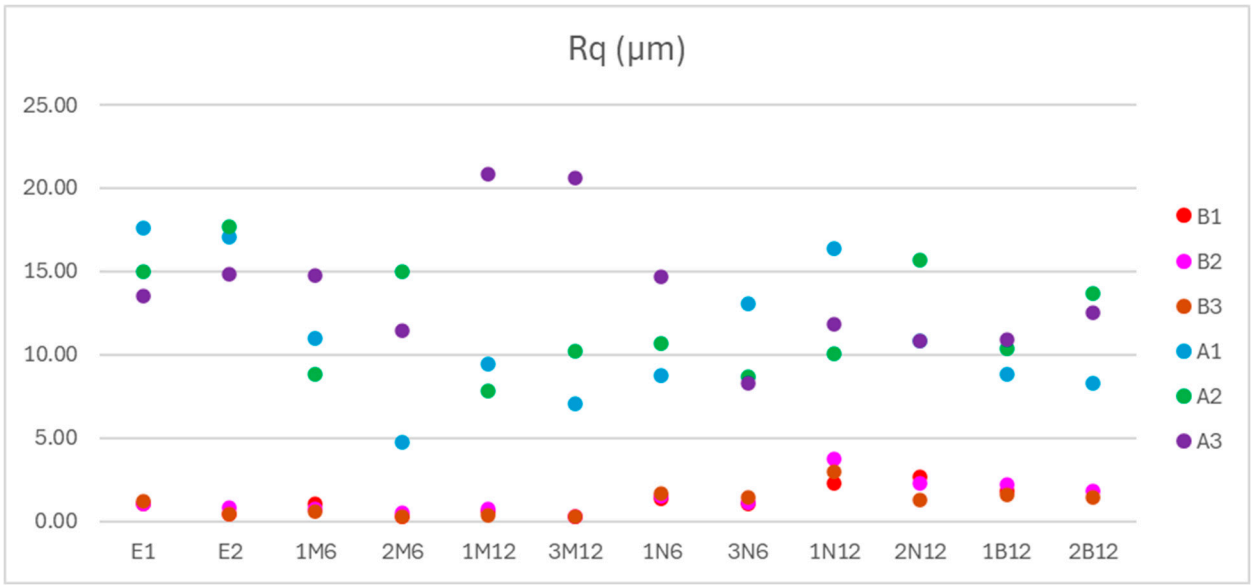

Figure A218. Plot for all the samples of Rq before and after wear.

Table A27. Measurement of Rz parameter for every sample before and after wear.

Rz (µm)	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	3.72	3.09	2.39	104.06	89.69	117.64
E2	3.22	2.41	4.33	121.74	138.01	88.89
1M6	3.88	2.04	1.66	77.14	57.23	112.06
2M6	1.26	1.66	1.08	49.19	119.18	83.04
1M12	1.38	2.18	1	88.39	78.4	136.39
3M12	1.07	1.06	1.08	77.96	93.89	147.06
1N6	1.42	1.87	2.46	77.14	69.98	99.25
3N6	1.87	2.4	1.58	99.21	66.98	60.17

Table A27. *Cont.*

Rz (µm)	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
1N12	3.31	5.84	5.61	118.26	91.95	71.66
2N12	4.49	3.94	4.64	87.61	106.33	87.66
1B12	3.41	3.58	5.5	75.85	80.92	93.07
2B12	0	7.46	3.94	68.48	71.48	89.53

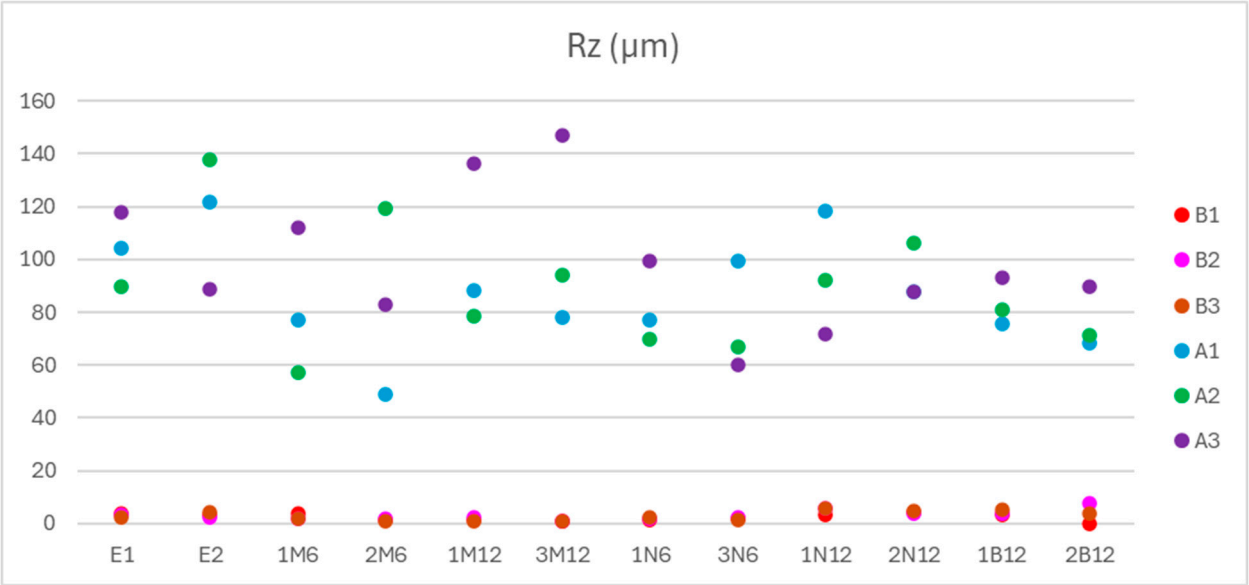

Figure A219. Plot for all the samples of Rz before and after wear.

Ra (average roughness), Rq (root mean square roughness), and Rz (maximum height of profile) generally increase after contact, indicating surface degradation or wear. Samples like E1, E2, and 1M6 show significant increases in Ra and Rz, suggesting material removal or plastic deformation during contact.

Table A28. Measurement of Rsk parameter for every sample before and after wear.

Rsk	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	1.9	1.44	1.29	−0.76	−0.67	−1.76
E2	0.73	1.07	2.62	−1.58	−1.63	−0.84
1M6	−1.33	−1.32	−0.94	−1.01	−0.95	−1.32
2M6	1.26	1.42	1.15	−1.56	−1.79	−1.89
1M12	−0.44	0.03	−0.77	−0.99	−1.8	−2.04
3M12	−0.29	−0.86	−0.05	−1.78	−1.88	−2.01
1N6	1.09	1	1.22	−1.6	−0.75	−0.37
3N6	1.11	1.17	1.1	−2.06	−1.99	−0.94
1N12	0.33	0.47	0.5	−1.12	−1.64	−0.33

Table A28. *Cont.*

Rsk	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
2N12	−0.02	0.14	−0.06	−0.92	−0.6	−1.9
1B12	1.37	1.25	1.57	−1.73	−1.95	−2.17
2B12	0.77	0.59	1.13	−1.53	−1.18	−1.3

