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Polymer Masking Chemical Machining of Alloy 617 for Process- and Intermediate- Heat Exchangers

Jae-Won Park, Jae-Un Kim, Min-Hwan Kim and Yong-Wan Kim*

Korea Atomic Energy Research Institute, Daejon-City, South.Korea
**Corresponding author: pjw@kaeri.re.kr*

1. Introduction

Both Process Heat Exchanger (PHE) and Intermediate Heat Exchanger (IHE) made of Alloy 617 require a formation of He flow channels and a diffusion bonding to assemble parts into a integrated system. In order to form He channels a mechanical machining method can be applied, however, this method not only costs a fortune but also is not suited for a mass production. For this reason, the use of photo-resist has been considered, however, this photochemical method turned out to be impossible for Alloy 617 etching due to its high corrosion resistance nature. Therefore, replacement with Teflon coating has been attempted in this work and the etching was conducted using Aqua Regia. The optimization of polymer coating process is discussed considering the etch factor (= Depth of etch/ Undercut).

2. Experiments and Results

2.1 Experiments

Prior to conducting this chemical etching, the surface was spray-coated to 3-4 mm thick with Teflon polymeric material and then the channels were eliminated to expose to the aqua resia. The coated sample was then cured at ~ 400℃ to stabilize the coating layer and to enhance the adhesion between the coating layer and Alloy 617 sheet. This curing might help in increasing the etch factor because the undercut effect could be reduced. An additional Teflon jig was used to prevent possible delamination of the polymer film during the etching with heating due to the difference in the thermal expansion coefficients between the metal and polymer. The etching of Alloy 617 was conducted with Aqua regia (HNO_3:HCl=1:3) etchant. During the etching, the etchant was heated-up to 50℃ ~ 100℃. A series of the experimental setup is shown in Fig. 1.

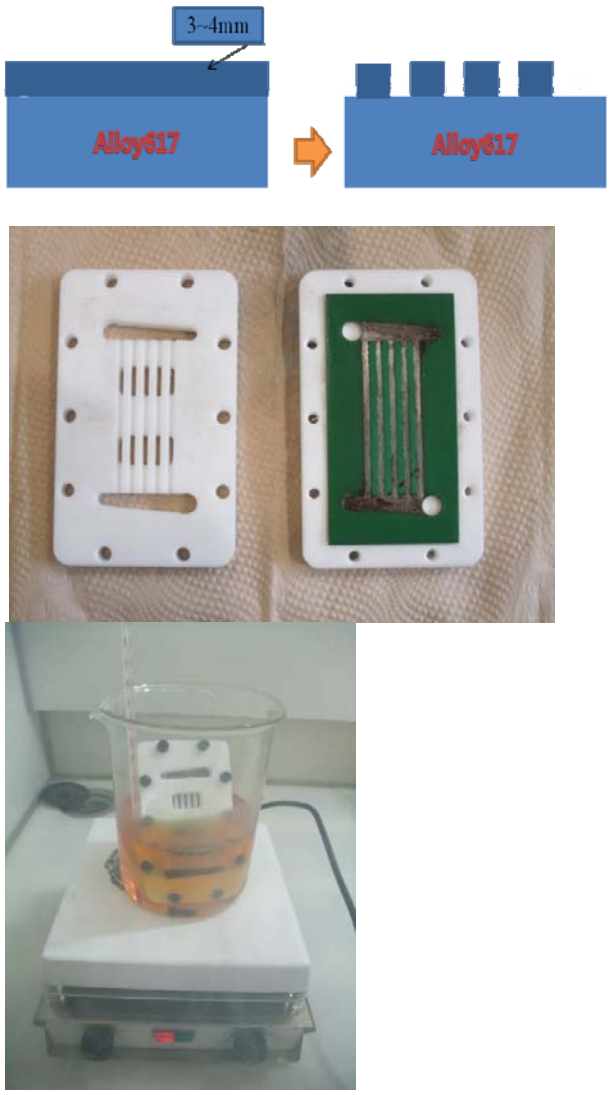


Fig.1. the etching experimental setup.

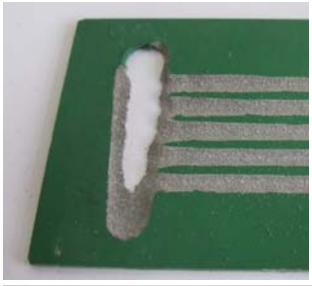
2.2 Results and Discussion

As shown in Fig.2, although Alloy 617 is highly corrosion resistant, the etching of alloy 617 is successful. The etching depth increases with an increased immersion period as well as the increased temperature in the aqua regia solution.

The etching depth of ~ 0.8 mm could be obtained after 1 hrs etching at ~ 60℃. Therefore, in the case of Alloy 617 an immersion in the aqua regia at 60 ℃ for less than 1 hr should be appropriate for the etching depth of 0.5 mm. A few tens minutes of etching should be good enough to control the etching depth.

Fig. 2. The optimum etching condition is obtained for Alloy 617.

The Teflon coated layer is highly resistant to a strong etchant such as aqua resia, since Alloy 617 sheet was pierced without affecting the coated layer with the etching in aqua resia for a few hrs (Fig. 3a). The etching depth of ~ 0.6 mm is obtained after 1 hrs at 50-60 ℃ with stirring the etchant and a sound etched sample was produced (fig. 3b). If we use the Teflon jig, the resolution of the etched line could be more improved. We can reduce the etching time if we increase the temperature.


(a)

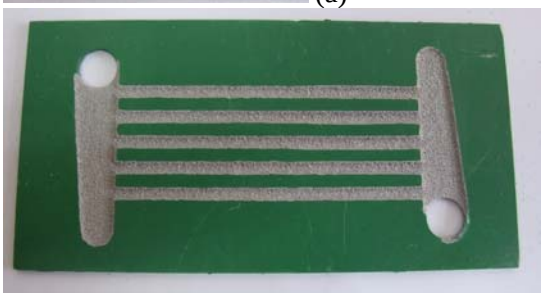

(b)

Fig. 3. The pierced etching (a) and the optimally etched channels.

This polymer masking machining of Alloy 617 for He channels uses strong chemical etchants such as aqua resia to remove unwanted workpiece material by controlled dissolution. This process involves corrosive oxidation of selected areas of Alloy 617 and does not alter the internal structure of Alloy 617 and the properties like hardness, grain structure, and ductility. The fluid flow passages for PCHEs have approximately a semi-circular cross section. The passage shape may be corrugated or straight, depending on a number of factors, such as the working fluid to be used, the heat load, and the pressure drop requirements.

The chemical etchability of Alloy 617 plates has been confirmed in this study and the other persons also proclaimed the possibility of the photochemical etchability [1]. Fig. 2 shows the channel cross section is approximately semi-circular with a channel width of ~ 1.5 mm. The chemical etching with Teflon coating proved to be advantageous as the evidence suggests.

3. Conclusions

The spray-coated to 3-4 mm thick with Teflon polymeric material on Alloy 617 sheet has proved to be feasible for the He channel machining. The Teflon coated layer is highly resistant to a strong etchant such as aqua resia. The etching depth of ~ 0.6 mm is obtained after 1 hrs at 50-60 ℃ with stirring the etchant.

Acknowledgement

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REFERENCES

[1] Mylavarapu, S.K., Sun, X., Christensen, R.N., “Photofabrication and surface roughness of flow channels for a compact high-temperature heat exchanger”. American Nuclear Society Winter Meeting, November 9–13, 2008, Reno, Nevada. Transactions of American Nuclear Society 99, 837–839.