Grant title Surface Functionalization by Magnetic Field Assisted Finishing
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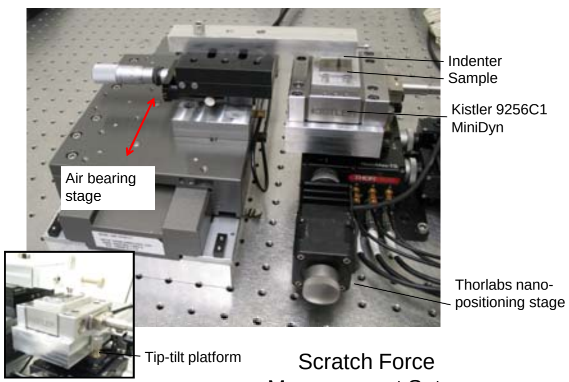
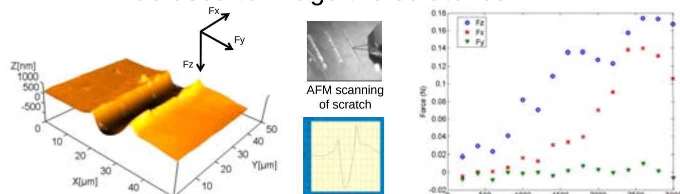
Abstract
The goal of this study is to produce surfaces with characteristics in the nanometer to micrometer range that enable desired functionality. Surface functionalization will be realized using a magnetic field to locally manipulate abrasives, which cause material removal and surface deformation. A scratching force measurement setup has been developed to model the material removal mechanism and a electromagnetic polishing machine has been developed to perform the surface finishing experiments.

Scratch Force Measurement Setup
The setup to scratch a sample with an indenter, while measuring 3D scratching forces has been developed. The setup entails a Thorlabs nano-positioning stage to enable nanometer level incremental feed of the indenter into the sample. An air bearing stage provides relative motion between the indenter and sample during scratching. The sample is mounted on a Kistler 9256C1 MiniDyn force sensor for 3D force measurement. A tip-tilt platform allows for accurate alignment of the sample surface with respect to indenter motion. A capacitance probe is used to align the sample. The entire assembly is mounted on a noise isolated table.



Scratch Force Measurement Setup

Scratch Force Mesurments
Some preliminary tests were done with a stainless steel sample (Type 410) using a diamond indenter. An AFM was used to image the scratches.



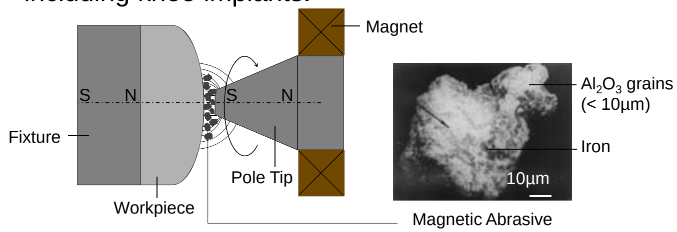
AFM image

AFM scanning of scratch

Average scratch cross-section

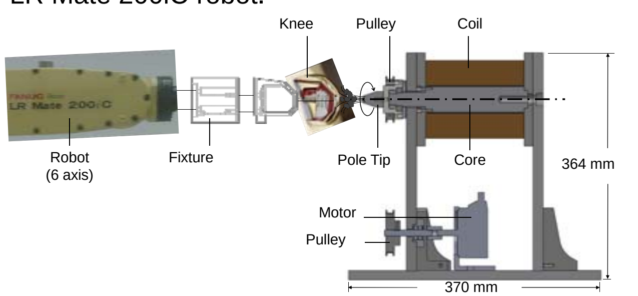
Preliminary test on SS Type 410

Magnetic Abrasive Finishing
The magnetic abrasive finishing process will be specifically applied to austenitic stainless steels and ultra high molecular weight polyethylene due to their immediate relevance to biomedical applications, including knee implants.



Schematic of Processing Principle

Machine Design
An electromagnetic polishing machine has been developed which generates a magnetic field at its pole tip. Relative motion between the magnetic field and the workpiece is achieved through the combination of a rotating pole tip (driven by pulleys) and the 6 axis motion of the workpiece by a Fanuc LR Mate 200iC robot.



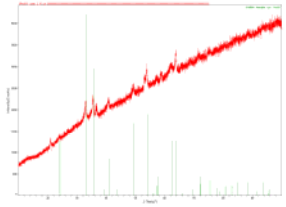
Experimental Setup

Magnetic Abrasive
Commercially available composite magnetic abrasives are too large to generate the small scale material removal necessary for the surface functionalization required; therefore, an attempt is made to synthesize a single hybrid magnetic abrasive nanoparticle.

$$FeSO_4 \cdot 7H_2O + NaO_2CCH_3 \xrightarrow[8h]{\Delta 100°C} FeOOH_{(ppt)} + Na_2SO_{4\,(aq)}$$

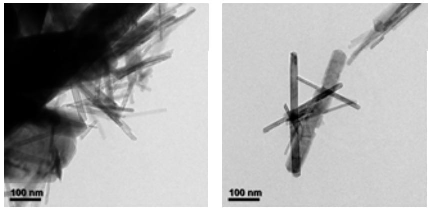
$$FeOOH \xrightarrow[Air,\ 8h]{\Delta 250°C} Fe_2O_3$$

FeOOH and Fe_2O_3 rods were initially synthesized using a solvothermal route.



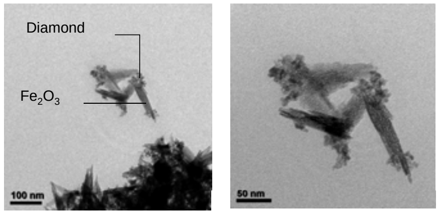
XRD Results of Fe_2O_3 Rods

Tang, B. et al. "Facile Route to α-FeOOH and α-Fe_2O_3 Nanorods and Magnetic Property of α-Fe_2O_3 Nanorods."



TEM Images of Fe_2O_3 Rods

A custom synthesis route was developed that consisted of a combination of commercial abrasives and the previous iron oxide nanorods in order to synthesize a hybrid particle.



Diamond / Iron Oxide

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