Characteristics of Cobalt Chromium Alloy Surfaces Finished Using Magnetic Abrasive Finishing

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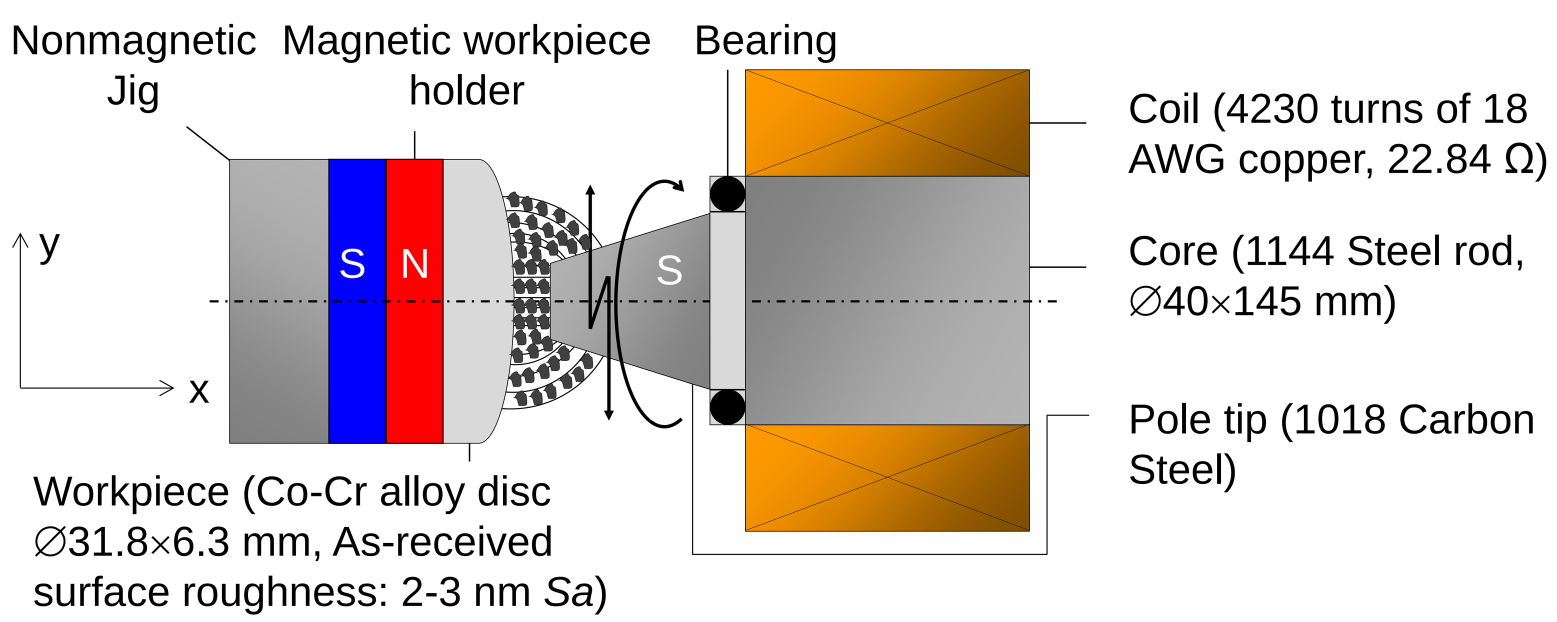
Abstract

Freeform surfaces, including the femoral component of knee prosthetics, present a significant challenge in manufacturing. Surface finish variations can lead to accelerated wear of the ultra high molecular weight polyethylene (UHMWPE) tibial component. This study applies Magnetic Abrasive Finishing (MAF) for nanometer-scale finishing of cobalt chromium alloys, which are commonly used in knee prosthetics. The goal of this study is to demonstrate the feasibility of MAF to alter the lay, while controlling the surface roughness. The effects of lay on wettability and coefficient of friction are also studied.

