Grant title Surface Functionalization by Magnetic Field Assisted Finishing
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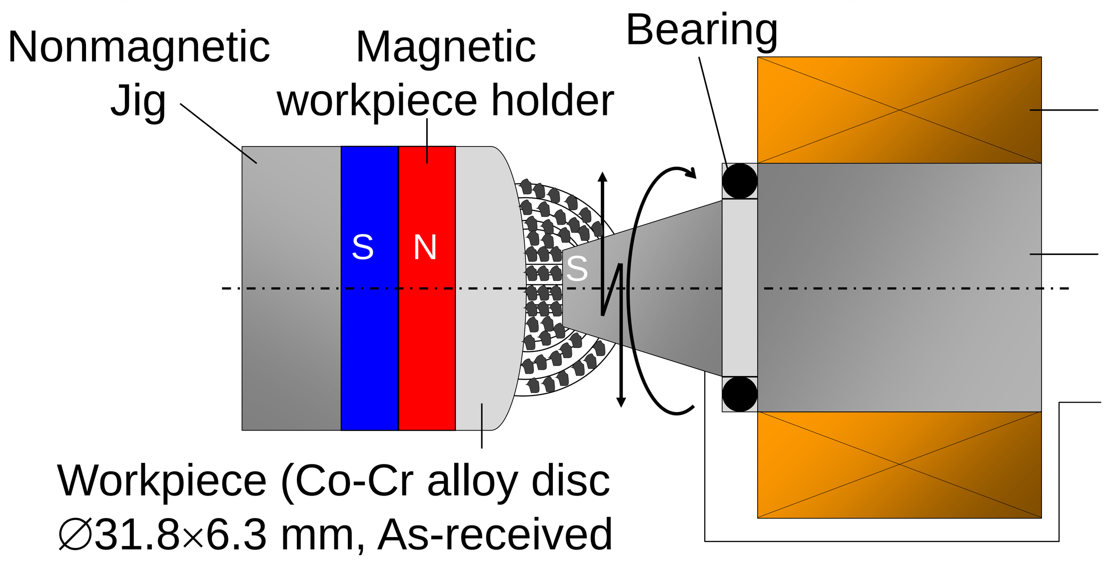
Abstract
The goal of this study is to produce surface characteristics in the nanometer to micrometer range that enable desired functionality. Surface functionalization will be realized using a magnetic field to locally manipulate abrasives, which cause material removal and surface deformation. An electromagnetic polishing machine has been developed to perform the surface finishing experiments. Polishing forces were also measured to identify relationships between the process parameters and surface roughness.

Magnetic Abrasive Finishing



Schematic of Processing Principle

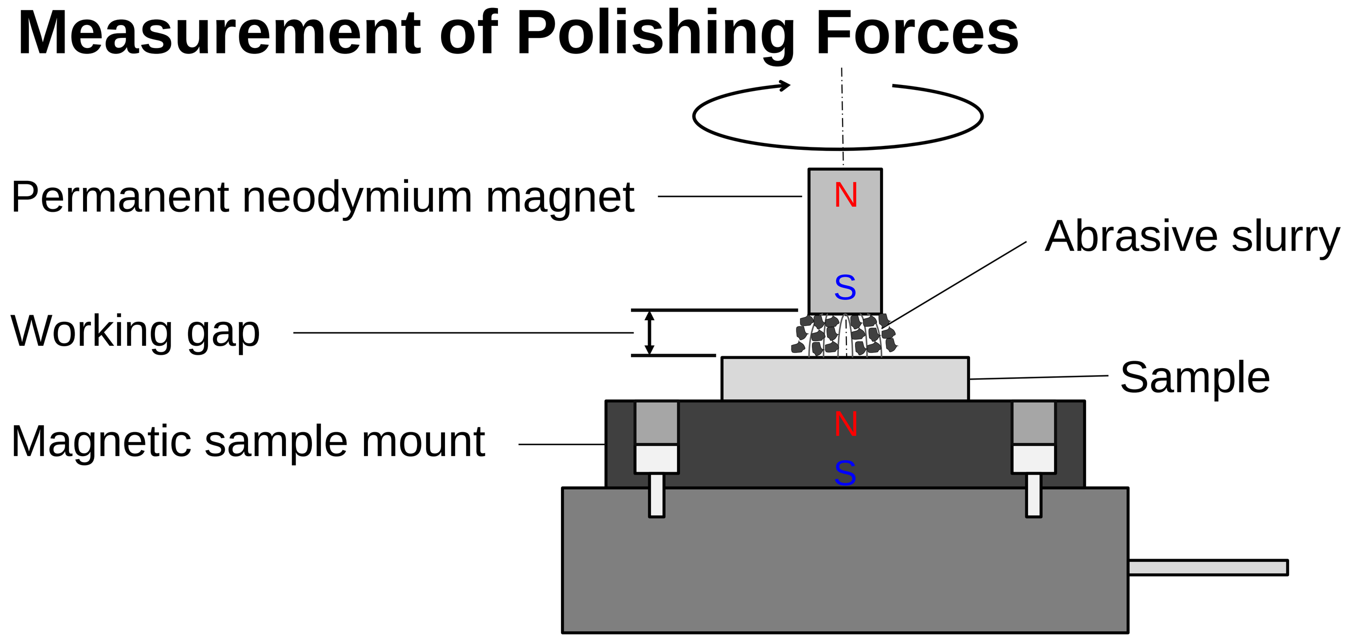
Magnetic abrasive particles are linked by magnetic force, *F*, in a magnetic field