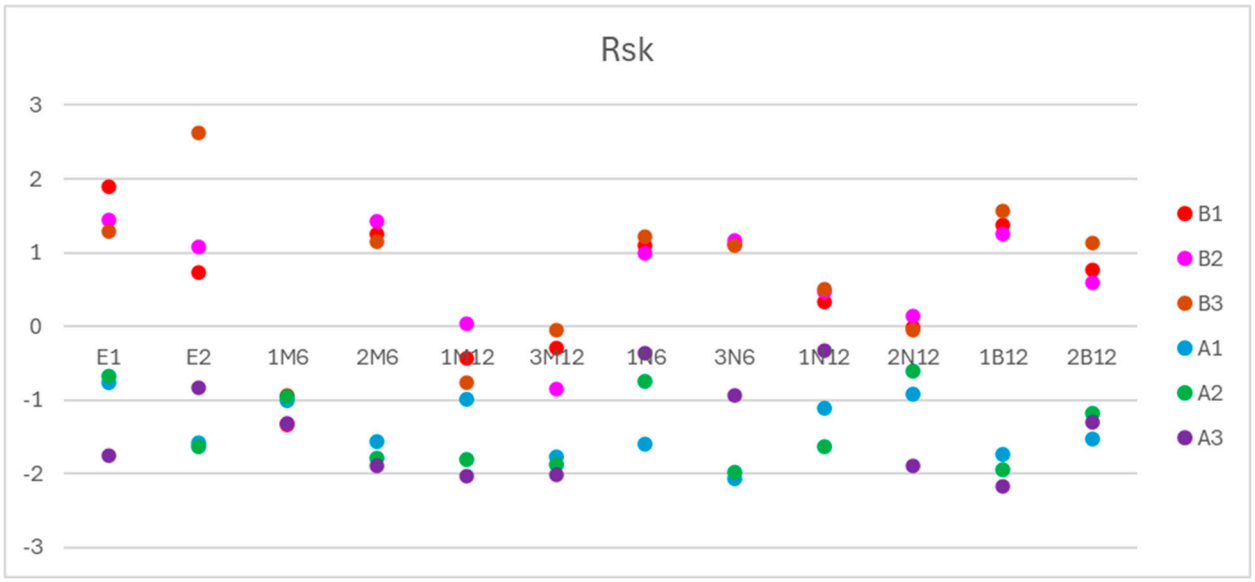

Figure A220. Plot for all the samples of Rsk before and after wear.

Rsk (skewness) values tend to shift from positive to negative, indicating a transition from peaked surfaces to plateaued or valley-dominated surfaces.

Table A29. Measurement of Rku parameter for every sample before and after wear.

Rku	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	5.98	2.41	1.86	3.77	3.9	9.22
E2	4.4	5.29	14.5	7.27	6.86	3.76
1M6	2.6	2.79	2.5	5.31	5.14	5.92
2M6	2.53	3.21	2.29	10.08	6.91	7.79
1M12	2.49	3.24	2.05	9.16	11.29	7.22
3M12	2.35	2.61	2.25	9.99	8.72	7.01
1N6	1.24	1.27	1.76	8.15	5.21	4.76
3N6	1.42	1.47	1.28	7.69	10.35	4.98
1N12	1.43	1.4	1.65	4.35	8.08	4
2N12	1.53	1.75	2.1	6.22	3.8	8.94
1B12	2.15	1.7	3.29	10.44	8.07	10.24
2B12	2.59	2.37	2.31	6.82	3.64	6.16

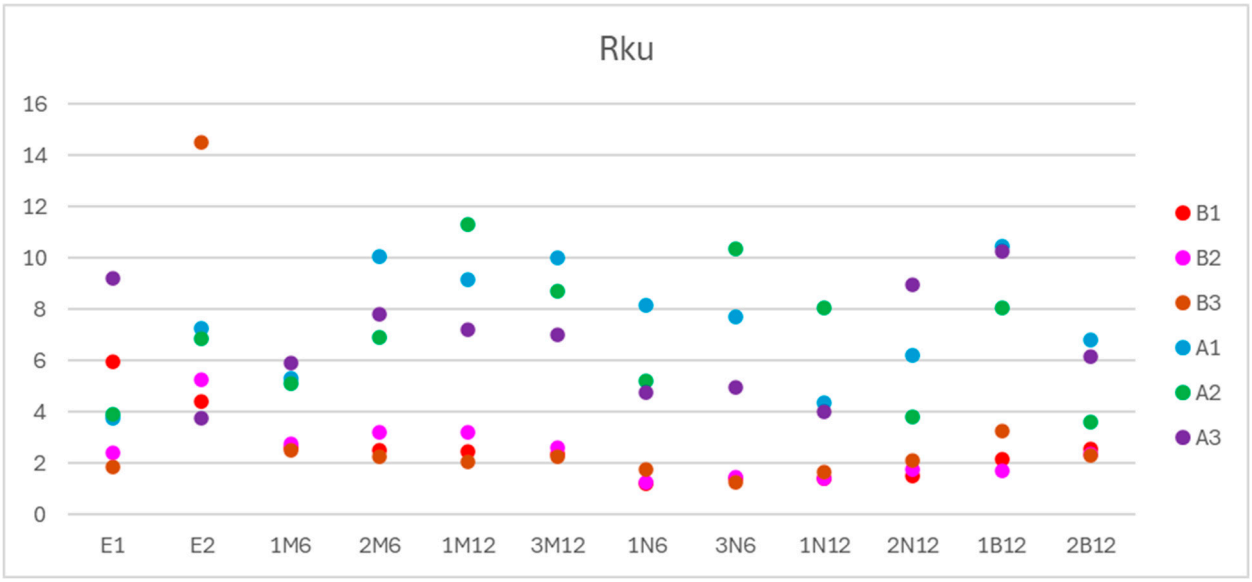

Figure A221. Plot for all the samples of Rku before and after wear.

Rku (kurtosis) values decrease in many samples, suggesting a flattening of surface features and a reduction in sharp peaks, which is consistent with wear.

In relation to the bearing area curve parameters, Rmr (material ratio) increases significantly at higher percentages (e.g., 50%, 60%, 70%, 80%) after contact, indicating that more surface area is in contact, which is typical of flattened or worn surfaces.

Table A30. Measurement of Rmr (10%) parameter for every sample before and after wear.

Rmr (10%)%	Before Wear			After Wear		
Sample	Diag. 1	Diag. 2	Diag. 3	Diag. 1	Diag. 2	Diag. 3
E1	0.18	0.55	0.35	6.3	8.41	7.16
E2	0.06	1.41	0.41	12.47	11.17	2.91
1M6	0.15	13.6	33.2	5.46	5.53	1.89
2M6	0.57	2.83	0.61	39.99	1.97	9.21
1M12	4.4	0.24	0.92	17.45	1.6	14.43
3M12	1.86	4.32	1	45.77	25.13	11.42
1N6	0.65	5.43	0.43	61.69	7.55	12.26
3N6	0.04	0.16	1.02	5.82	1.65	1.74
1N12	4.24	6.92	5.8	0.03	21.31	21.4
2N12	9.39	18.72	1.24	28.03	6.33	8.99
1B12	1.1	3.06	0.51	18.86	7.7	5.53
2B12	1.59	1.41	1.3	4.18	13.44	29.36

Table A31. Measurement of Rmr (20%) parameter for every sample before and after wear.

Rmr (20%)%	Before Wear			After Wear		
Sample	Diag. 1	Diag. 2	Diag. 3	Diag. 1	Diag. 2	Diag. 3
E1	0.33	1.93	2.51	19.38	58.24	58.71
E2	0.1	6.2	0.62	41.69	57	12.35
1M6	0.35	54.26	80.54	19.91	24.67	29.38

Table A31. *Cont.*

Rmr (20%)%	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
2M6	4.23	9.74	3.81	94.55	10.94	48.03
1M12	46.63	0.29	3.95	72.49	20.97	49.26
3M12	4.9	40.27	7.21	93.68	87.21	54.08
1N6	11.26	32.48	0.74	93.1	39.7	42.12
3N6	1.69	0.27	8.3	54.9	49.91	38.75
1N12	14.67	25.05	9.14	0.04	73.8	63.9
2N12	21.19	34.74	4.36	76.6	37.3	57.79
1B12	5.4	4.02	2.73	90.42	67.3	50.44
2B12	3.99	2.26	2.74	37.9	37.99	81.28