Femoral Knee Component

Magnetic Abrasive Finishing



Schematic of Processing Principle

Magnetic abrasive particles are linked by magnetic force, *F*, in a magnetic field

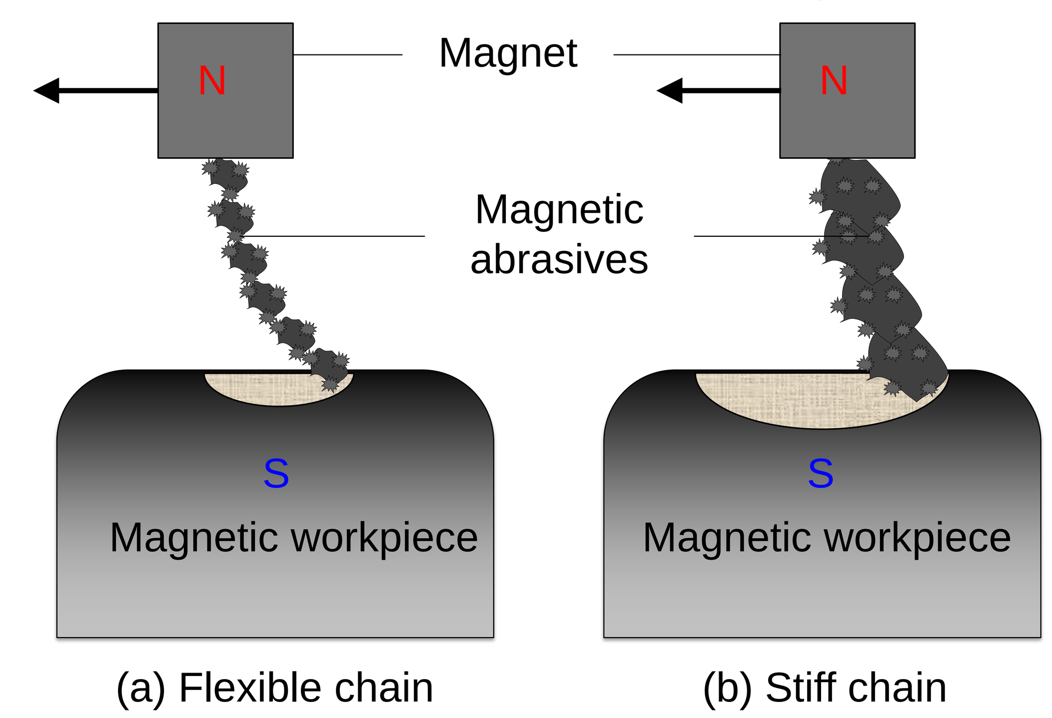
$$F = V \cdot \chi \cdot H \cdot \nabla H$$

V: Volume of magnetic particle
χ: Magnetic susceptibility
H, ∇*H*: Magnetic field intensity and its gradient

When the pole tip rotates, the magnetic abrasive rotates with the pole tip. This generates relative motion against the target surface and finishes it smoothly. The feed motion of the workpiece (attached to a robot) extends the finishing area in the y direction.

Finishing Conditions

Increasing the magnetic field intensity or magnetic abrasive size increases the particle chain stiffness, resulting in longer cutting marks. Four finishing conditions were developed to generate four kinds of surface lays on a flat Co-Cr alloy workpiece



Schematic of Magnetic Brush

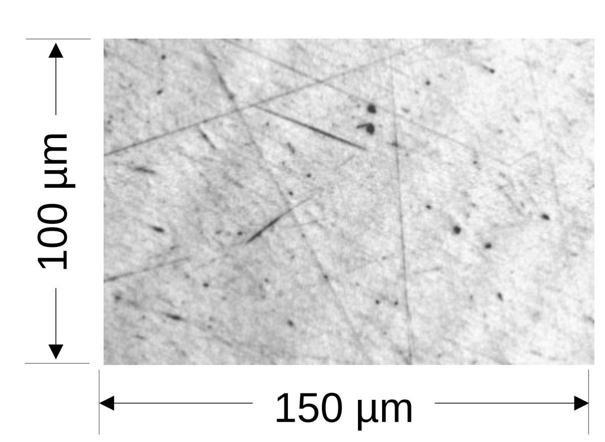
Finishing Conditions

Condition	1	2	3	4	
Diamond abrasive size, µm	0-0.25	0-0.25	0-0.5	0-0.25	
Diamond abrasive amount, mg	50	50	50	50	
Iron particle size, µm	45-150	45-150	45-150	0-45	
Iron particle amount, mg	500	500	500	500	300
Workpiece feed rate, mm/s	50	10	1	1	
Workpiece feed, mm	43	43	43	43	
Pole tip revolution, min^{-1}	100	100	500	500	150
Clearance between pole tip and workpiece, mm	1	1	1	1	
Magnetic flux density (1mm from pole tip), T	0.23	0.23	0.23	0.23	0.13
Finishing time, min	15	15	15	15	45

