INTERNAL FINISHING OF CAPILLARY TUBES BY MAGNETIC ABRASIVE FINISHING USING A METASTABLE AUSTENITIC STAINLESS STEEL TOOL

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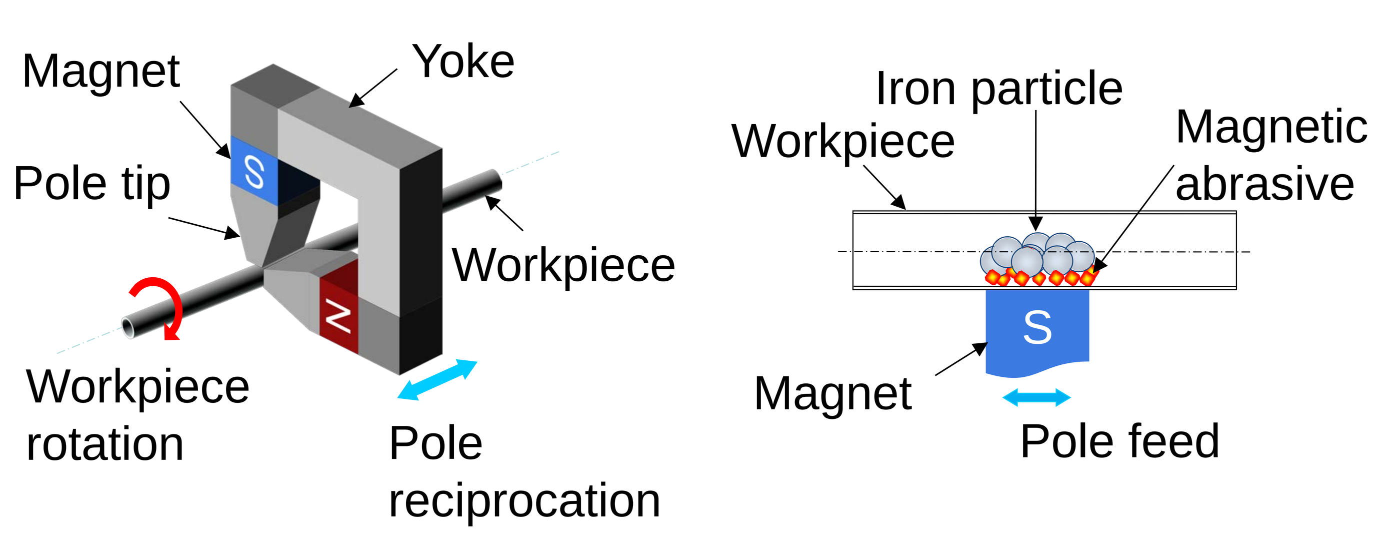
ABSTRACT

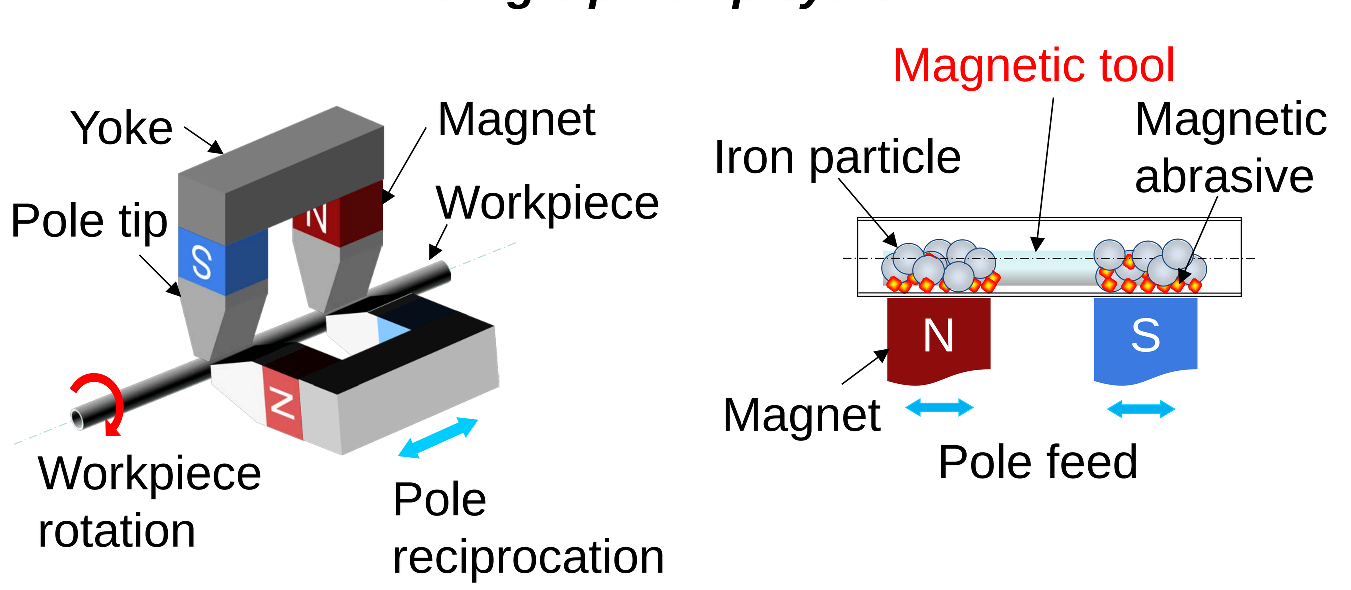
In magnetic abrasive finishing, as the tube inner diameter becomes less than 1 mm, critical control of the magnetic field at the finishing area is required to generate the force acting on the magnetic abrasive needed for finishing. That control can be achieved by modifying the pole-tip geometry. However, due to difficulties in lubricant control at the finishing area, the finished length is limited in practice to just a few times the pole tip width. The accumulation of multiple short finishing passes is needed for long tube finishing, and the longer finishing time is a critical drawback for practical applications. The aim of this paper is to propose a method to extend the default finished length using a heat-treated metastable austenitic tool in combination with multiple pole tips, which enables (1) the simultaneous finishing of multiple regions, and (2) the efficient long-length finishing with a short-pole tip feed stroke.