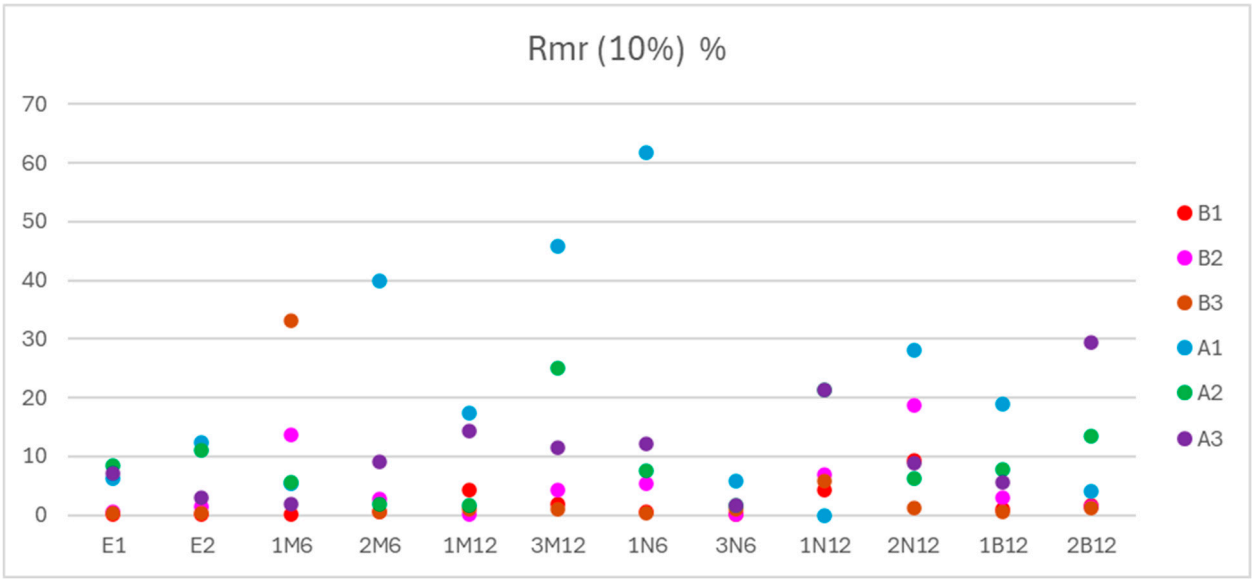

Figure A222. Plot for all the samples of Rmr (10%) before and after wear.

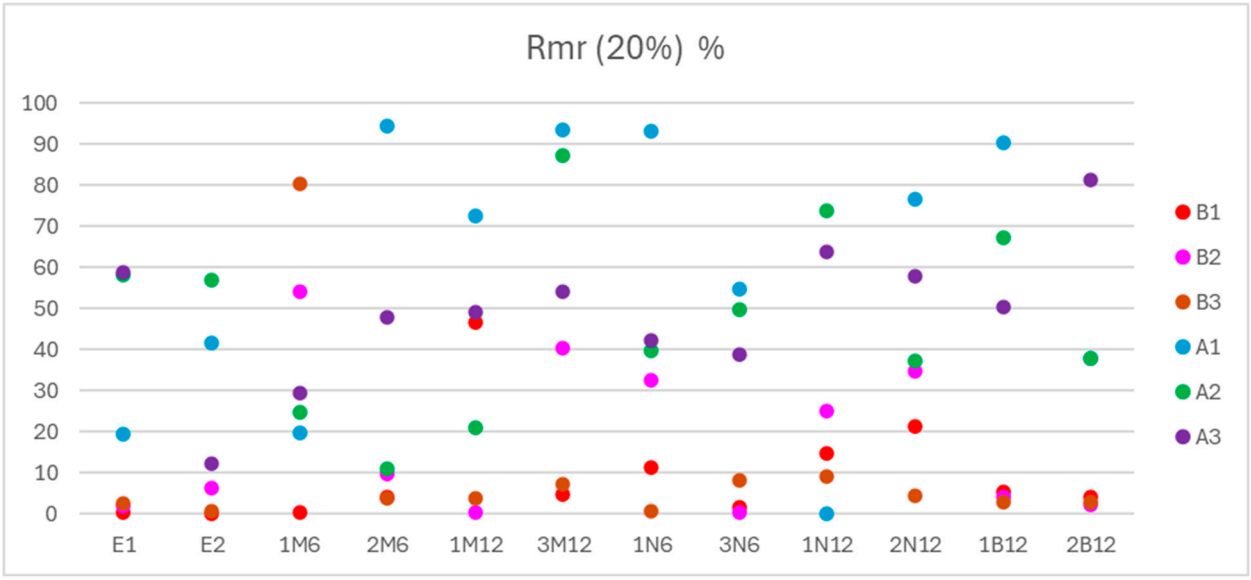

Figure A223. Plot for all the samples of Rmr (20%) before and after wear.

Table A32. Measurement of Rmr (30%) parameter for every sample before and after wear.

Rmr (30%)%	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	0.49	2.54	4.25	60.56	81.19	86.99
E2	0.25	10.17	0.81	76.24	85.4	47.88
1M6	0.7	68.34	86.51	67.96	65.04	85.45
2M6	11.43	12.09	13.04	95.42	77.48	88.37
1M12	74.84	2.24	12.46	93.89	87.44	83.16
3M12	11.38	76.75	15.39	97.38	95.84	91.63
1N6	36.67	59.89	7.58	96.61	85.11	84.85
3N6	9.76	2.49	10.23	85.17	87.5	89.4
1N12	43.48	52.04	11.85	1.59	91.32	89.2
2N12	40.28	50.16	10.82	92.03	67.93	81.81
1B12	10.29	5.36	5.7	95.08	90.54	89.94
2B12	10.13	8.37	7.92	81.79	71.57	93.39

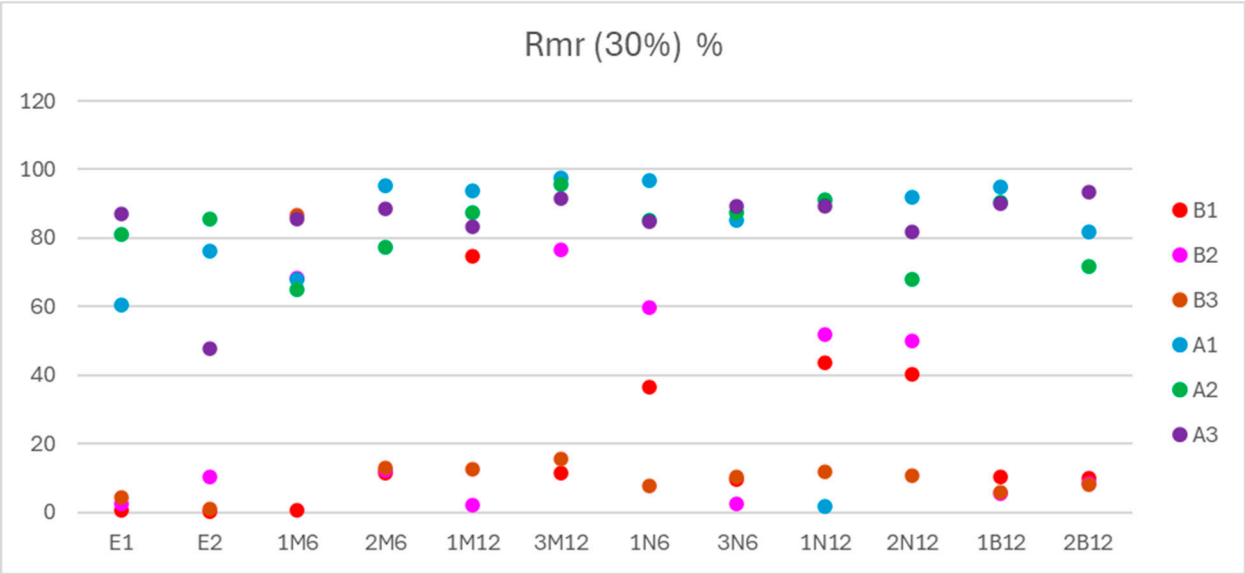

Figure A224. Plot for all the samples of Rmr (30%) before and after wear.

Table A33. Measurement of Rmr (40%) parameter for every sample before and after wear.

