Magnetic Abrasive Finishing with Hybrid Magnetic Tools

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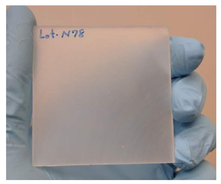
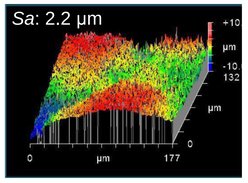
Abstract

In manufacturing, finishing of components may require multiple processes to achieve desired surface characteristics or function. Implementing multiple processes may require multiple costly machine tools, and may add time to the manufacturing process. This research explores the use of hybrid magnetic tools to alter both form accuracy and roughness on ceramic workpieces. Hybrid magnetic tools consist of magnetic particles bonded together with water-soluble glue. It was found that the transition behavior and finishing characteristics of hybrid magnetic tools are influenced by the tools' glue content. Although each hybrid magnetic tool spent a different amount of time in each phase due to the varying glue content, each tool reduced the ceramic's roughness *Sa* from approximately 1.0 µm to below 0.1 µm with 10 minutes of finishing.

Yttrium Aluminum Garnet (YAG) Ceramics

- Applications in in high power lasers (~500 MW)
  - Metal cutting
  - Precision machining
  - Surgical instruments
- Target values:
  - Roughness: 0.2 nm *Sa*
  - Flatness: < λ/10
  - Parallelism: 10 arcsec





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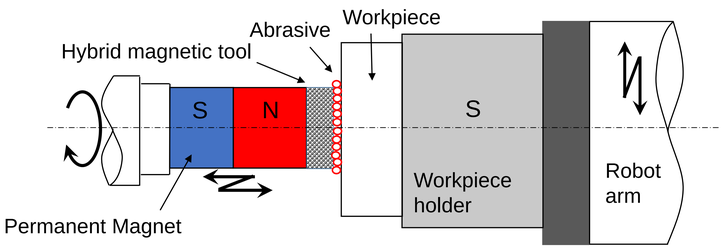
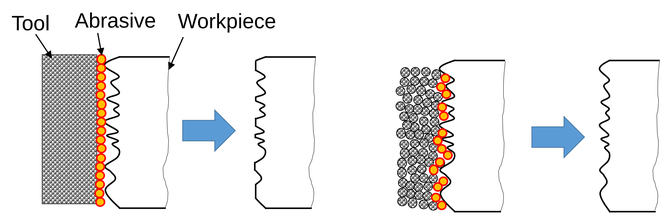
Force acting on particle: $F = V\chi \boldsymbol{H} \cdot \nabla \boldsymbol{H}$

V: particle volume
χ: magnetic susceptibility
H: magnetic field strength

Tool characteristics

1. Bonded particle phase – magnetic particles are bound together by a binder; material removal occurs at peaks because magnetic particles cannot move into the valleys
2. Brush phase – binder breaks down when lubricant is applied and magnetic particles align to the magnetic field; material removal occurs evenly across surface

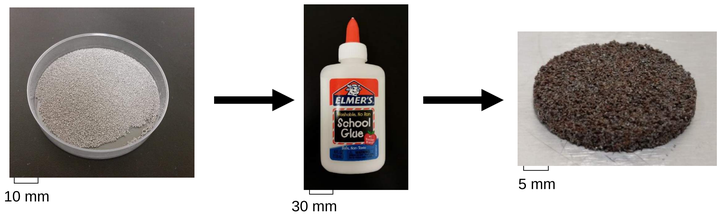




Bonded particle phase

Brush phase

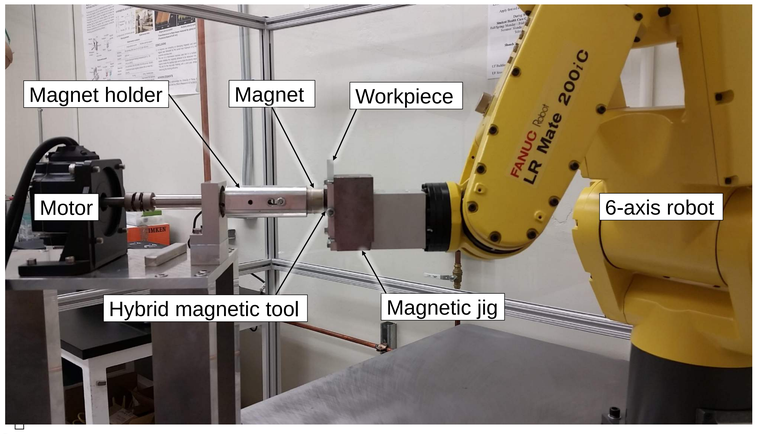
Hybrid Magnetic Tool Fabrication



Iron particles | Binder | Hybrid magnetic tool

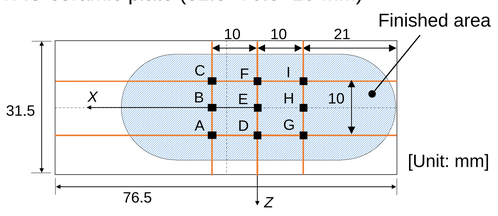
Hybrid Magnetic Tool Parameters							
Iron particles	#30-#80 (150-600 µm mean diameter), 5 g						
Binder	Water soluble polyvinyl acetate craft glue						
Binder volume	0 mL	0.1 mL	0.2 mL	0.3 mL	0.4 mL	0.5 mL	0.6 mL