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

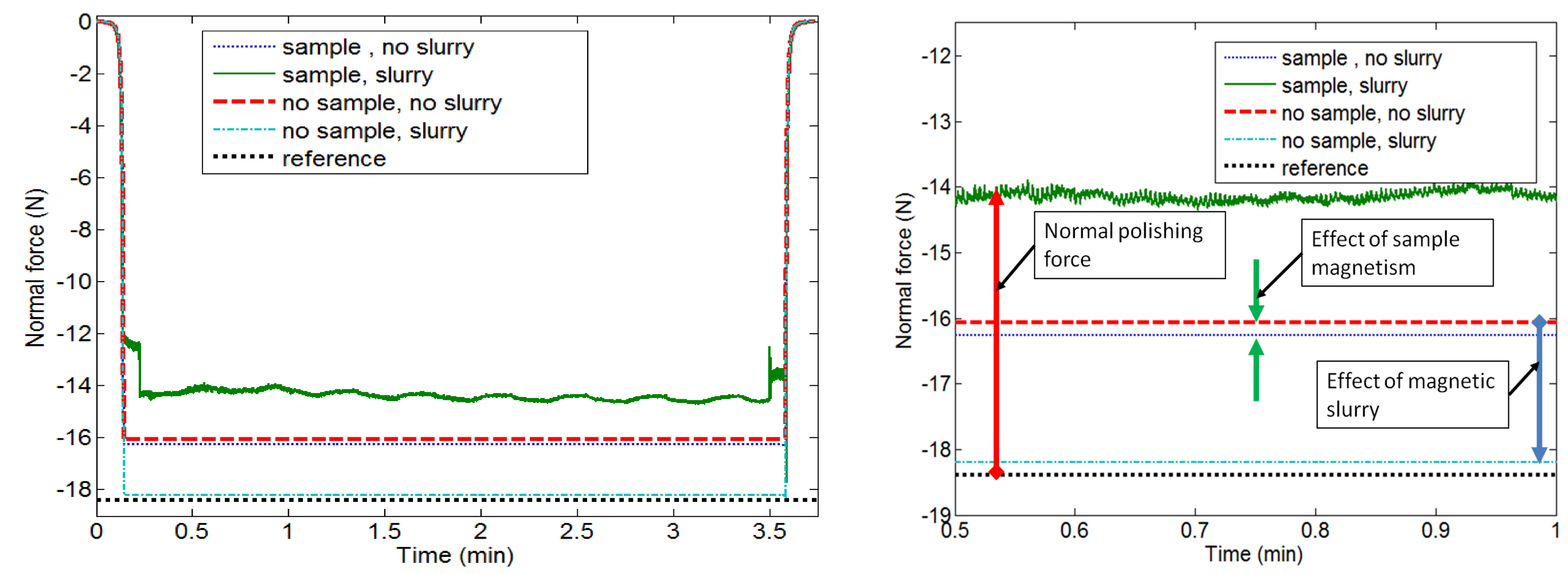
V: Volume of magnetic particle
χ: Magnetic susceptibility
H, ∇H: Magnetic field intensity and its gradient

The workpiece surface is finished via relative motion between the magnetic abrasive and the workpiece through the combination of motions of a rotating pole tip and the workpiece attached to a robot.