Rmr (40%)%	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	1.12	6	6.64	82.33	95.66	93.45
E2	0.39	14.93	0.86	90.08	93.19	77.76
1M6	0.8	74.89	89.71	85.82	86.79	95.41
2M6	24.77	15.13	26.84	96.89	91.66	92.68
1M12	83.49	12.36	31.18	97.17	97.23	88.19
3M12	17.93	88.3	22.6	98.68	97.3	93.33

Table A33. *Cont.*

Rmr (40%)%	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
1N6	66.98	73.73	19.47	98.18	91.72	92.12
3N6	25.12	6.73	14.38	90.53	94.77	94.66
1N12	63.47	62.99	23.28	30.56	96.33	95.52
2N12	44.6	68.84	36.12	97.08	86	93.96
1B12	14.21	7.94	10.97	97.69	94.07	94.81
2B12	18.69	23.08	17.3	91.32	80.93	98.29

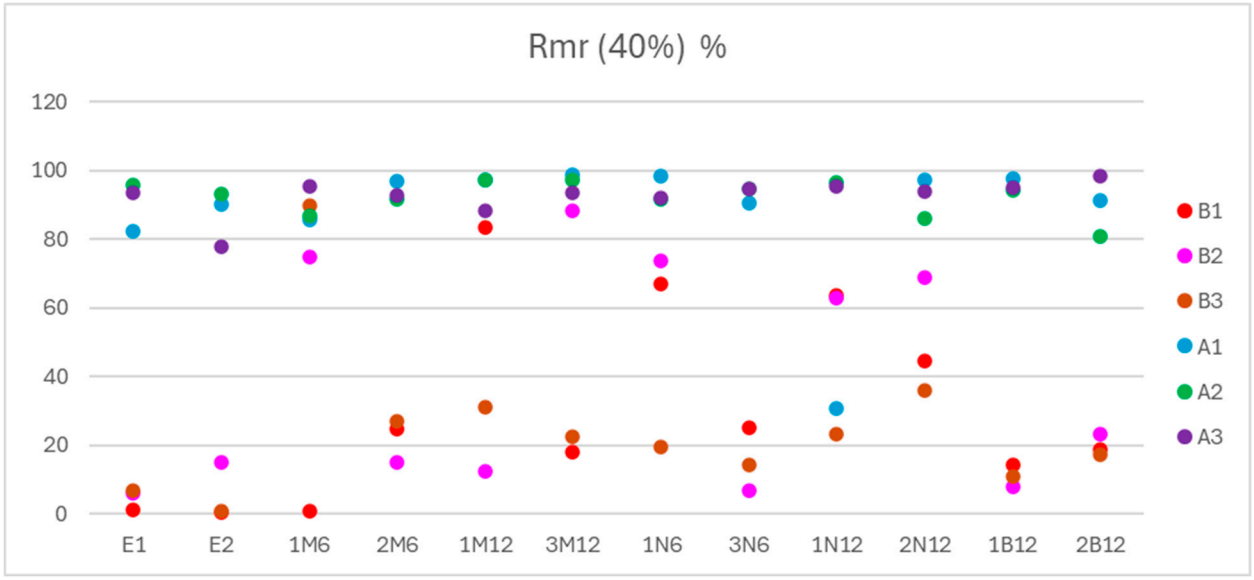

Figure A225. Plot for all the samples of Rmr (40%) before and after wear.

Table A34. Measurement of Rmr (50%) parameter for every sample before and after wear.

Rmr (50%)%	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	5.41	10.4	8.95	89	96.7	95.39
E2	7.6	18.32	1.12	94.18	96.24	91.02
1M6	12.23	85.33	92.65	91.5	93.12	97.01
2M6	44.66	26.45	56.7	97.45	95.66	94.11
1M12	87.65	61.68	63.23	98.4	98.44	91.78
3M12	27.62	94.24	41.69	99	98.28	94.92
1N6	81.65	78.53	33.83	98.73	94.01	94.08
3N6	51.83	16.12	23.35	94.08	97.13	97.2
1N12	71.18	69.43	46.47	80.18	97.99	96.82
2N12	50.64	74.46	54.44	98.62	91.33	97.38
1B12	21.57	12.74	17.32	98.65	96.23	97.17
2B12	28.39	45.49	33.87	95.38	87.78	99.3

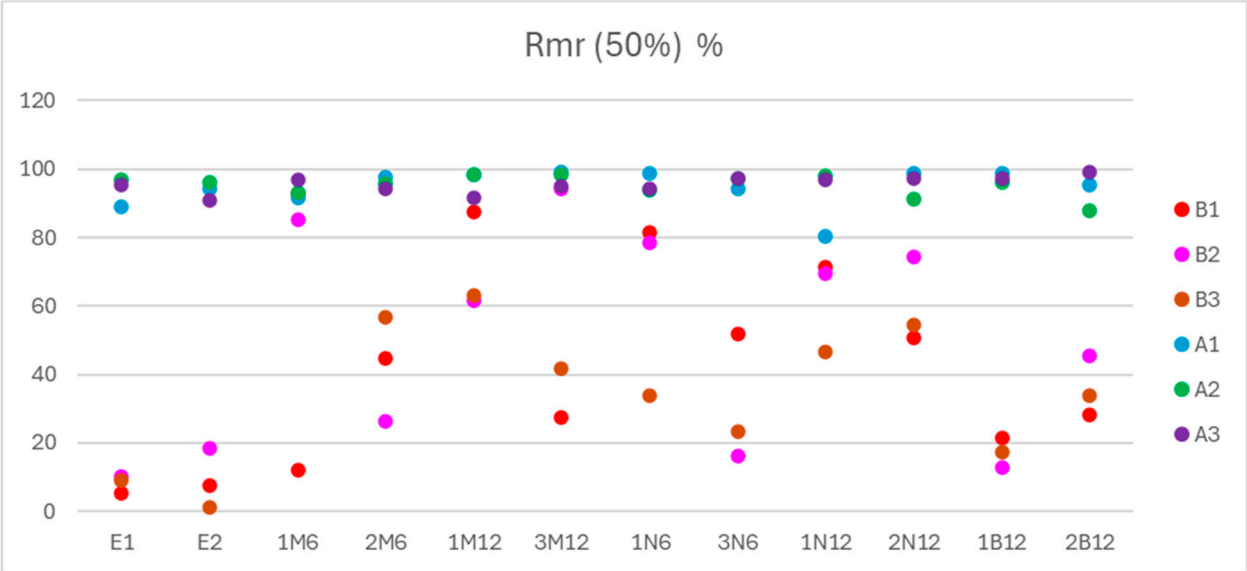

Figure A226. Plot for all the samples of Rmr (50%) before and after wear.

Table A35. Measurement of Rmr (60%) parameter for every sample before and after wear.

Rmr (60%)%	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	17.35	14.78	12.12	93.15	97.46	96.73
E2	86.54	22.37	1.44	97.79	97.39	95.36
1M6	76.63	89.12	94.49	96.06	94.87	98.13
2M6	69.39	56.09	86.09	98.76	98.45	95.94
1M12	90.87	80.87	83.85	99.13	99.18	95.14
3M12	60.6	95.84	62.07	99.23	99.09	96.26
1N6	88.99	86.4	65.37	98.91	97.52	97.22
3N6	64.5	38.83	38.54	96.28	98.59	98.74
1N12	76.33	75.72	64.09	93.92	98.9	97.9
2N12	58.86	78.01	64.9	99.01	95.8	98.25
1B12	31.41	21.01	32.02	99.04	98.07	97.92
2B12	42.78	84.73	50.79	97.43	92.48	99.35

Table A36. Measurement of Rmr (70%) parameter for every sample before and after wear.

Rmr (70%)%	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	30.46	23.04	1.17	95.16	98.32	98.29
E2	98.95	32.28	4.26	99.35	98.39	97.61
1M6	88.2	92.98	95.47	98.98	96.02	99.11
2M6	89.31	89.95	96.9	99.36	99.06	96.79
1M12	93.99	89.48	90.84	99.47	99.47	97.05
3M12	85.57	96.87	87.88	99.47	99.36	97.94
1N6	95.35	87.81	90.07	99.09	98.38	98.77

Table A36. *Cont.*

Rmr (70%)%	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
3N6	79.46	68.44	65.89	97.48	99.58	99.43
1N12	82.24	79.83	78.14	96.49	99.3	99
2N12	69.47	80.35	84.9	99.37	97.75	98.86
1B12	53.08	32.55	49.5	99.39	98.59	99.02
2B12	70.76	97.86	72.99	98.63	94.61	99.43

