Inner Polishing of Small-Diameter Stainless Steel Pipe Using Wire Grinding Tool

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Abstract. Polishing is an important and essential process for finishing of products. For products with complicated shapes, manual polishing is required. However, it is difficult to polish the inner surface of a small-diameter pipe manually. Therefore, we propose a wire polishing tool developed using the electrostatic flocking method. The proposed tool does not require special equipment, and thus enables low-cost polishing. The tool manufacturing method is presented herein. A nylon pile is attached to an epoxy-coated wire using the electrostatic flocking method. Thereafter, abrasive grains are adhered using a commercially available adhesive diluted with ethanol, and the tool is prepared. In this study, polishing was performed by combining rotary and vertical motions by using a mini-milling machine and a linear actuator. A stainless steel pipe having a length of 30 [mm] and an inner diameter of 6.0 [mm] was used as the specimen. To maintain the performance of the tool, it was replaced with a new tool every 10 [min], and the polishing was carried out for 240 min. The roughness improved from 3.594 [μmRa] to 0.082 [μmRa] after polishing using grains GC#46 to GC#150.

Introduction

The polishing process is indispensable as the final finishing process for mechanical products even today. However, polishing is mostly performed manually, especially for complicated workpiece shapes. Generally, polishing of the inner surface uses an electro polishing method [1]. Several studies have focused on techniques to enable polishing the inner surface of pipes, for example, those on magnetic-abrasive finishing [1] and internal polishing for circular pipes by controlling the flow of slurry [2]. However, in the techniques proposed in these studies, large and complex equipment is required, and thus, the operational cost is high. Therefore, we propose the development of a wire polishing tool using the electrostatic flocking method, and conduct polishing experiments using commercially available materials and general purpose machines. Previous studies using small diameter copper pipes confirmed that wire tools have polishing ability [3]. In this study, we performed an experiment involving polishing the inner surface of a stainless steel pipe with a small diameter.

Principle of electrostatic flocking method and wire tool production

The electrostatic flocking processing technique is a surface processing technology in which electrostatic force causes nylon short fibers, called a pile, to accumulate onto a workpiece painted with epoxy; this principle is shown in Fig. 1. The pile is prepared to be subjected to electrodeposition treatment on the electrode board, which is charged to the positive electrode. For the negative electrode, a workpiece thinly coated with a conductive adhesive (epoxy) is prepared. An electric field is generated by applying a DC high voltage between the two electrodes; by doing so, polarization occurs in the charged pile. As a result, the piles fly along the lines of electric force and are implanted on the surface of the workpiece.

Fig. 2 shows the procedure for manufacturing the wire tool. The epoxy resin is applied thinly to the wire (φ 1.0 [mm] piano wire), except at a length of 20 [mm] of the wire from both ends. A nylon pile 3.2 [mm] in length is spread on the electrode plate of the simple electrostatic flocking device. Then, DC high voltage of 15 [kV] is activated, and the pile is flocked in the whole wire. In order to cure the epoxy resin, the wire tool is allowed to dry for 24 [h]. Next, styrene butadiene rubber is sprayed on the wire. Similar to the method adopted previously, arbitrary abrasive grains are prepared on the electrode plate, and voltage is applied to dry the plate. The adhesive is sprayed again to prevent abrasive grains from falling off, and the plate is allowed to dry for 24 [h]. When an extremely high voltage is applied, the abrasive grains concentrate locally; thus, the voltage is set to 15 [kV] or less.

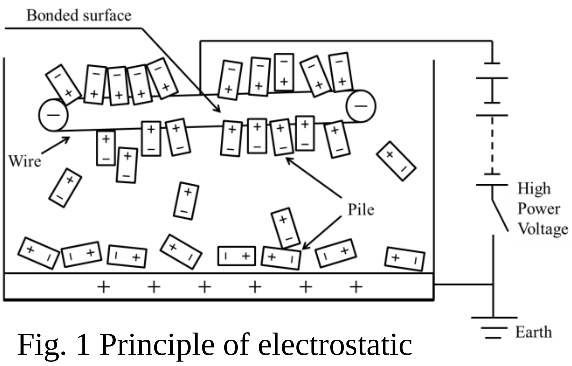
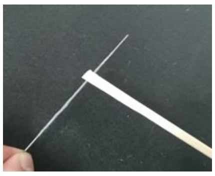


Fig. 1 Principle of electrostatic flocking method.



