Superfinishing Process of Ball Bearings

İrem Gül Aslanbaş[1*] (iD) Samet Akar[1**] (iD)

[1] Department of Mechanical Engineering, Çankaya University, Ankara, Türkiye

Keywords	Abstract
Superfinishing, Ball bearings, Surface, Ra, Rz.	Superfinishing is one of the most crucial machining process stage in the production of ball bearings. This process determines the quality, form, and geometry of ball bearing raceway. The factors influencing the performance of the superfinishing process are not only processing parameters but also the characteristics of the superfinishing stone used. In this study, experiments with different material components and chemical compositions of stones were conducted to achieve the desired surface topography, specifically on the inner raceway of a 6206-type bearing. In experiments using four different superfinishing stones, Ra and Rz measurements were taken to evaluate the performance of the stones. As a result of the experiments, it was observed that the White Alumina stone provided the best Ra results in these process parameters.

1. Introduction

Superfinishing stands out as the paramount step in the machining process for manufacturing ball bearings, exerting a significant influence on quality, desired form, and geometry [1]. It plays a crucial role in decreasing surface roughness and enhancing bearing load capacity [2], fatigue resistance [3], microstructure, and surface topography, thereby impacting bearing functionality [4], surface quality, and achieving high form accuracy [5]. Additionally, superfinishing contributes to exceptional wear resistance and low friction characteristics [6], exhibiting a negative skew that implies the presence of a limited number of high peaks capable of eroding rapidly, along with deep valleys that retain traces of lubricant [7].

Stone honing, initially employed by The Timken Company in the early 1930s, marked the inception of finishing raceways for tapered roller bearings [1]. Notably, strong secured the first patent for a superfinishing machine for ball-bearing raceways in 1935, followed by Conner obtaining the second patent for superfinishing cylindrical surfaces in 1936. The term "superfinishing" had not been coined at that time. Following grinding, the utilization of a fine abrasive technique called superfinishing became standard practice for creating precise bearing surfaces.

Emphasizing the pivotal role of superfinishing in achieving the desired surface quality, this study expands its scope to elucidate the nuanced interplay between microstructure and surface topography, with a keen focus on their consequential impact on bearing functionality [4]. Superfinishing, an abrasive finishing technique, involves oscillating a bonded abrasive stone at high frequencies while simultaneously loading it onto the spinning workpiece's surface. This procedure is instrumental in producing superior surface topography, including roughness and waviness, and refining the geometry of engineering components after grinding or turning [8, 9].

Furthermore, our investigation delves into the precious raceway of the surface obtained after the removal of the stone chip. The stone operates under a specific amount of pressure on the rotating component, contributing to the overall effectiveness of the superfinishing process.

Superfinishing stones produced from materials such as SiC, FA, WA, and CBN find applications in various industrial fields. Superfinishing stones derived from materials including silicon carbide (SiC), Fused Alumina (FA), White Alumina (WA), and Cubic Boron Nitride (CBN) are widely employed across diverse industrial sectors. The increasing use of CBN stones in recent times has prompted this experimental study, which aims to examine the performance of CBN stones compared to other stones.

This paper focuses on the performance of different stone types in chip removal under identical processing conditions. It aims to investigate how these stones will demonstrate machining performance under the same processing conditions. The behavior of CBN stones in conjunction with stones having different grit sizes but the same binder is examined, with a specific emphasis on their superfinishing performance

The parameters Ra and Rz have been the subject of investigation in this study, owing to their widespread usage and ease of quick measurement within the industrial domain. During production, Ra plays a pivotal role in facilitating rapid decision-making and determining the manufacturing conditions for bearings.

2. Experimental

In the experimental phase of this investigation, the focus was directed toward the analysis of profile parameters about the processed inner rings of diverse stone structures subjected to identical processing conditions. A comprehensive set of 125 pieces was processed for each stone variant, and meticulous measurements of surface parameters were conducted both before and after the processing of each piece.

