

# Fabrication Techniques of the Sample Supporting Jigs for Post Irradiation Examination with 3 Dimension Printer

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## Abstract

To verify the reliability and safety of spent fuels, long term Post Irradiation Examinations (PIEs) were conducted by the Reactor Fuel Examination Facility (RFEF) at Japan Atomic Energy Agency (JAEA). In order to handle samples of various sizes and shapes using a manipulator, several kinds of jigs were used in PIEs. Nowadays, the sample size is getting smaller due to PIEs data required further details.

Though the jigs are usually manufactured by machining process, we attempt to make PLA resin jigs using 3D printers for the purpose of reducing manufacturing time and improving dimensional accuracy. It became clear that the actual dimensions of the 3D-printed jigs were slightly smaller at the concave section and larger at the convex section compared to the plan, therefore, it is necessary to take this into consideration when designing for jigs to be made with 3D printers.

Further applications of 3D-printed jigs include those used in SEM observation, for good carbon film deposition, and in metallography, where jigs are applicable without harmful effects on polishing and etching processes.

## 1. Introduction

Recently, several types of 3D printer is merchandized in open market, high priced 3D printer have the various systems to make the molding piece precisely. Although low priced one is weak for the processing accuracy. So, we verify the mechanical characterizations of the low priced 3D printer and consider the optimum design on the 3D CAD software to make the jigs precisely. 3D printer has an advantage shown below.

- Molding time is largely shorter than machining process.
- A design change is easy.
- Anyone can produce the same product.

## 2. Mechanism of 3D printer

The 3D printer is composed of the nozzle head, the nozzle head driving units, and the molding bed as shown in figure1. The nozzle head take in a filament and melted filament inject on the molding bed continually. The nozzle head moves parallel to the X-Y plane on the bed. The 3D printing process turns a jig into tiny little slices from the bottom-up.

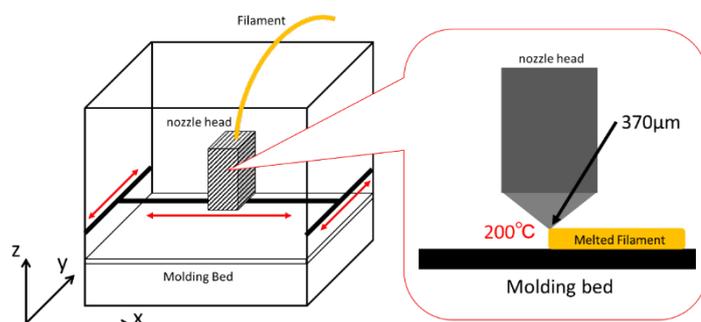


Fig.1 Composition of the 3D printer

## 3. The jig for fracture surface observation by SEM

Required specification of the jigs is shown below.

- The fracture surface of sample should be hold horizontally on the scanning base.
- After SEM observation, the sample should be removed from the jig easily to use it for a metallographic examination.

Dimensions of the sample are shown in figure 2. The sample should be stood vertically and

entered into the holding section of the jigs. Therefore, shape of the jigs is designed as shown in figure 3. Method to enter the sample is shown in figure 4. As a result of molding the jigs used 3D printer at first, the holding section is not mold as shown in figure 5.