(a) Application of epoxy resin

(b)Adhesion of piles

(c)Adhesion of grains

(d) Completed tool

Fig. 2 Tool manufacturing

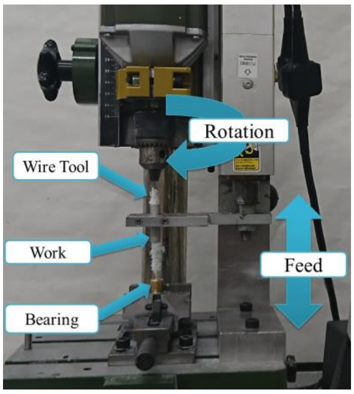


Fig. 3 Experiment device appearance

Table 1 Polishing condition for stainless pipe using WA and CG grain

Quality of material	Stainless SUS304TP
Inner diameter , Length	φ6.0mm , L = 30mm
Spindle speed by machine	3,400 rpm
Used abrasive grain and polishing time	WA#46,GC#46 50[min](10[min]*15times) WA#80,GC#80 40[min](10[min]*4times) WA#150,GC#150 50[min](10[min]*5times)

Polishing experiment

A stainless steel pipe (SUS 304 TP) was used for the work. The dimensions of the pipe were: inner diameter φ 6.0 [mm], length L = 30 [mm], and wall thickness 1.0 [mm]. One end of the manufactured tool was secured to the spindle of the desk-top milling machine (PROXXON No. 16000). The other end of the polishing tool was fixed with a bearing. Further, the work was moved in the range of 20 [mm] using a linear actuator. The setup of the experimental apparatus is shown in Fig. 3. The experimental conditions listed in Table 1 were used to perform the polishing experiments on stainless steel pipes. Since the 3.2 [mm] pile was implanted on the piano wire of φ 1.0 [mm], the theoretical tool diameter was φ 7.4 [mm].

For the evaluation, the surface roughness *Ra* [μmRa] of the inner surface of the pipe and the workpiece weight were measured every 10 min. We also replaced the tool with a new tool every 10 [min] to maintain the tool's polishing ability. The surface roughness of the inner surface of the workpiece after processing was measured five times in the longitudinal direction, and the average value thus obtained was used.

In this experiment, the effectiveness of polishing by GC abrasive grains and WA abrasive grains was investigated. First, polishing was carried out for 140 [min] using abrasive grains of GC#46 and WA#46. At this instant, the surface roughness Ra with GC#46 attained a value of approximately 0.2 [μmRa]. Thereafter, polishing was carried out for 40 [min] using GC#80 and WA#80, and then for 50 [min] using GC#150 and WA#150.

Experimental result and discussion

Fig. 4 shows the results of grinding using GC abrasive grains, and Fig. 5 shows the results of grinding using WA abrasive grains. In experiments using GC abrasive grains, the amount of polishing that could be performed per 10 min varied when GC#46 abrasive grains were used; it took 150 [min] for the surface roughness to become approximately 0.2 [μmRa]. In contrast, in experiments using WA#46 abrasive grains, it was found that a larger amount of polishing could be performed per 10 [min] compared to when using GC abrasive grains. A comparison of the weights of the workpieces show that the WA abrasive grains have larger polishing amount per use than the GC abrasive grains. Therefore, the surface roughness app

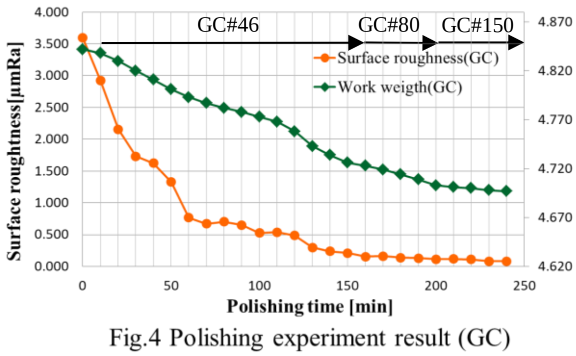


Fig.4 Polishing experiment result (GC)