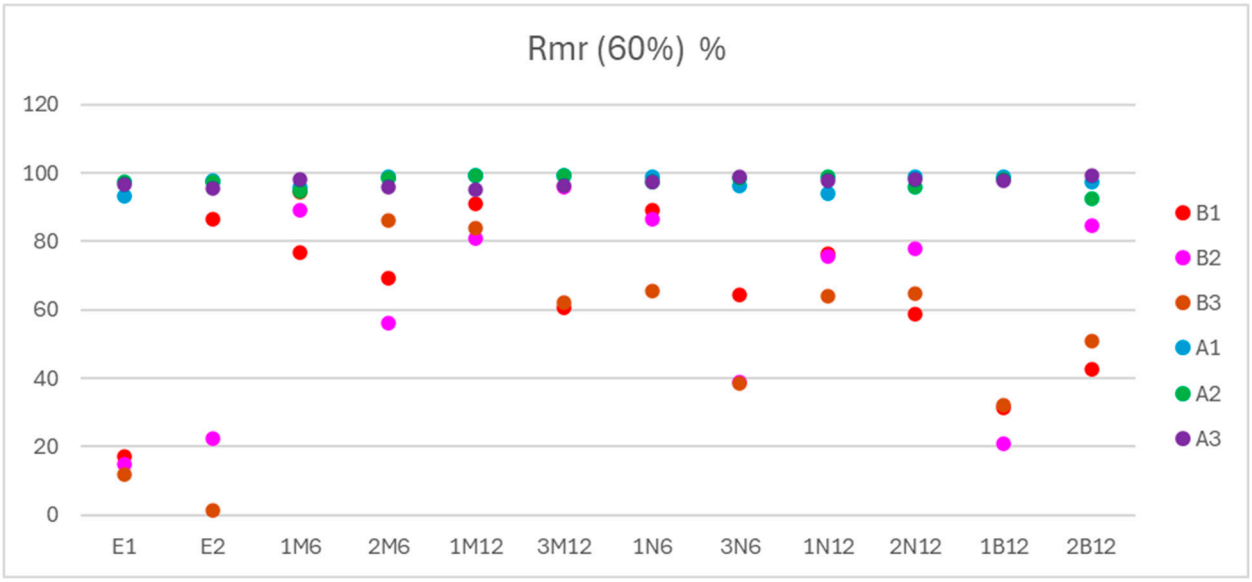

Figure A227. Plot for all the samples of Rmr (60%) before and after wear.

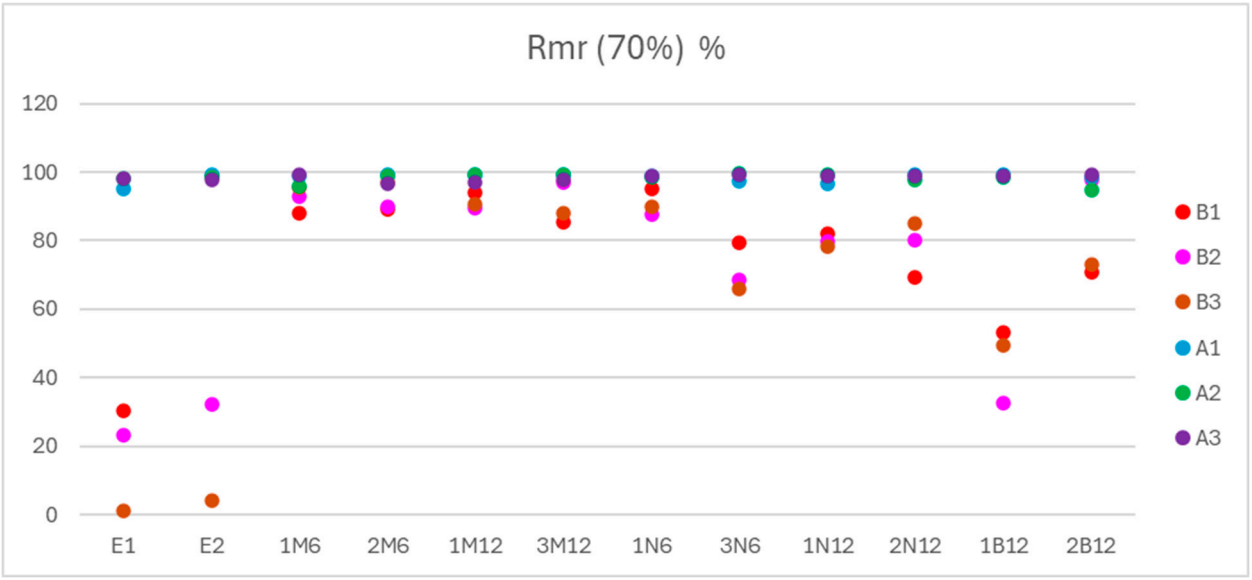

Figure A228. Plot for all the samples of Rmr (70%) before and after wear.

Table A37. Measurement of Rmr (80%) parameter for every sample before and after wear.

Rmr (80%)%	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	58.55	40.29	1.28	97.15	98.96	99.06
E2	99.11	56.68	18.67	99.57	99.08	98.76
1M6	91.57	0.77	97.01	99.48	98.69	99.46
2M6	97.55	98.49	99	99.71	99.5	97.83
1M12	96.15	92.46	96.44	99.67	99.63	98.15
3M12	93.29	97.8	96.76	99.63	99.59	99.1
1N6	97.78	89.7	95.76	99.48	99.06	99.17
3N6	88.1	88.68	81.16	98.87	99.71	99.55
1N12	84.87	84.03	88.86	97.95	99.55	99.6
2N12	75.31	84.42	95.95	99.61	98.96	99.33
1B12	69.88	64.07	70.37	99.64	98.96	99.37
2B12	86.52	98.46	89.44	98.97	97.23	99.59

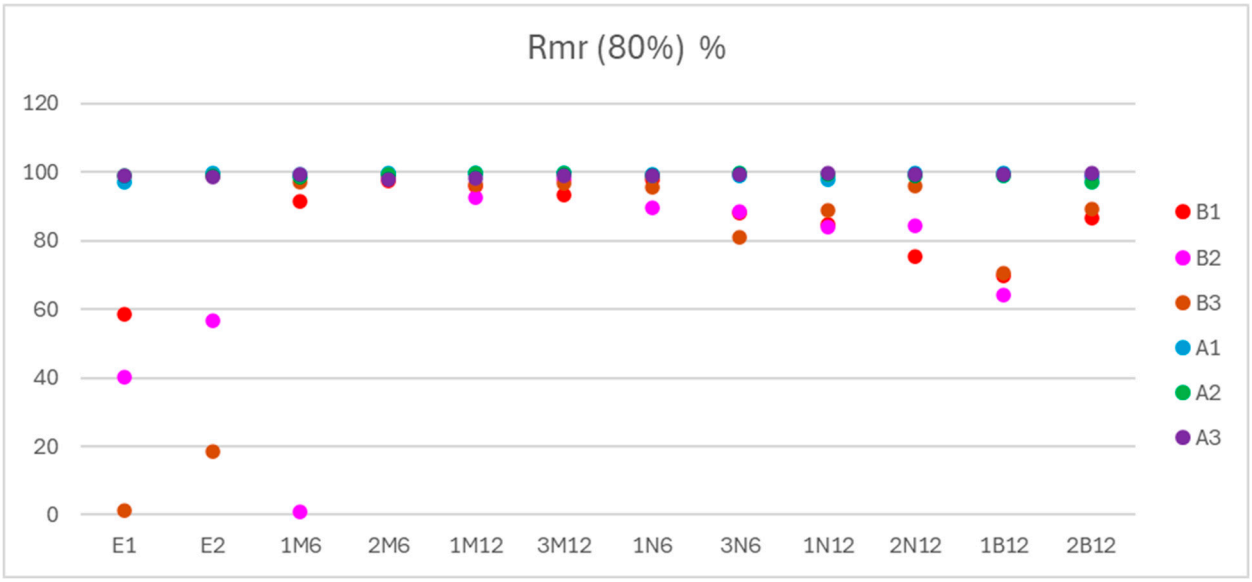

Figure A229. Plot for all the samples of Rmr (80%) before and after wear.

Table A38. Measurement of Rmr2 (0.0%, 10%) parameter for every sample before and after wear.