METHOD USING A HEAT-TREATED METASTABLE AUSTENITIC STAINLESS STEEL TOOL IN COMBINATION WITH MULTIPLE POLE TIPS

To the single pole-tip system, an additional pair of pole tips is added, and a long magnetic tool which features alternating magnetic and nonmagnetic regions, is introduced inside the tube as a guide for mixed-type of magnetic abrasive. The magnetic tool increases the magnetic force acting on the magnetic abrasives, and the iron particles help the magnetic abrasive to conform to the finished surface. Therefore, two separated mass of mixed-type magnetic abrasive simultaneously perform the finishing operation, doubling the finishing area and thus the finishing efficiency.

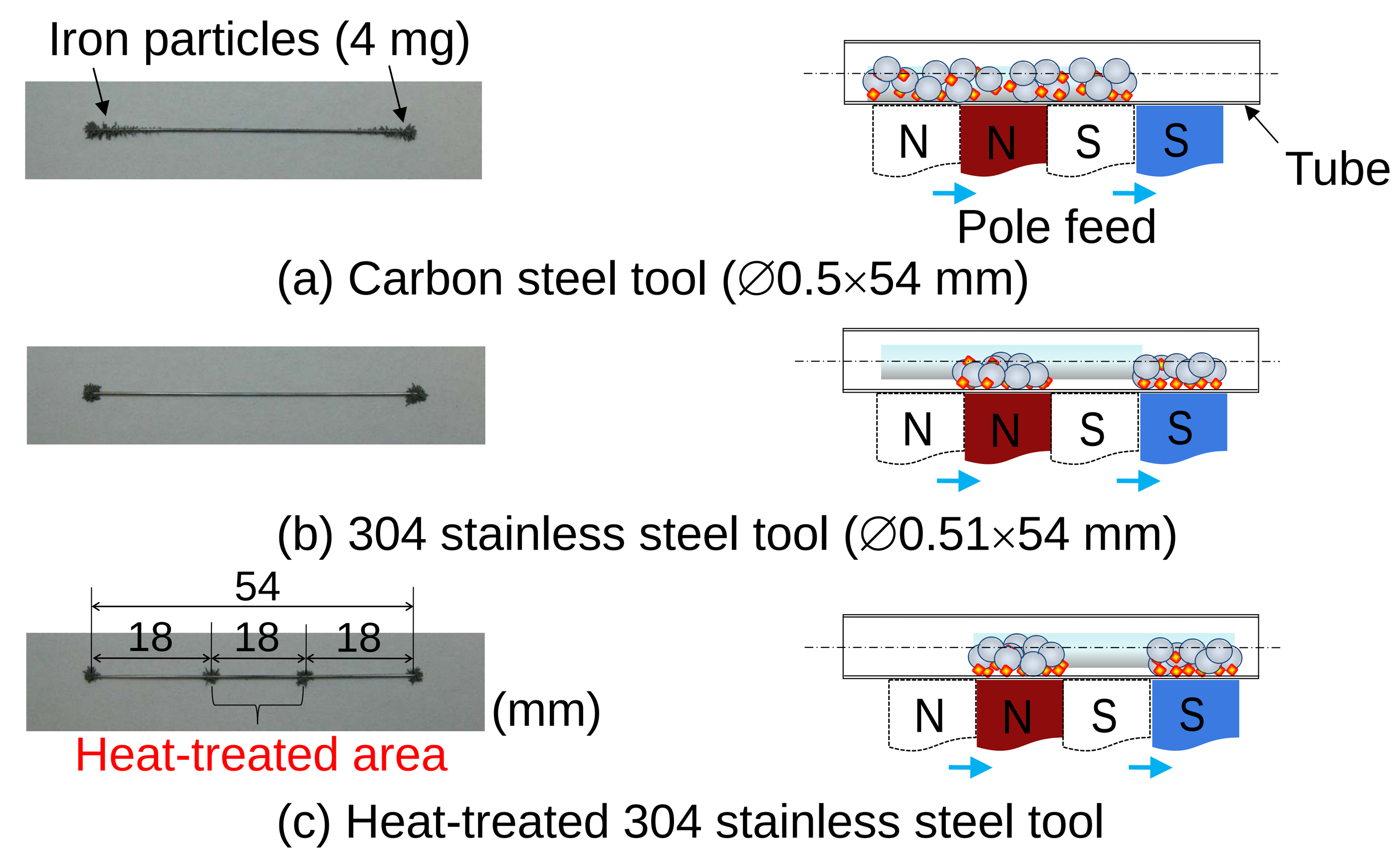


Single pole-tip system



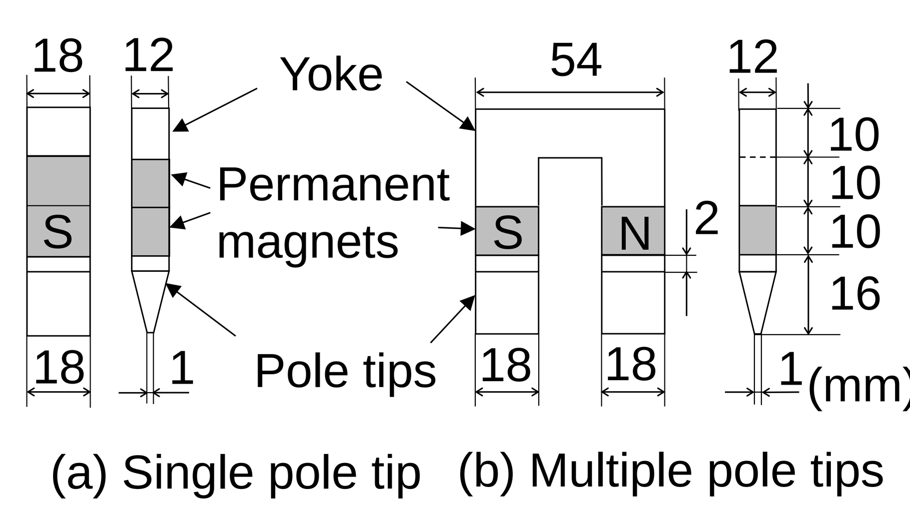
Multiple pole-tip system

Once the metastable austenitic stainless steel tool has undergone cold working, it experiences a martensitic transformation and exhibits ferromagnetism. However, the austenitic phase can be retrieved by heat treatment beyond the Curie temperature (at least 600 °C). This treatment can make multiple alternations in the magnetic properties of a single tool. The middle section of the tool exhibits paramagnetism; thus the iron particles are attracted to the ends of ferromagnetic sections.