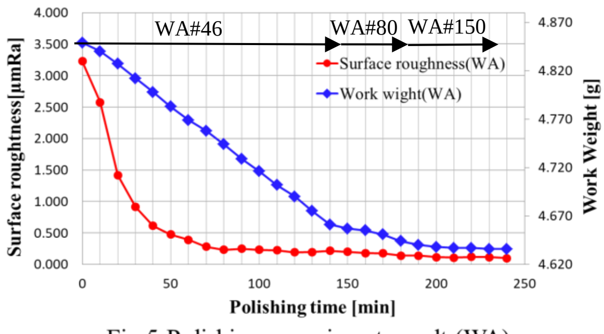


Fig.5 Polishing experiment result (WA)

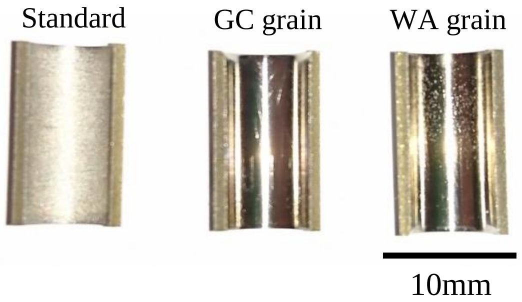


Fig.6 Surface appearance before and after polishing.

roaches 0.2 [μmRa] in less than 100 [min]. From Fig. 5, it appears that the improvement in surface roughness becomes constant after approximately 70 [min]

Because stainless steel contains iron, WA abrasive grains having high toughness are considered to have high compatibility for polishing with stainless steel. In contrast, GC abrasive grains are used for stainless steel polishing because they have high hardness and autogenous action due to abrasive grinding. Fig. 6 shows the state of the surface before and after polishing with GC abrasive grains and WA abrasive grains. It was confirmed that both WA and GC abrasive grains demonstrate polishing ability. In the polishing process from the initial roughness to a roughness of approximately 0.2 [μmRa] using the WA abrasive grain, which is said to have good compatibility with stainless steel, polishing can be accomplished in a short duration. In contrast, in the case of polishing from 0.2 [μmRa] to 0.1 [μmRa], the GC abrasive grains, which may be used for finishing, are noted to be more efficient. In this experiment method, because the polishing pressure is not excessively high, and because cleavage fracture of abrasive grains does not occur, it is considered that the WA abrasive grains perform more efficient polishing. Therefore, we believe that polishing can be performed in a shorter duration by using WA abrasive grains for rough surface polishing, and GC abrasive grains for finer polishing.

Conclusions

The stainless steel pipe was polished using the wire polishing tool, and the following conclusions were obtained.

1. It was demonstrated that the developed wire grinding tool is effective for polishing stainless steel pipes.
2. It was found that polishing with WA#46 abrasive grains proceeds faster than when using GC#46 grains.
3. The time required for polishing can be reduced by using GC and WA abrasive grains selectively.

Acknowledgements

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References

[1] Shuo-Jen Lee, Yu-Ming Lee, Ming-Feng Du, The polishing mechanism of electro-chemical mechanical polishing technology, Journal of Materials Processing Technology, 140 (2003) pp.280-286

[2] H. Yamaguchi and T. Shinmura, Study on a New Internal Finishing Process by the Application of Magnetic abrasive Machining, J. Jpn. Soc. Precis. Eng, 62, 11, (1996), 1617 , (In Japanese)

[3] T. Shimizu, K. Fukasawa, Y.A.Rahim, Y.Haramiishi and S. Hagiwara, Proposal of internal polishing process for circular pipes by controlling the flow of slurry. J.Jpn. Soc. Abras. Tecno, 60, 3,(2016), pp.153-158, (In Japanese)

[4] K. Amano, Y. Haramiishi, S. Haramiishi, Small diameter pipe polishing based on development of Wire poshing tool. J. Jpn. Soc. Mechanic. Eng. Yamanashi district conference, (2017), pp.73-74, (In Japanese)