Particular emphasis was placed on the examination of Type 6206 inner rings, and the experimental setup involved two distinct stations denoted as the first and second stations. The first station was involved in stock removal processes, while the second station was specifically dedicated to activities related to mirroring. Notably, the surface characteristics of the 6206 inner rings' raceway, with a Ra range of approximately 0.450 µm, were meticulously scrutinized.

To ensure precision in surface measurements, Taylor Hobson PGI 1230 device was employed in this experimental study. This device is capable of measuring only the surface profile parameters, specifically the Ra and Rz values, through linear measurement. The device facilitated accurate and reliable data acquisition, enabling a detailed assessment of the inner ring surfaces before and after the processing stages. This methodological approach aimed to capture the nuanced variations in profile parameters and surface characteristics, providing valuable insights into the impact of different stone structures under standardized processing conditions.

Abrasive stone and the inner is placed like the drawing. Ri is called before superfinishing and Rf is the final position abrasive stone after superfinishing.
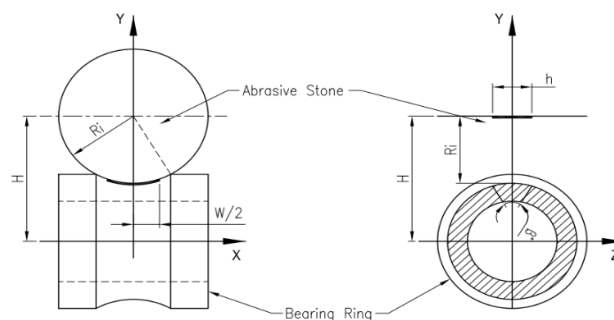

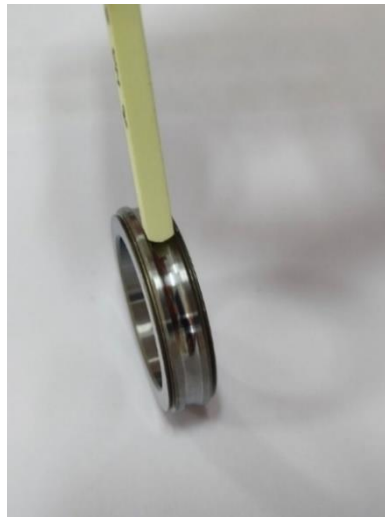**Figure 1.** Stock Removal Sketch [8]

Figure 2. Inner ring and Superfinishing Stone

The experiments are performed with 100Cr6 steel. The system fluid is Honilo 981.
  – Viscosity @ 40˚C DIN 51562 4,8 mm^2
  – Density @ 15 ˚C DIN 51757 831 kg/m^3
  – Flash point > 125 ˚C

AISI 52100 is a type of steel also known as 100Cr6 or DIN 1.3505, and it is widely used in the manufacture of bearings. This steel contains a high carbon content and is known for its high hardness, durability, and wear resistance. The name is derived from the steel's main alloying elements, which are 1% carbon and 1% chromium.100Cr6 steel is ideal for bearing races, balls, and other bearing components. Table 1 explains the chemical compositions of 100Cr6

Table 1. Chemical Composition

Grade	Quality	Quantity		C%	Si%	Mn%	P%	S%	Cr%	Ni%	Mo%
100Cr6	803J	BQ	Min	0.95	0.2	0.2			1.35		
			Max	1	0.35	0.4	0.025	0.015	1.6	0.25	0.08

100Cr6 steel is ideal for bearing races, balls, and other bearing components. This steel is specifically designed to meet the high strength, hardness, and wear resistance requirements of bearings. Bearings are typically rotating components that must withstand high loads, so durability and performance are essential. Table 2 explains the mechanical properties of 100Cr6.

Table 2. Mechanical Properties

Young Modulus (GPa)	Poisson's Ratio	Shear Modulus (GPa)	Density(kg/m3)
210	0.3	80	7800

The available ranges for the process parameters are:

- Workpiece speed = 100- 6000 rpm

- Oscillation frequency = 600 cycles/min.

- Infeed pressure = 0.5-4 bar

In this experiment Process conditions are

- Workpiece speed = 1290 rpm

- Oscillation frequency= 273 cycles/min.