Rmr2 (0.0%, 10%) %	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	0.18	0.55	1.29	6.3	8.41	7.16
E2	0.06	1.41	0.41	12.47	11.17	2.91
1M6	0.15	2.04	33.2	5.46	5.53	1.89
2M6	0.57	2.83	0.61	0	1.97	9.21
1M12	4.4	0.24	0.92	17.45	0	14.43
3M12	1.86	4.32	1	45.77	25.13	11.42
1N6	0.65	5.43	0.43	61.69	7.55	12.26

Table A38. *Cont.*

Rmr2 (0.0%, 10%) %	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
3N6	0.04	0.16	1.02	5.82	1.65	1.74
1N12	4.24	6.92	5.8	0.03	21.31	21.4
2N12	9.39	18.72	1.24	28.03	6.33	8.99
1B12	1.1	3.06	0.51	18.86	7.7	5.53
2B12	1.59	1.41	1.3	4.18	13.44	29.36

Rmr2, which measures the material ratio between two heights, also shows a marked increase, reinforcing the conclusion of surface smoothing and increased contact area.

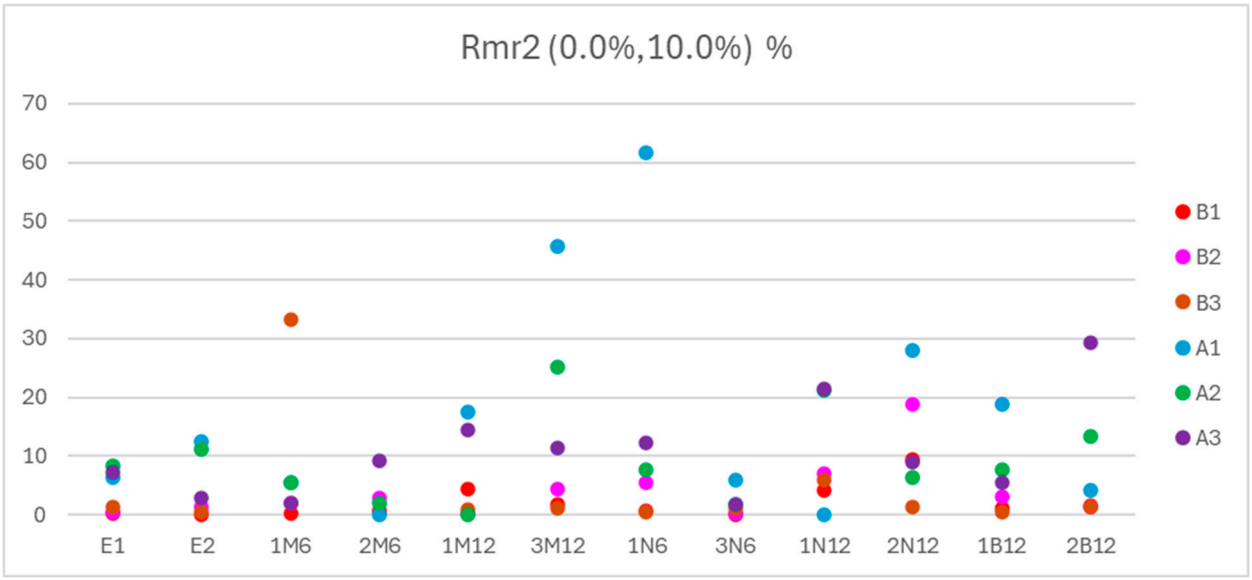

Figure A230. Plot for all the samples of Rmr2 (0.0%, 10.0%) before and after wear.

Table A39. Measurement of Rmr2 (0.0%, 20%) parameter for every sample before and after wear.

Rmr2 (0.0%, 20%) %	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	0.33	1.93	1.86	19.38	58.24	58.71
E2	0.1	6.2	0.62	41.69	57	12.35
1M6	0.35	−1.32	80.54	19.91	24.67	29.38
2M6	4.23	9.74	3.81	39.99	10.94	48.03
1M12	46.63	0.29	3.95	72.49	1.6	49.26
3M12	4.9	40.27	7.21	93.68	87.21	54.08
1N6	11.26	32.48	0.74	93.1	39.7	42.12
3N6	1.69	0.27	8.3	54.9	49.91	38.75
1N12	14.67	25.05	9.14	0.04	73.8	63.9
2N12	21.19	34.74	4.36	76.6	37.3	57.79
1B12	5.4	4.02	2.73	90.42	67.3	50.44
2B12	3.99	2.26	2.74	37.9	37.99	81.28

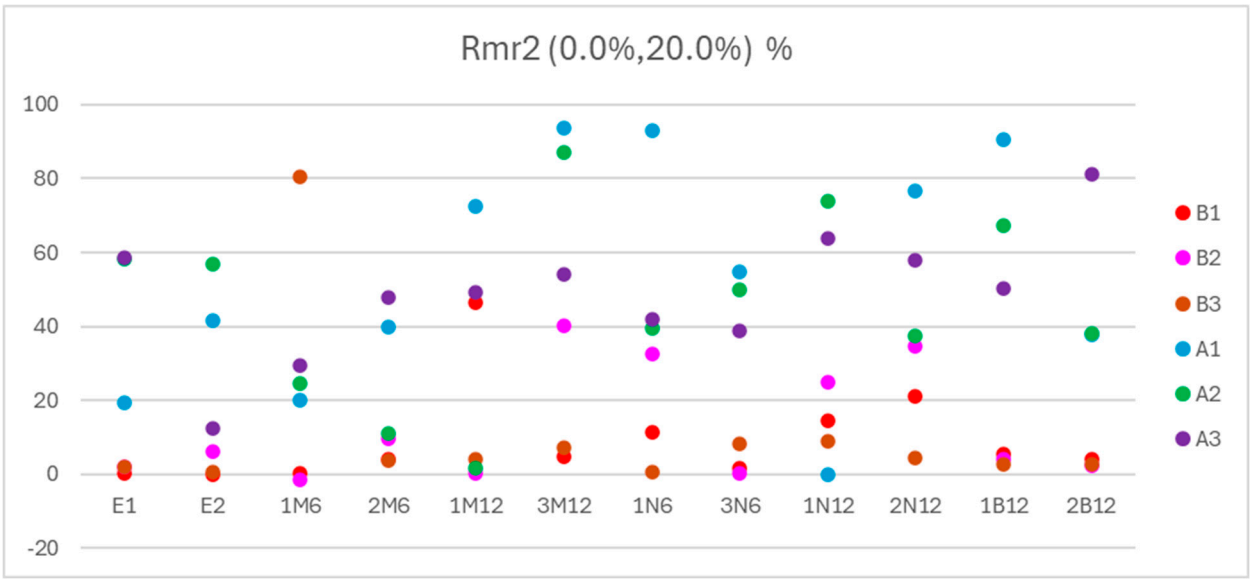

Figure A231. Plot for all the samples of Rmr2 (0.0%, 20.0%) before and after wear.

Table A40. Measurement of Rmr2 (0.0%, 30%) parameter for every sample before and after wear.

Rmr2 (0.0%, 30%) %	Before Wear			After Wear		
Sample	Diag. 1	Diag. 2	Diag. 3	Diag. 1	Diag. 2	Diag. 3
E1	0.49	2.54	1.29	60.56	81.19	86.99
E2	0.25	10.17	0.81	76.24	85.4	47.88
1M6	0.7	2.79	86.51	67.96	65.04	85.45
2M6	11.43	12.09	13.04	94.55	77.48	88.37
1M12	74.84	2.24	12.46	93.89	20.97	83.16
3M12	11.38	76.75	15.39	97.38	95.84	91.63
1N6	36.67	59.89	7.58	96.61	85.11	84.85
3N6	9.76	2.49	10.23	85.17	87.5	89.4
1N12	43.48	52.04	11.85	1.59	91.32	89.2
2N12	40.28	50.16	10.82	92.03	67.93	81.81
1B12	10.29	5.36	5.7	95.08	90.54	89.94
2B12	10.13	8.37	7.92	81.79	71.57	93.39

Table A41. Measurement of Rmr2 (0.0%, 40%) parameter for every sample before and after wear.

