IOP Conf. Series: Materials Science and Engineering **205** (2017) 012004 doi:10.1088/1757-899X/205/1/012004

The Effects of Different Electrode Types for Obtaining Surface Machining Shape on Shape Memory Alloy Using Electrochemical Machining

S G Choi[1], S H Kim[1], W K Choi[1], G C Moon[1], E S Lee[2, *]

[1]School of Mechanical Engineering, Inha Univ., 253 Yonghyun-Dong, Nam-Gu, Incheon, Korea.
[2]Department of Mechanical Engineering, Inha Univ., 253, Yonghuyn-Dong, Nam-Gu, Incheon, Korea.

Abstract. Shape memory alloy (SMA) is important material used for the medicine and aerospace industry due to its characteristics called the shape memory effect, which involves the recovery of deformed alloy to its original state through the application of temperature or stress. Consumers in modern society demand stability in parts. Electrochemical machining is one of the methods for obtained these stabilities in parts requirements. These parts of shape memory alloy require fine patterns in some applications. In order to machine a fine pattern, the electrochemical machining method is suitable. For precision electrochemical machining using different shape electrodes, the current density should be controlled precisely. And electrode shape is required for precise electrochemical machining. It is possible to obtain precise square holes on the SMA if the insulation layer controlled the unnecessary current between electrode and workpiece. If it is adjusting the unnecessary current to obtain the desired shape, it will be a great contribution to the medical industry and the aerospace industry. It is possible to process a desired shape to the shape memory alloy by micro controlling the unnecessary current. In case of the square electrode without insulation layer, it derives inexact square holes due to the unnecessary current. The results using the insulated electrode in only side show precise square holes. The removal rate improved in case of insulated electrode than others because insulation layer concentrate the applied current to the machining zone.

1. Introduction

Shape memory alloy (SMA) is applied to the various industries like medical industry and aero- space industry. Shape memory alloy has a special characteristic which is called the shape memory effect. Shape memory effect refers to the recovery of a deformed alloy to its original state through the application of temperature or stress to the alloy. For this reason, it is required to fabricate the micro and complex shape on SMA [1-2]. As this method of process that electrochemical machining, it can be machined on minute space of micro parts without stress and transmutation of material. The reason of achieving these advantages is non-contact machining between tool and workpiece, using metal dissolution by electrochemical reaction. Non-traditional machining methods, such as laser machining, electro-discharge machining, MR fluid machining, etching and Electro Chemical Machining, have been studied for smart materials [3-4]. Insulated electrode is required to acquire the precise results in electrochemical machining. The influence of the insulation layers which could affect current distribution has been investigated. In this paper, the square shape machining area were fabricated with electrochemical machining using the square electrode, the square electrode insulated only on the side. It is possible to obtain precise square shapes on the SMA using four type electrodes.

2. Experimental Setup

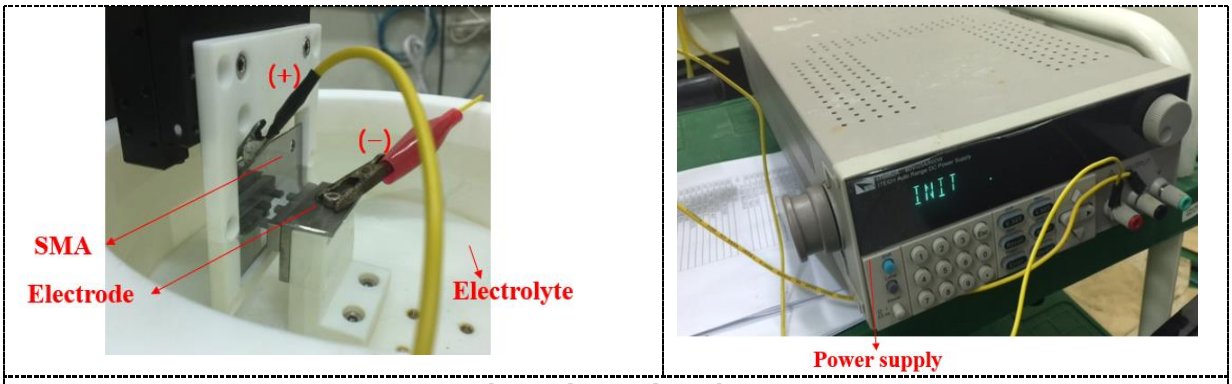
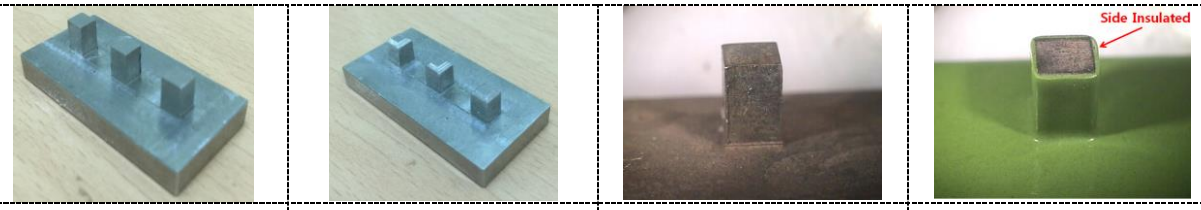