- Infeed pressure=1.1-1.5 bar

- Cycle time =8.6 seconds

Table 3. Superfinishing Stone Properties

Abrasive Type	Grit Size	Main Grain Diameter (μm)	Bond Type	Treatment
1. White Alumninaoxide	900	6.5	Vitrified	Wax
2. Silicon Carbide	800	8	Vitrified	Wax
3. Alumninaoxide	800	8	Vitrified	Wax
4. Cubicboronnitride	1500	4	Nonconventional	Wax

Table 3 is shown the superfinishing stone properties which are used in experiments.

In the experiments, four different kinds of abrasive materials were employed: Silicon Carbide, White Alumina Oxide, Alumina Oxide, and Cubic Boron Nitride. The major grain widths varied between 4 and 8 micrometres, while the grit sizes ranged from 800 to 1500. These abrasives underwent wax treatment and vitrified bonding. Whereas Silicon Carbide had a major grain diameter of 8 micrometres and a grit size of 800, white alumina oxide had a 6.5 micrometre main grain diameter. Regarding grit size (800) and primary grain diameter (8 micrometres), Alumina Oxide and Silicon Carbide were comparable. Conversely, Cubic Boron Nitride was notable for having a primary grain diameter of 1500 and a grit size of 1500.

The measurement of surface roughness obtained after the SF process is also crucial. The terms "traverse" and "cut-off" used in surface measurement analysis have been elucidated.

"Traverse" describes the path or route that the measuring device or instrument takes along the surface being measured in the context of profile measurement. Depending on the precise needs of the measurement, this path could be straight, curved, or follow any other pattern. The length of the surface that is taken into consideration for analysis or characterization is sometimes referred to as the "cut-off distance" in profile measurement. It is an indication of how far along the route the measurements are considered. To guarantee that only pertinent areas of the surface profile are examined and that any anomalies or characteristics that extend past the designated cut-off distance are ignored, this distance is frequently provided.
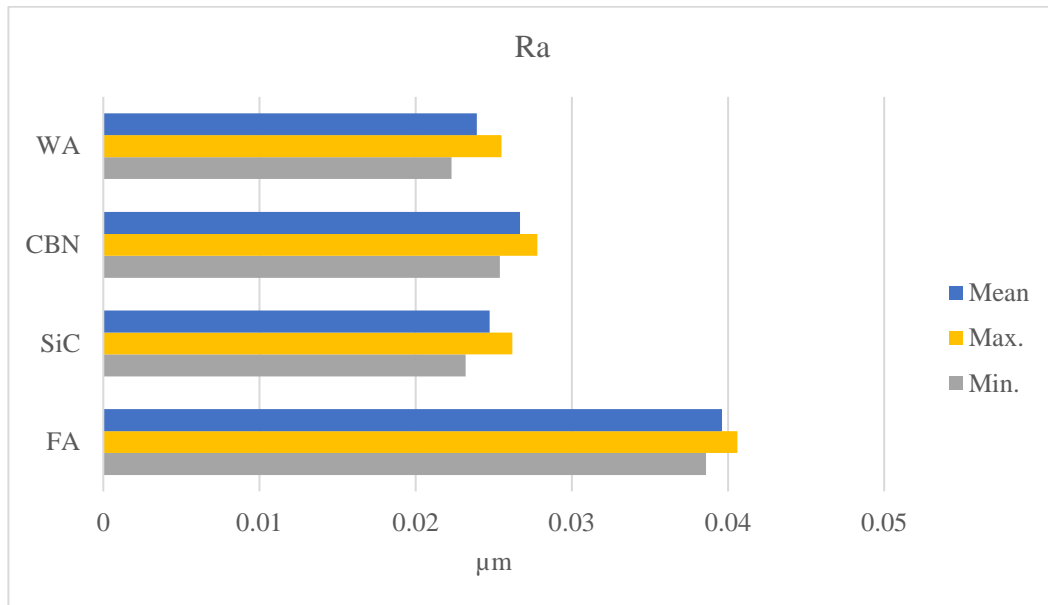
Figure 3. Ra compative to stone types.