Polishing Setup

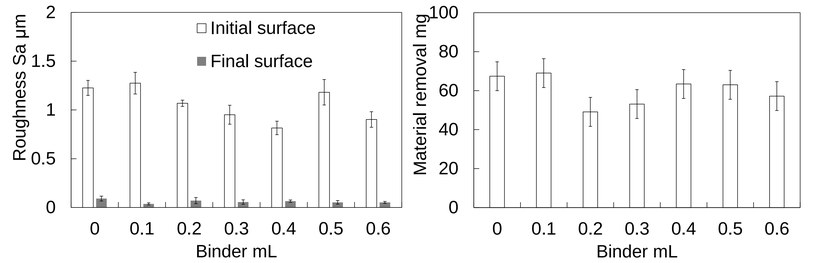


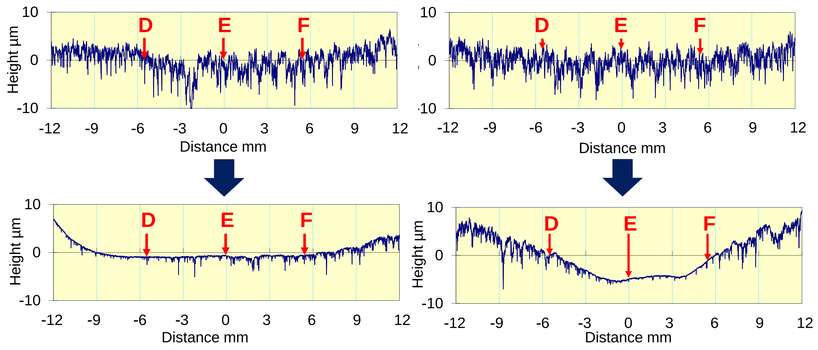
10 mm

Experimental Conditions

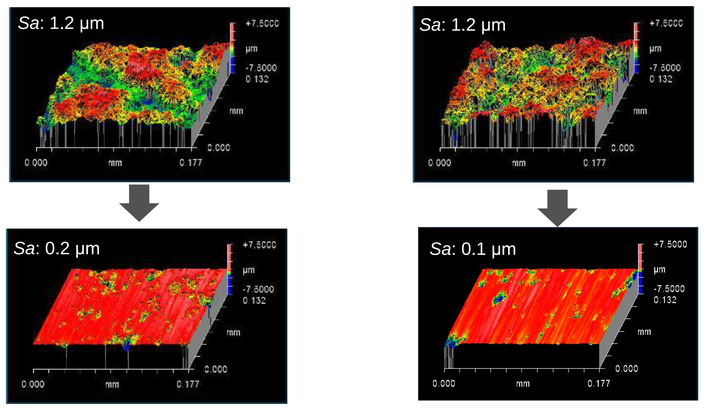
Workpiece	YAG ceramic plate (31.5×76.5×10 mm) 
Workpiece feed	Length 74 mm/s, feed rate1 mm/s
Abrasive	4-8 µm diamond, 0.400 g
Magnets	Nd-Fe-B ∅24.5×12.7 (3 magnets)
Magnetic flux density	0.70 T at the center of magnet surface 0.67 T at 2 mm away from magnet surface
Magnet rotation	500 min^{-1}
Magnet-workpiece clearance	2 mm (minimum)
Lubricant	Water soluble-type barrel finishing compound 1.0 mL + Deionized water 0.6 mL
Finishing time	8 passes (9 min 52 s)

Polishing Characteristics





(a) 0.1 mL tool (b) 0.5 mL tool



(a) 0.1 mL tool (Pont B) (b) 0.5 mL tool (Pont B)

Conclusions

- Hybrid magnetic tool material removal mechanism changes with phase
  - Bonded particle phase removes material from peaks of the surface working towards the valleys and flattens the surface
  - Brush phase removes material evenly from the flattened surface
- Time spent in each phase material removal mechanism can be controlled by varying binder content

Future Work

- Test tools with varying abrasive sizes
- Expand finishing capabilities to non-planar workpieces

Acknowledgements

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