Rmr2 (0.0%, 40%) %	Before Wear			After Wear		
Sample	Diag. 1	Diag. 2	Diag. 3	Diag. 1	Diag. 2	Diag. 3
E1	1.12	6	2.6	82.33	95.66	93.45
E2	0.39	14.93	0.86	90.08	93.19	77.76
1M6	0.8	0.84	89.71	85.82	86.79	95.41
2M6	24.77	15.13	26.84	95.42	91.66	92.68
1M12	83.49	12.36	31.18	97.17	87.44	83.16
3M12	17.93	88.3	22.6	98.68	97.3	93.33
1N6	66.98	73.73	19.47	98.18	91.72	92.12

Table A41. *Cont.*

Rmr2 (0.0%, 40%) %	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
3N6	25.12	6.73	14.38	90.53	94.77	94.66
1N12	63.47	62.99	23.28	30.56	96.33	95.52
2N12	44.6	68.84	36.12	97.08	86	93.96
1B12	14.21	7.94	10.97	97.69	94.07	94.81
2B12	18.69	23.08	17.3	91.32	80.93	98.29

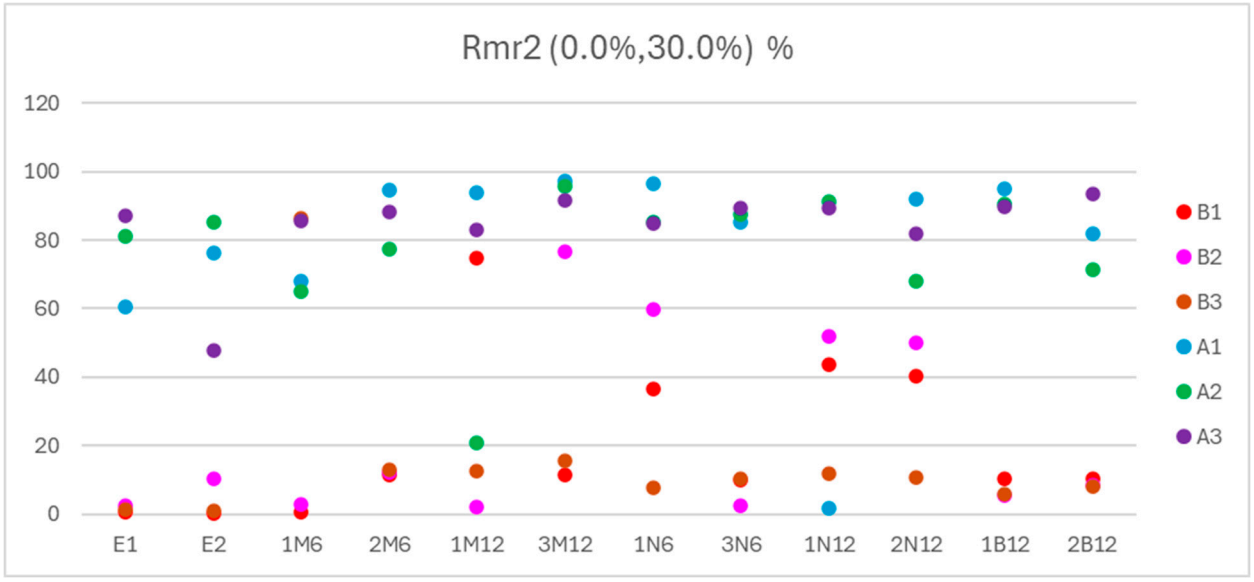

Figure A232. Plot for all the samples of Rmr2 (0.0%, 30.0%) before and after wear.

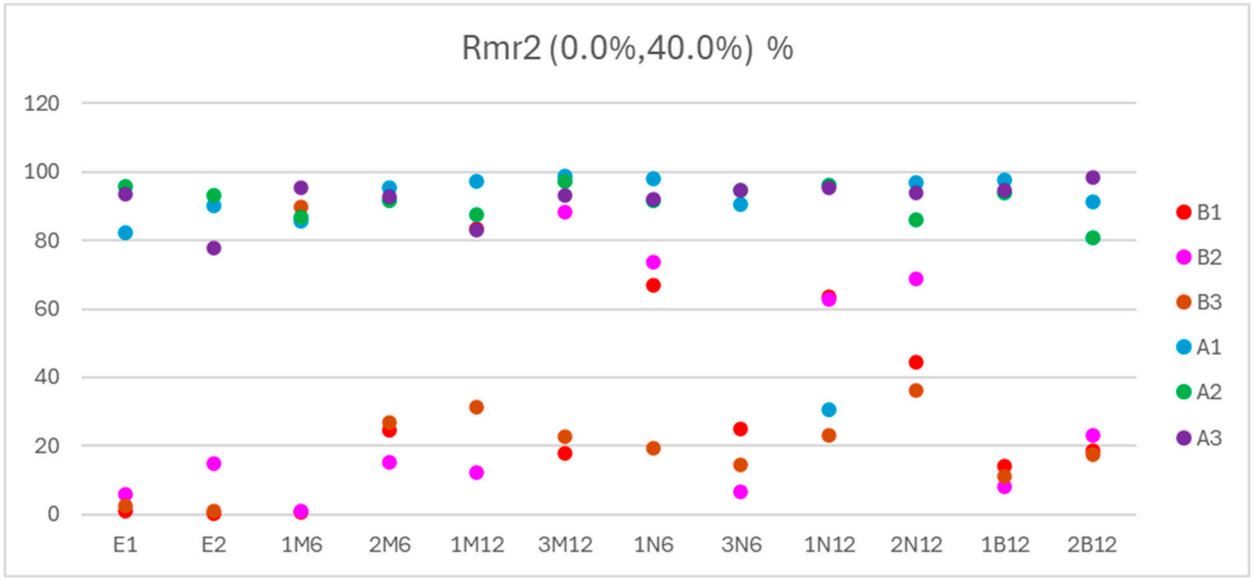

Figure A233. Plot for all the samples of Rmr2 (0.0%, 40.0%) before and after wear.

Table A42. Measurement of Rmr2 (0.0%, 50%) parameter for every sample before and after wear.

Rmr2 (0.0%, 50%) %	Before Wear			After Wear		
Sample	Diag. 1	Diag. 2	Diag. 3	Diag. 1	Diag. 2	Diag. 3
E1	5.41	10.4	0.16	89	96.7	95.39
E2	7.6	18.32	1.12	94.18	96.24	91.02
1M6	12.23	0.17	92.65	91.5	93.12	97.01
2M6	44.66	26.45	56.7	96.89	95.66	94.11
1M12	87.65	61.68	63.23	98.4	97.23	88.19
3M12	27.62	94.24	41.69	99	98.28	94.92
1N6	81.65	78.53	33.83	98.73	94.01	94.08
3N6	51.83	16.12	23.35	94.08	97.13	97.2
1N12	71.18	69.43	46.47	80.18	96.33	96.82
2N12	50.64	74.46	54.44	98.62	91.33	97.38
1B12	21.57	12.74	17.32	98.65	96.23	97.17
2B12	28.39	45.49	33.87	95.38	87.78	99.3

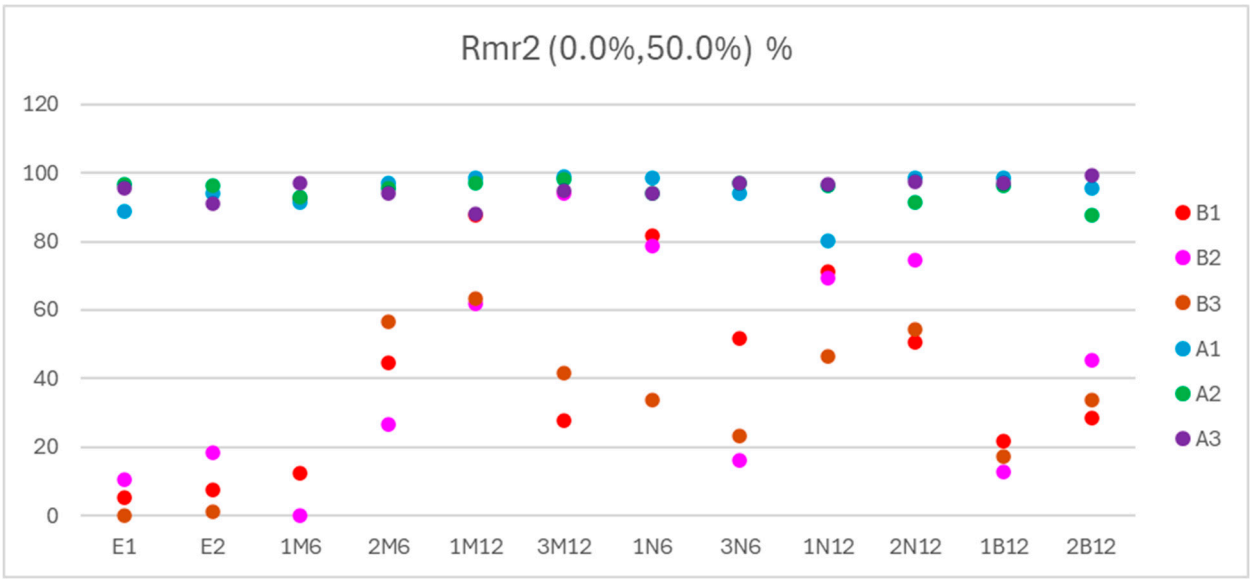

Figure A234. Plot for all the samples of Rmr2 (0.0%, 50.0%) before and after wear.