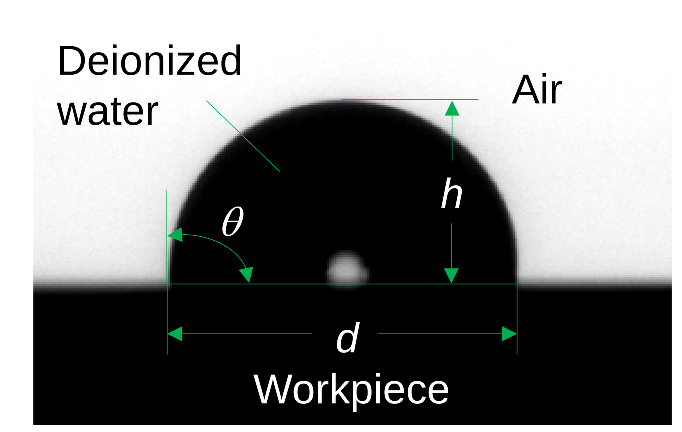
Surface Characterization

The relationship between the surface lay, contact angle (measure of wettability) and coefficient of friction of nanometer-scale surface roughness was investigated.

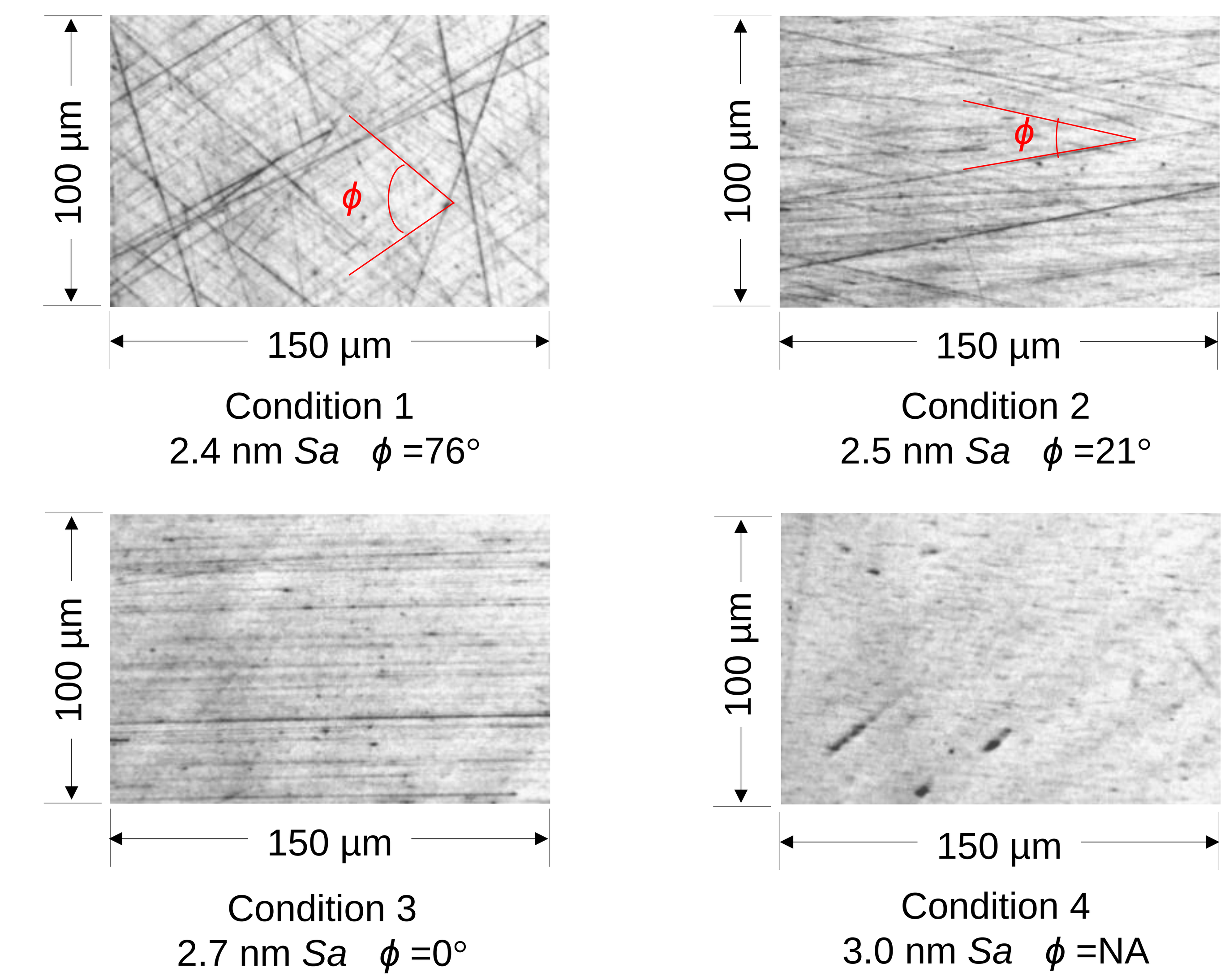
$$\theta = 2 \cdot \tan^{-1}\left(2\frac{h}{d}\right)$$