Figure. 1 Electrochemical machining system

Figure 1 shows the experimental electrochemical machining system. The workpiece was SMA with 51% Ni and 49% Ti. A cathode made of steel was used as the electrode. The anode was connected to the SMA, which was connected to a dedicated jig. A power supply supplies the current. Table. 2 shows the experiment conditions. Machining was performed by immersion in an electrolyte with an electrode gap of 1 mm. The constant current is employed in this experiment, and the current value is 30A. The appropriate electrolyte was determined in previous research, and it is found that NaCl electrolyte with a concentration of 0.27 wt% produces better workability than other electrolytes. Figure 2 shows the electrodes used in the experiment. The electrode was the general electrode, second electrode was the fillet, third electrode was non-insulated and finally electrode was the insulated.

Table 1. Experiment condition.

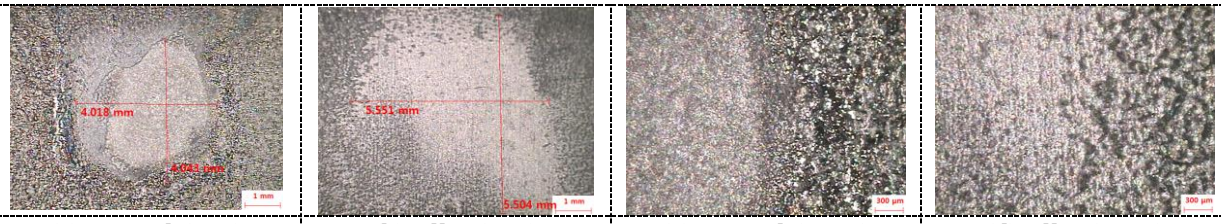
Conditions	Value
Current	30A
Electrolyte	NaCl 0.27 wt%
Electrode	General electrode, Fillet electrode, Non-insulated electrode, Insulated electrode
Electrode gap	1 mm
Workpiece	Shape memory alloy (SMA) (Ni: 51%, Ti: 49%)



(a)General electrode (b)Fillet of edge point (c)non-insulated (d)side of insulated

Figure. 2 Four type electrodes

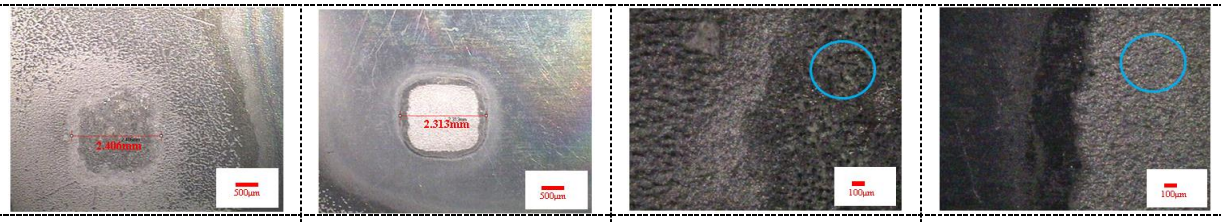
3. Results and discussion



(a)General (x40) (b)Fillet (x40) (c)General (x100) (d)Fillet (x100)