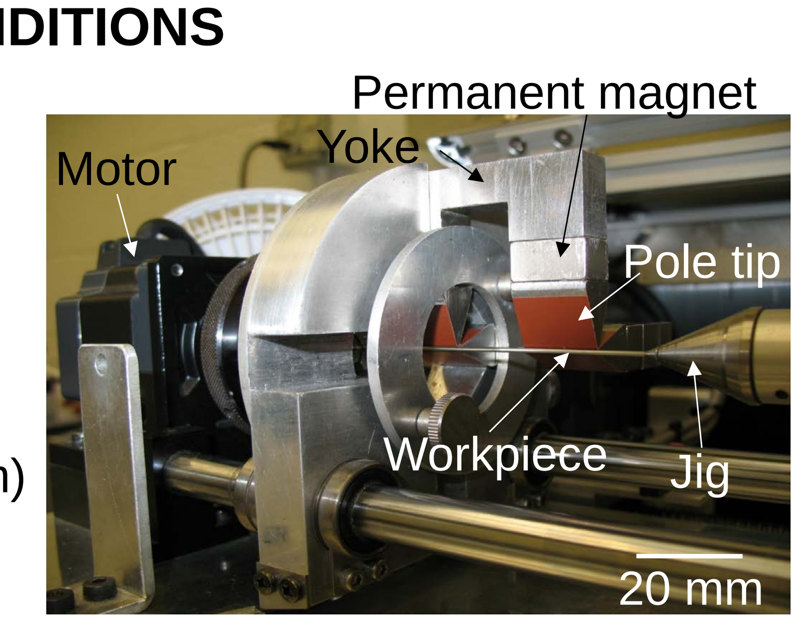


Magnetized tools with iron particles and their behavior

EXPERIMENTAL SETUP AND CONDITIONS



Pole-tip geometry



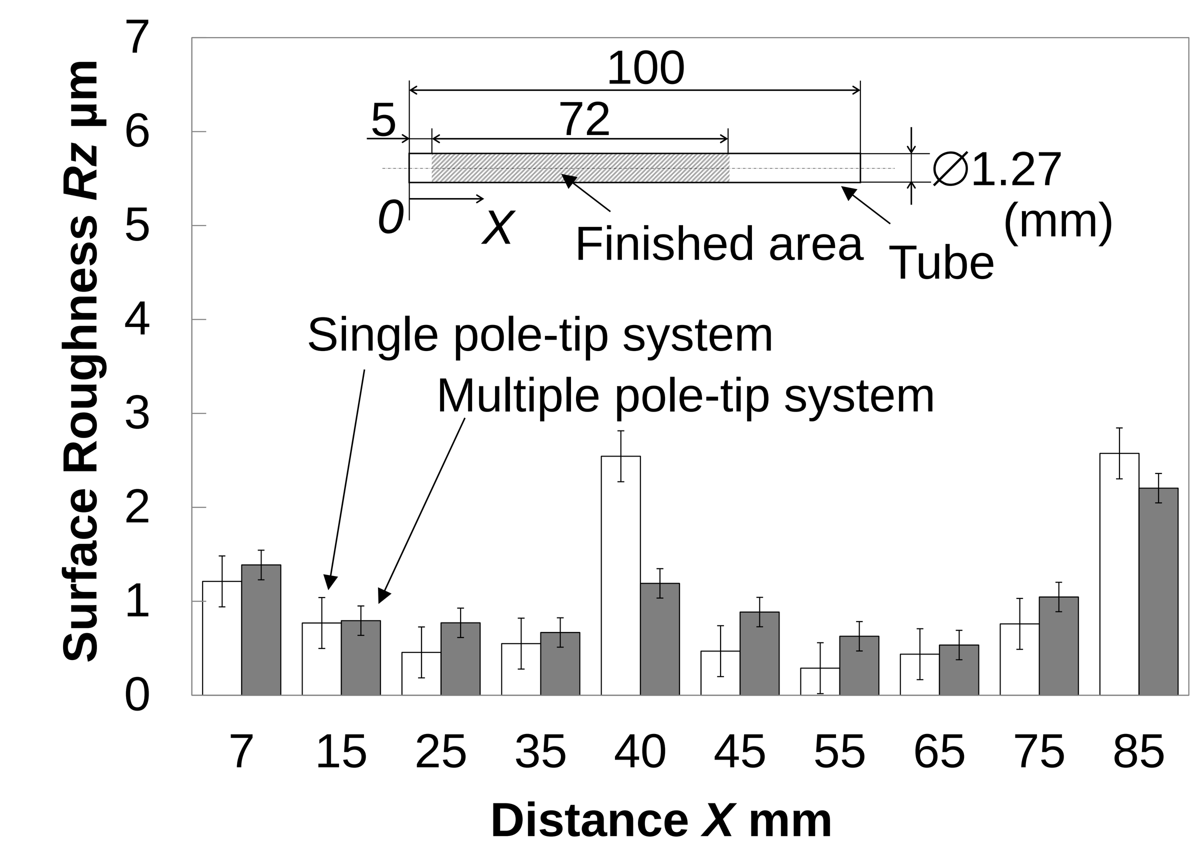
Experimental setup

Experimental conditions

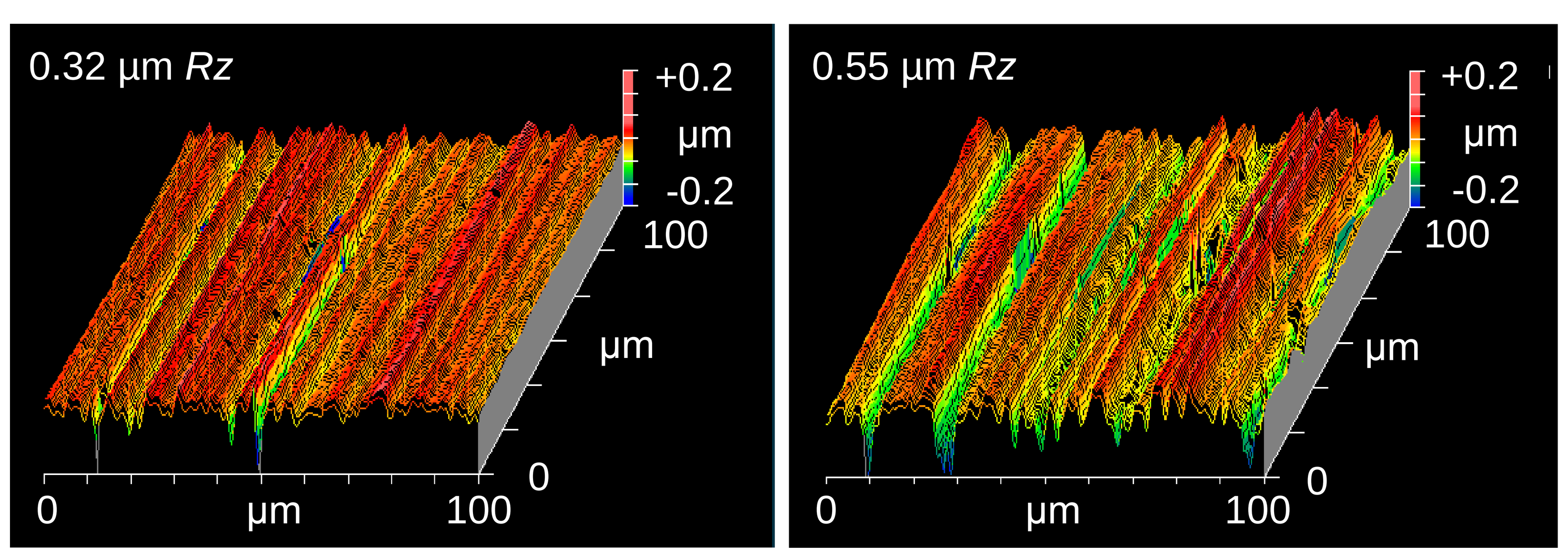
	Single pole-tip system	Multiple pole-tip system
Workpiece	304 stainless steel tube (∅1.27×∅1.06×100 mm)	
Workpiece revolution	2500 min^{-1}	
Lubricant	Soluble-type barrel finishing compound (pH 9.5, 755 mPa·s at 30°C)	
Mixed-type magnetic abrasive	Iron particles (-50/+100 mesh, 150-300 µm dia.): 80 wt% + Aluminum oxide magnetic abrasive (80 µm mean dia.) : 20 wt%	
	15 mg	8 mg / finished area
Magnetic tool	———	Heat-treated 304 stainless steel rod: ∅0.51×54 mm
Pole feed	18 mm/step, 0.59 mm/s 180 strokes	18 mm, 0.59 mm/s 180 strokes
Processing time	6 hr (3 hr/step)	3 hr

FINISHING CHARACTERISTICS

Due to the unstable abrasive motion at the pole tip edges, the surface near X= 5, 41, and 77 mm are less finished. The number of cutting edges active in the multiple pole-tip system is estimated to be about a half of the number with the single pole-tip system. Regardless of the greater magnetic force acting on the magnetic abrasive in the multiple pole-tip system, the lower number of active cutting edges resulted in less material removal and a rougher surface than in the case of the single pole system.



Changes in surface roughness Rz with distance X



Single pole-tip system *Multiple pole-tip system*

Three-dimensional surface shapes measured by optical profiler (Finished surfaces at X=65 mm)

CONCLUSIONS

1) A magnetic tool consisting of alternating magnetic and nonmagnetic regions was fabricated by the partial heat treatment of a metastable austenitic stainless steel.
2) The use of a heat-treated stainless steel tool in a multiple pole-tip system enables the magnetic abrasive to be separated into multiple regions inside the capillary tube and to follow the pole-tip reciprocation. This led to the long-tube finishing with a short pole stroke length, improving the finishing efficiency.

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