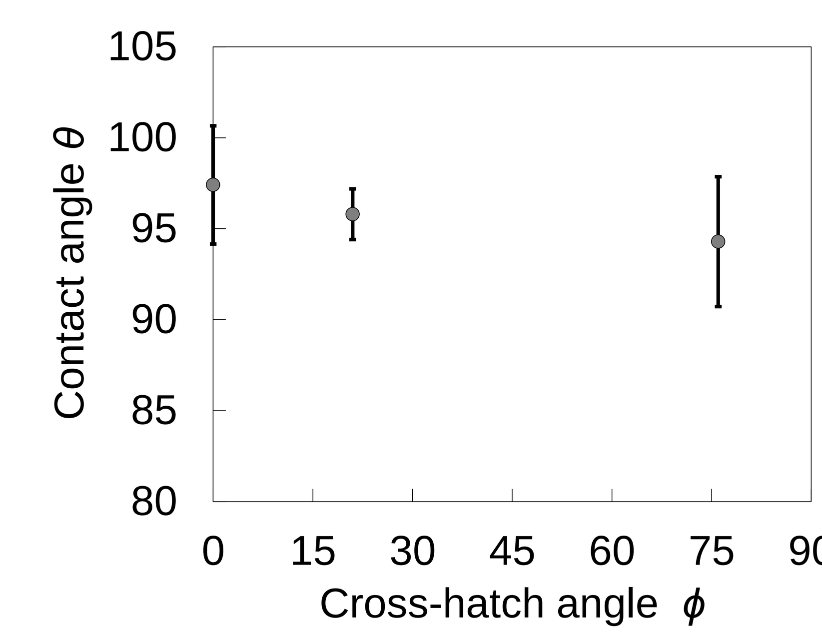
As-received surface 2.8 nm *Sa*

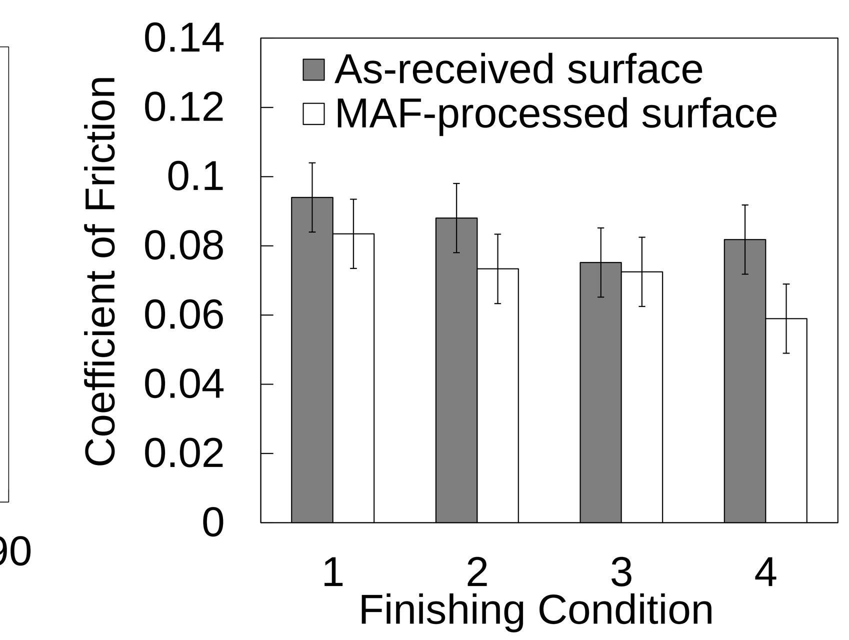


Wettability Test



Images of MAF-finished surfaces captured by an optical profilometer





Conclusions

1. Finishing experiments on flat workpieces demonstrated the feasibility of MAF to alter surface lay while controlling the nanometer-scale surface roughness by changing the length, depth, and direction of cutting marks.
2. Surfaces with unidirectional cutting marks exhibit the least wettability, and increasing the cross-hatch angle in the MAF-produced surfaces increases the wettability.
3. Surfaces consisting of short, intermittent cutting marks with less directionality are the most wettable.
4. MAF-processed surfaces show a decrease in coefficient of friction due to their reduced surface roughness.

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