Figure. 3 Micrographics of first SMA experiment

Figure 3 shows micrographs of first SMA machined. Figure 3-(a), (b) shows a magnification of x40. Figure 3-(a) shows the machined shape from the general electrode. It was processed into a faint square shape. The size of electrode and machining shape size are different and the non-machining zones was also machined. Because a current flow in the non-machining zones. Figure 3-(b) shows the machining zones was expanded. In addition, the machining shape was not a square shape. Since the current flow due to the fillet electrode, current was spread to the outside. Figure 3-(c), (d) shows a magnification of x100. Also the left was machining zones and the right was non-machining zones. Since the concentrated of current density in machining zones, the surface is smooth. But, due to the imperfect current density, the machining surface was rough in the non-machining zones. The boundary line was clear in both zones. in case of the figure 3-(d), the boundary line was indistinct in the machining zones and non-machining zones. When the fillet edge, the direction of the current is spread out, it is affecting even by non-machining zones.



(a)not insulated (x40) (b)insulated (x40) (c)non-insulated (x100) (d)insulated (x100)

Figure. 4 Micrographics of second SMA experiment

Figure 4 shows micrographs of second SMA machined. Figure 4-(a), (b) shows a magnification of x40. Blue circle was the machining zone, machining lines was the border zone, the other zone was the non-machining zone. Figure 4-(a) shows the machining shape using not insulated electrode. The non-machining zones as well as the machining zone was machined. Although the machining shape was a square shape, do not appear correctly and the machining lines are irregular, the machining surface was not smooth. In case of the non-insulated electrode without insulation layer, it derives inexact square shapes due to the unnecessary current. Figure 4-(b) shows the machining shape using side insulated electrode. The non-machining zones was not machining and the current was concentrated in the machining zones has been machining. The machining shape was shown clearly in a square shape. In addition, the machining lines are regularly and machined surface has been processed uniformly. The results using the insulated electrode show precise square shapes. Figure 4-(c), (d) shows a magnification of x100. The machining surface was not smooth in the machining zone. Non-machining zone was also machining, because of not insulated electrode, and due to excessive current, the border zone was also irregular. The machining surface was very smooth in the machining zones and the non-machining zone was not machined. Due to excessive current, the interface was also irregular. The border zone was a little regularly because the current concentrated in the machining zones.

4. Conclusion

Through this study, the analysis in machining shapes of shape memory alloy (SMA) according to four electrodes. First experiment using the general electrode and fillet electrode. In the case of the fillet electrode, the appearance was emitted small, the current is concentrated in the fillet point. And the current was spread to the outside. If the fillet of edge point was the current is spread widely. In case of the non-insulated electrode without insulation layer, it non-machining zone as well as the machining zone was machined. When the fillet edge, the direction of the current is spread out, it is affecting even by non-machining zones.
Second experiment using the non-insulated electrode and insulated electrode. The results using the insulated electrode in only side show precise square shapes. The most precise square shapes have been found when the square electrode insulated is applied because the insulation layer concentrate the unnecessary current to machining zone. The removal rate improved in case of square electrode insulated than others because insulation layer concentrate the applied current to the machining zone.

5. References

[1] R. Mukherjee, T. F. Christian and R. A. Thiel, An actuation system for control multiple shape memory alloy actuator, Sensor and Actuators A:physics, 55 (1996) 185-192.
[2] M. Manjaiah, S. Narendranath, S. Basavarajappa, Review on non-conventional machining of shape memory alloys, Transactions of Nonferrous Metals Society of China 24(2014) 12-21.
[3] M. J. Shin, S. Y. Baek and E. S. Lee, A study for improving surface roughness and micro-deburring effect of nitinol shape memory alloy by electropolishing, Transactions of the Korean Society of Machine Tool Engineers,16 (6) (2007) 49-54.
[4] C. Xuezhen, X. Zhengyang, Z. Dong, F. Zhongding, Z. Di, Experimental research on electrochemical machining of titanium alloy Ti60 for a blisk, Chinese Journal of Aeronautics (2015).

Acknowledgments

This research was supported by the Strengthening competitiveness business of industrial clusters funded by the Korea Industrial Complex Corporation.