Measurement of Polishing Forces



Experimental Setup



Normal polishing force

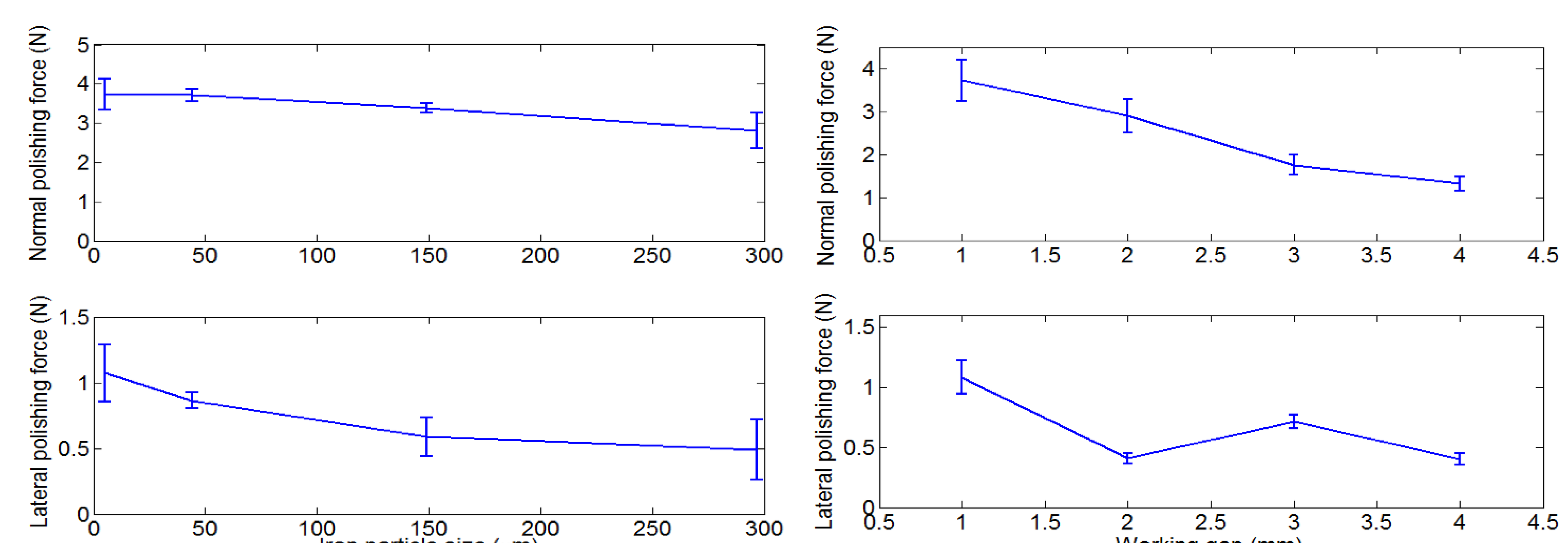
Forces due to magnetic field interactions

Effect of sample mount, $F_{sm} = -F_{n(\text{no sample, no slurry})}$
Effect of slurry, $F_{sl} = F_{n(\text{no sample, slurry})} - F_{n(\text{no sample, no slurry})}$
Effect of sample, $F_{sa} = F_{n(\text{sample, no slurry})} - F_{n(\text{no sample, no slurry})}$
Reference $= -F_{sm} - F_{sl} - F_{sa}$