Table A43. Measurement of Rmr2 (0.0%, 60%) parameter for every sample before and after wear.

Rmr2 (0.0%, 60%) %	Before Wear			After Wear		
Sample	Diag. 1	Diag. 2	Diag. 3	Diag. 1	Diag. 2	Diag. 3
E1	17.35	14.78	30.23	93.15	97.46	96.73
E2	86.54	22.37	1.44	97.79	97.39	95.36
1M6	76.63	2.15	94.49	96.06	94.87	98.13
2M6	69.39	56.09	86.09	97.45	98.45	95.94
1M12	90.87	80.87	83.85	99.13	98.44	91.78
3M12	60.6	95.84	62.07	99.23	99.09	96.26

Table A43. *Cont.*

Rmr2 (0.0%, 60%) %	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
1N6	88.99	86.4	65.37	98.91	97.52	97.22
3N6	64.5	38.83	38.54	96.28	98.59	98.74
1N12	76.33	75.72	64.09	93.92	97.99	97.9
2N12	58.86	78.01	64.9	99.01	95.8	98.25
1B12	31.41	21.01	32.02	99.04	98.07	97.92
2B12	42.78	84.73	50.79	97.43	92.48	99.35

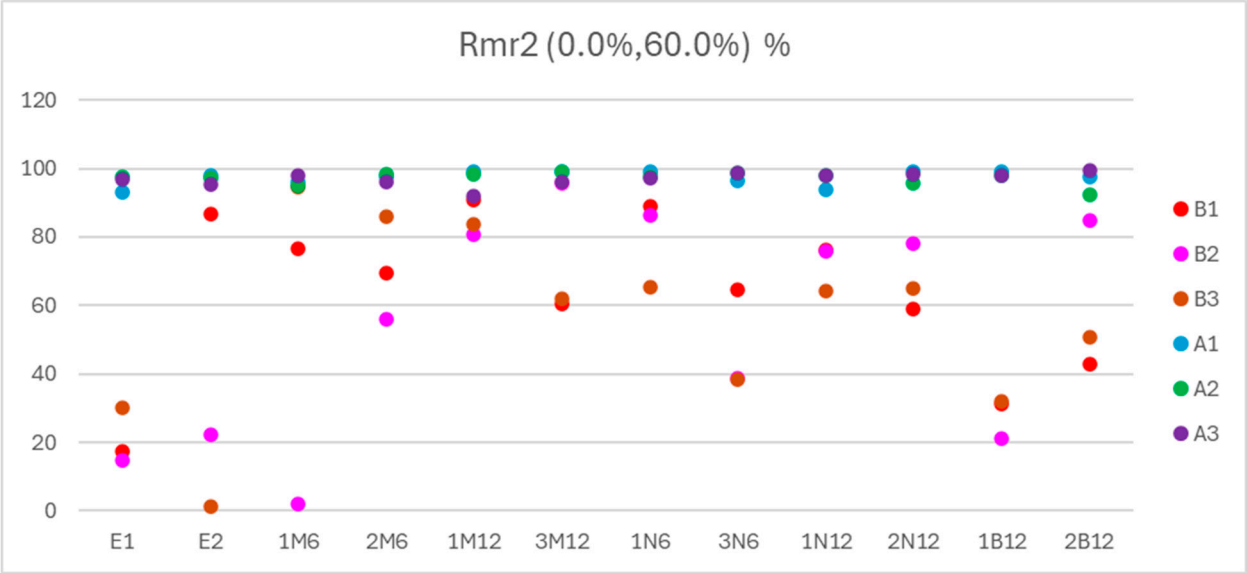

Figure A235. Plot for all the samples of Rmr2 (0.0%, 60.0%) before and after wear.

Table A44. Measurement of Rmr2 (0.0%, 70%) parameter for every sample before and after wear.

Rmr2 (0.0%, 70%) %	Before Wear			After Wear		
Sample	**Diag. 1**	**Diag. 2**	**Diag. 3**	**Diag. 1**	**Diag. 2**	**Diag. 3**
E1	30.46	23.04	96.42	95.16	98.32	98.29
E2	98.95	32.28	4.26	99.35	98.39	97.61
1M6	88.2	4.31	95.47	98.98	96.02	99.11
2M6	89.31	89.95	96.9	98.76	99.06	96.79
1M12	93.99	89.48	90.84	99.47	99.18	95.14
3M12	85.57	96.87	87.88	99.47	99.36	97.94
1N6	95.35	87.81	90.07	99.09	98.38	98.77
3N6	79.46	68.44	65.89	97.48	99.58	99.43
1N12	82.24	79.83	78.14	96.49	98.9	99
2N12	69.47	80.35	84.9	99.37	97.75	98.86
1B12	53.08	32.55	49.5	99.39	98.59	99.02
2B12	70.76	97.86	72.99	98.63	94.61	99.43

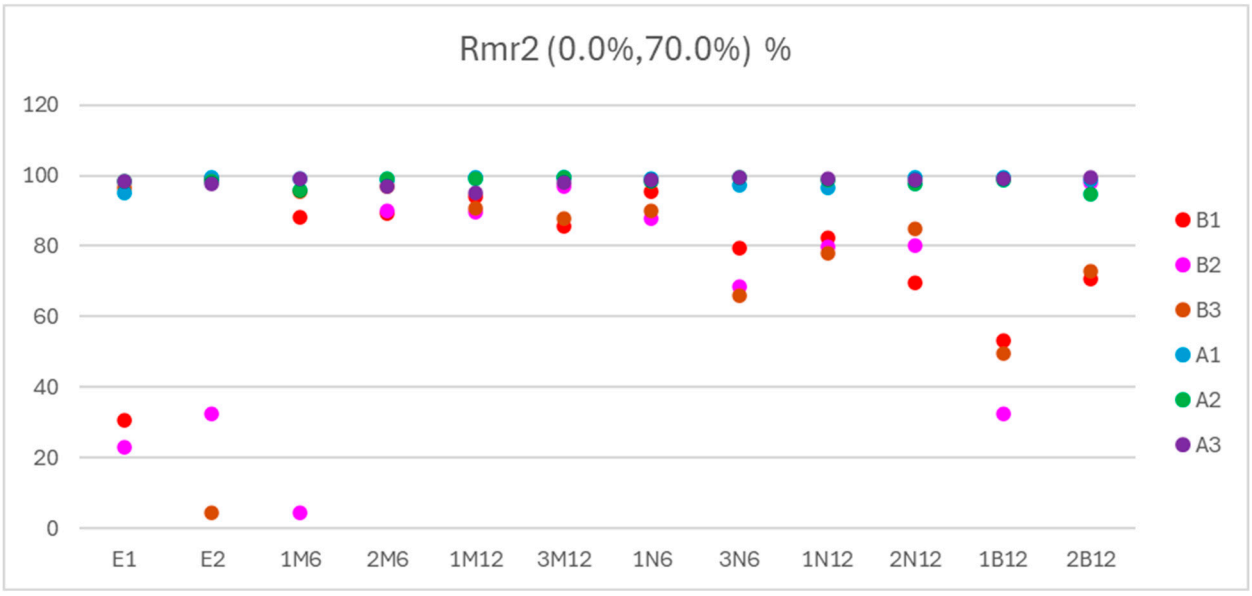

Figure A236. Plot for all the samples of Rmr2 (0.0%, 70.0%) before and after wear.

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