In the context of Ra values, the comparative analysis reveals that Silicon Carbide, CBN, and White Alumina Oxide exhibit superior performance compared to Alumina Oxide. A comprehensive examination involving 125 inner ring components was undertaken, with subsequent computation of the mean values for each abrasive material. The resultant mean values were then meticulously compared with Figure 3.

In Table 4, statistical data defining the surface roughness Ra measurements of 125 inner rings have been provided.

In WA stones, the maximum standard deviation is observed, whereas in FA stones, it is observed to be the minimum. Additionally, in WA stones, the range between the minimum and maximum values is greater compared to the others.

Table 4. Statiscal Data of Ra

	FA	SiC	CBN	WA
Mean	0.0396	0.0247	0.0267	0.0239
StandarDev.	0.0006	0.0009	0.0007	0.0010
Min.	0.0386	0.0232	0.0254	0.0223
Max.	0.0406	0.0262	0.0278	0.0255

To further elucidate the statistical significance of the findings, standard deviations, and other relevant statistical parameters were calculated and incorporated into the comparative figure. This approach serves to provide a comprehensive overview of the variations and reliability associated with the Ra values obtained from the inner ring measurements. The utilization of Silicon Carbide, CBN, and White Alumina Oxide as abrasives in the processing of inner rings emerges as particularly noteworthy, substantiated by their superior performance, as evidenced by the Ra values and accompanying statistical analyses.
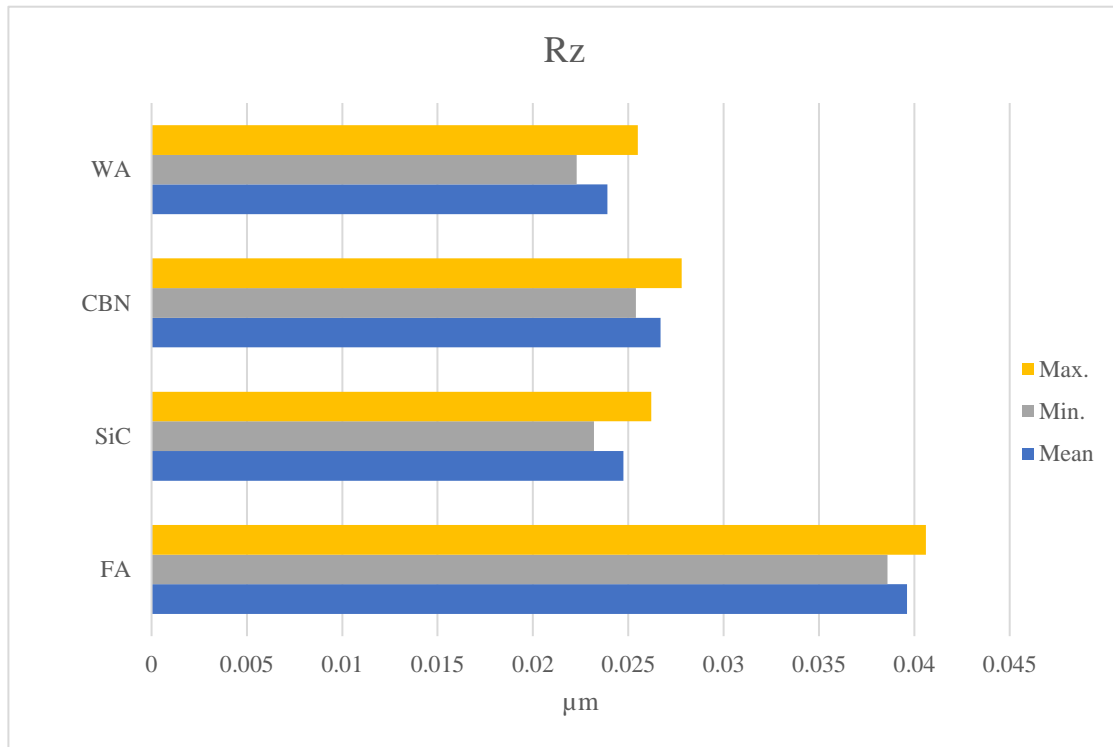
Figure 4. Rz competitive to stone types

The analysis of Rz values reveals notable distinctions among abrasive materials, as evidenced by the accompanying figure. Silicon Carbide, CBN, and White Alumina Oxide demonstrate superior performance in comparison to Alumina Oxide based on the provided Rz value figure. The experimental methodology involved the measurement of 125 inner ring components and the subsequent calculation of mean values for each abrasive material.