Normal polishing force

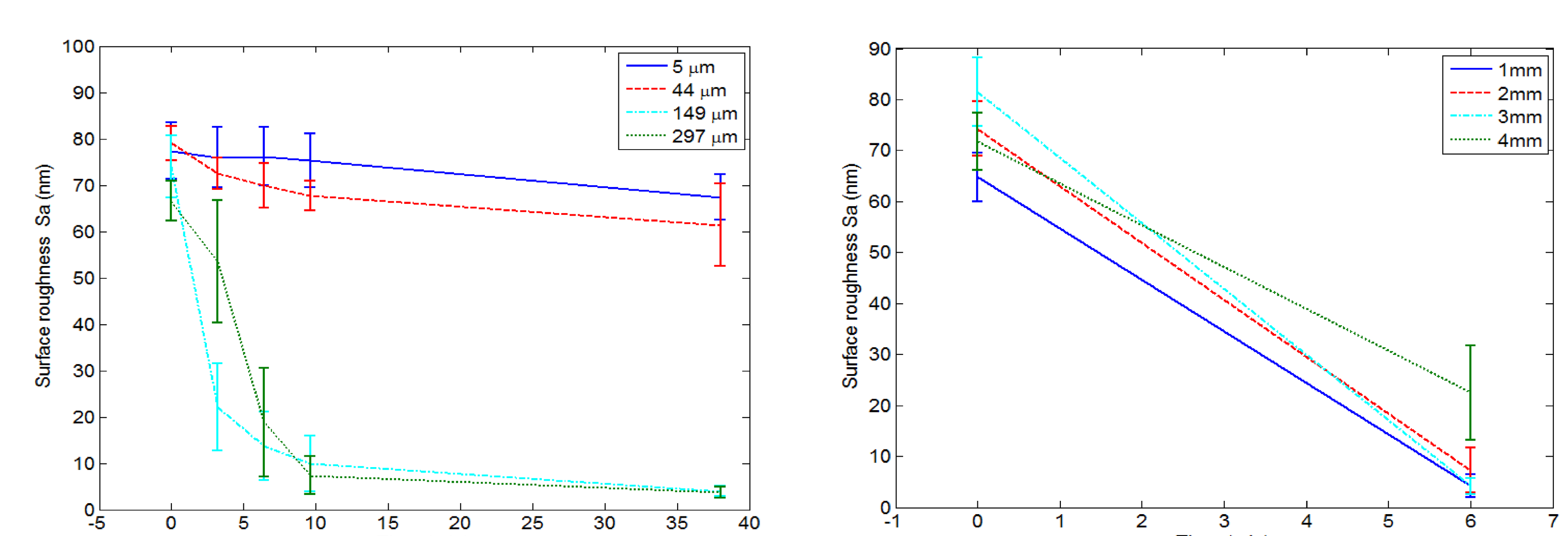
Normal polishing force, $F_{npol} = F_{n(\text{sample, slurry})} - \text{Reference}$

A) Polishing Force Results



Polishing force vs. iron particle size | Polishing force vs. working gap

B) Surface Roughness Results

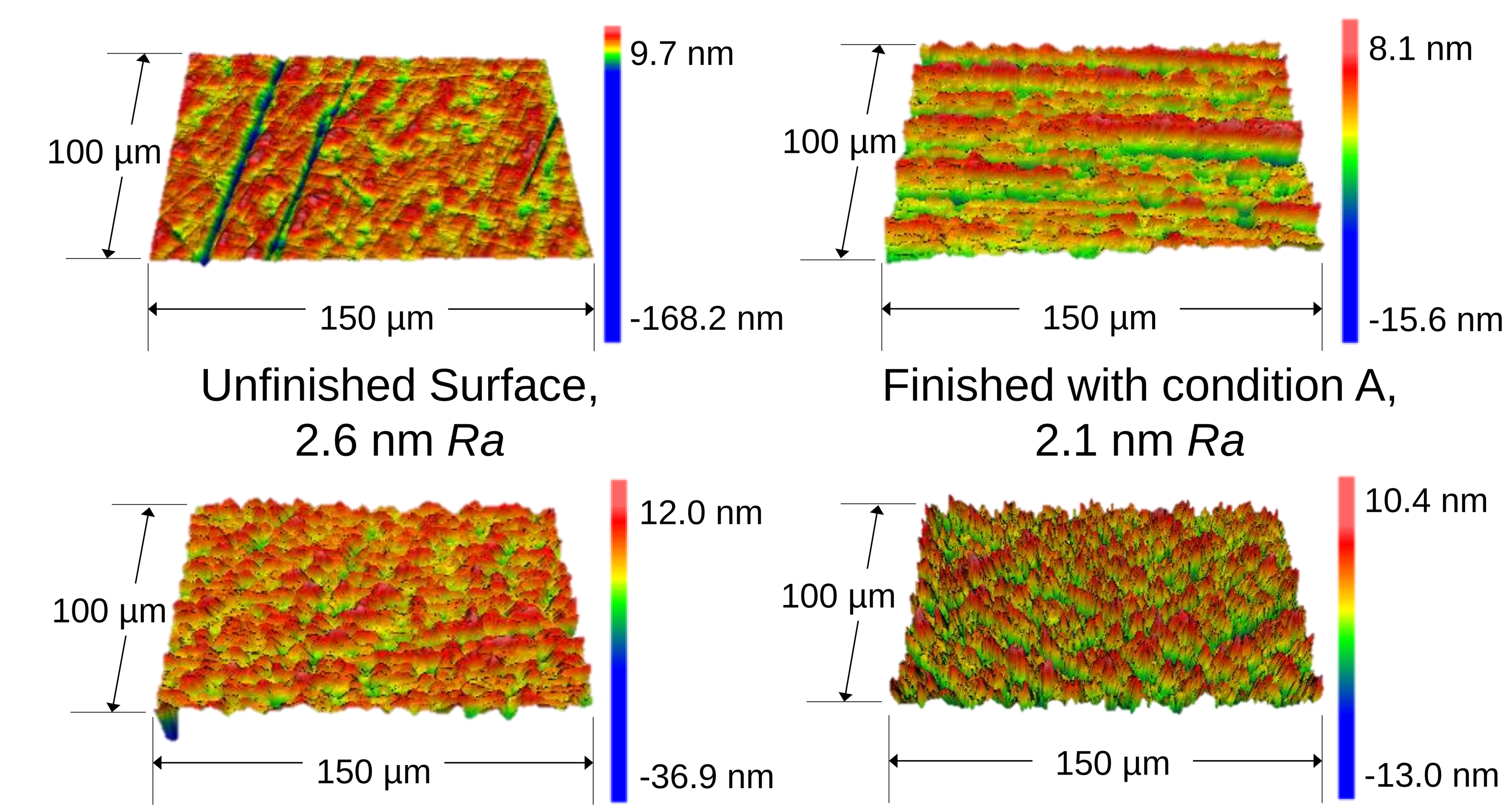


Surface roughness vs. iron particle size | Surface roughness vs. working gap

Surface Functionalization
Various surface patterns were produced using MAF on a Co-Cr alloy workpiece. The relationship between these patterns and wettability were investigated.

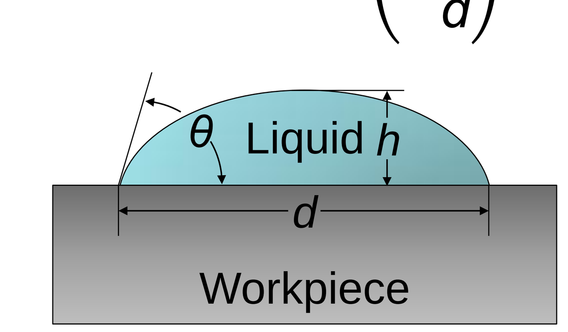
Experimental Conditions

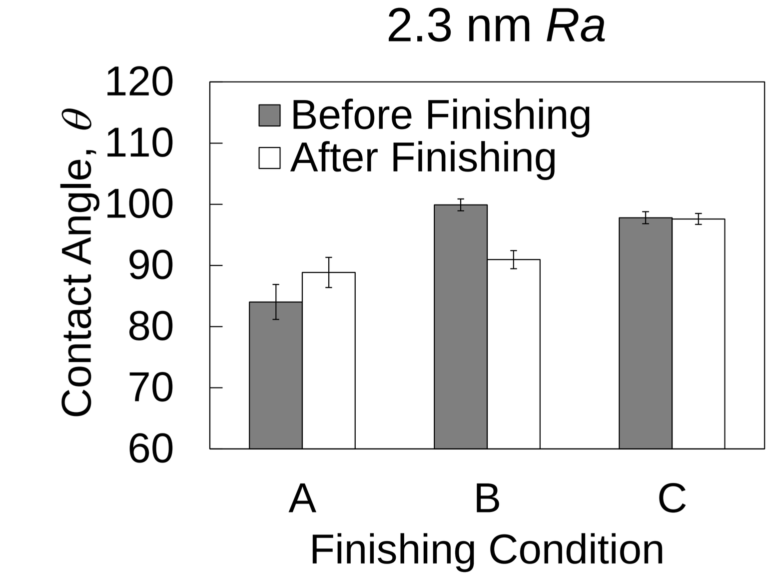
Finishing conditions	A	B		C
Diamond abrasive size, μm	0-0.5	0-0.25		0-0.25
Diamond abrasive amount, mg	50	50		50
Iron particle size, μm	44-149	44 (mean)		44-149
Iron particle amount, mg	500	300		500
Workpiece feed rate, mm/s	1	1		50
Workpiece feed, mm	20	20		20
Pole tip revolution, min^{-1}	500	500	150	100
Clearance between pole tip and workpiece, mm	1	1		1
Magnetic flux density (1mm from pole tip), T	0.23	0.23	0.13	0.23
Finishing time, min	15	15	120	15



Unfinished Surface, 2.6 nm *Ra* | Finished with condition A, 2.1 nm *Ra*
Finished with condition B, 2.9 nm *Ra* | Finished with condition C, 2.3 nm *Ra*

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





Conclusions
1. Normal forces were found to have an inverse relationship with iron particle size and working gap.
2. Surface roughness with polishing time depends strongly on the iron particle size.
3. Surface patterns consisting of long cutting marks cause an increase in contact angle, whereas surfaces with short intermittent cutting marks cause a decrease in contact angle.

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