In Table 5, statistical data defining the surface roughness Rz measurements of 125 inner rings have been provided.

In SiC stones, the maximum standard deviation is observed, whereas in WA and CBN stones, it is observed to be the minimum. Additionally, in WA stones, the range between the minimum and maximum values is greater compared to the others.

Table 5. Statistical Data of Rz

	FA	SiC	CBN	WA
Mean	0.3329	0.1683	0.1920	0.2550
StandarDev.	0.00058	0.00059	0.00057	0.00057
Min.	0.3319	0.1673	0.191	0.254
Max.	0.3339	0.1693	0.193	0.256

The computed mean values were then meticulously compared against the Rz value figure, facilitating a comprehensive assessment of the efficacy of Silicon Carbide, CBN, and White Alumina Oxide about Alumina Oxide. This comparative approach aids in discerning the nuanced variations in surface roughness characteristics among the different abrasive materials.

As part of a rigorous academic inquiry, statistical analyses, including standard deviations and other pertinent parameters, were systematically incorporated into the comparative figure. This meticulous approach enhances

the reliability of the findings and provides a comprehensive understanding of the comparative performance of Silicon Carbide, CBN, and White Alumina Oxide in the context of Rz values for inner ring surfaces.

3. Conclusions

This study investigates the comparative performance of different stone types when subjected to identical cycle times, focusing on the analysis of raceway topography of 6206 bearings' inner rings about Ra values. ANSI 52100 steel was employed in the experimentation, revealing that Silicon Carbide, CBN, and White Alumina Oxide stones exhibited nearly identical surface roughness values. The examination of various stone structures under uniform processing conditions offered valuable insights into stone selection about chip removal and surface parameters.

The efficiency of superfinishing is heavily influenced by preceding grinding operations, with superior outcomes observed on surfaces possessing lower roughness values. While Ra and Rz values manifest variability depending on the stone type, consistency is noted among values within the same stone type. Notably, WA demonstrates superior performance compared to other stone types. Moreover, Ra and Rz values may vary with different cycle times.

In recent industrial practices, CBN stones have gained popularity due to their longevity; however, this study indicates that the superfinishing performance of CBN stones is comparatively lower than that of WA stones based on Ra and Rz values.

As the importance of superfinishing in industry continues to grow, there is a pressing need to optimize process parameters and reduce process cycle times. Future research endeavors should prioritize the optimization of cycle times, a critical aspect within the industry, employing methodologies such as the Design of Experiments (DOE).

While Ra serves as a commonly utilized surface parameter in the industry due to its quick, average-value representation, it is crucial to consider other surface factors. The condition of the bearing rings' raceway surface holds particular significance in tribology and bearing lifespan. As the industry advances, ongoing research and optimization initiatives will remain instrumental in enhancing the efficiency and efficacy of superfinishing processes.

This study is a culmination of a sequence of experiments performed by subjecting 125 inner rings to trials using 4 distinct stones under identical processing conditions. It illuminates areas within the expansive domain of surface roughness that remain ripe for enhancement. The outcomes of the statistical analyses are elaborated upon in the respective tables.

This article has been written to observe surface quality and processing conditions, and experimental studies have analyzed the behavior of superfinishing stones, referred to as cutting tools, under the same processing conditions. This analysis also includes the response of bearing steel, defined as 100Cr6, to the superfinishing process. As the cost and lifespan of cutting tools are important industrially, the effects of the behavior of cutting tools that affect surface quality under the same process conditions on the final product have been examined.

Acknowledgments

Declaration of Competing Interest

No conflict of interest was declared by the authors.

Authorship Contribution Statement

İrem Gül ASLANBAŞ: Writing, Reviewing, Data Preparation.
Samet Akar: Writing, Reviewing, and Editing.

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