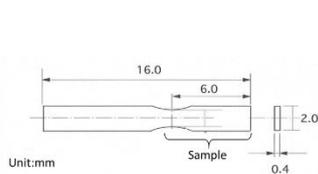


Fig.2 The sample

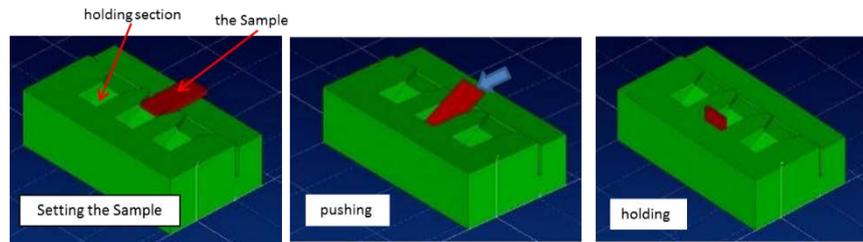


Fig.4 Method to enter the sample

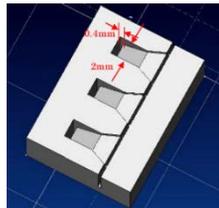


Fig.3 Design the jigs

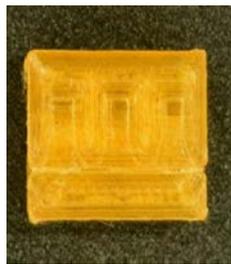


Fig.5 Molded result at first

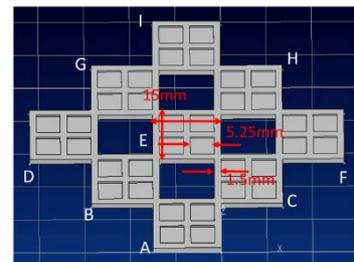


Fig.6 model to evaluate dimensional accuracy

#### 4. Design concept of the model to evaluate dimensional accuracy

To evaluate the dimensional accuracy of the jigs used 3D printer, the model is designed as shown in figure.6. A block is designed square of 15mm and are formed concave and convex portions. To evaluate change of dimension precision on arbitrary position of bed, nine blocks is connected.

#### 5. Evaluation of molding size at the convex section and peripheral size

The size of convex section ( $x_1, x_3, x_5, x_6, x_8, x_{10}, y_1, y_3, y_5, y_6, y_8, y_{10}$  shown in figure.7) is measured to evaluate the dimensional accuracy of molding at the convex section of each block. The measured dimensions are compared with designed value. In this result, the size of convex section is approximately 40% ( $\pm 10\%$ ) larger than the designed size on X-axis and Y-axis. The maximum deference is about 60%. It is considered that dimensional increment of the convex section molded around the concave section is due to bloat of filament.

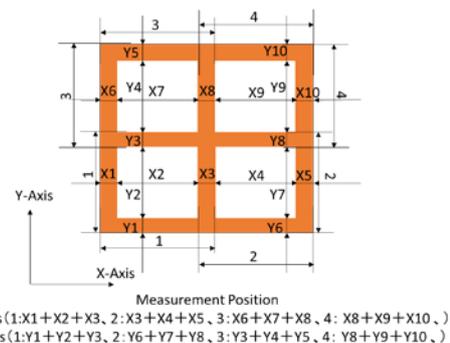


Fig.7 Measurement position

To evaluate the dimensional accuracy of peripheral size each blocks (A-I), dimensions of 1~4 on X axis and Y axis shown in figure.7 is calibrated. In this result, there is a little difference on each blocks, precision of outline size increase about 5% (max: 10%).

#### 6. Effect of layer height for molded dimension

Effect of layer height for molded dimension in the X-axis direction and Y-axis direction is evaluated. Models are cube of width:15mm depth:15mm, molded height is 4 conditions (5mm, 10mm, 15mm, 20mm), layer height is 3 conditions ( 300 $\mu$ m, 150 $\mu$ m, 50 $\mu$ m ). Dimensions in the X-axis direction and Y-axis direction are measured on each height. Effect of layer height for molded dimension is shown same trend in either layer height.

### 7. Molding to apply this study

By molding size evaluation of convex section and peripheral size, it can be seen that dimension of the concave section is decreased because of dimensional increment of the convex section which occurred both sides of the concave section due to bloat of filament.

Because of the above situation, the jigs design of figure 2 was revised. Before and after revised measurement and molding result is shown figure 8. The measurement of the revised model are satisfied with the jigs design of figure 2.

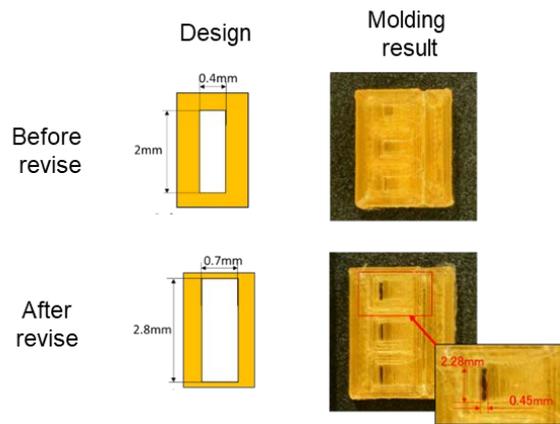


Fig.8 Comparison result

### 8. Jigs for SEM, metallography and tool for penetration tube

The molding jig by 3D printer was provided to the preliminary experimentation for the fracture surface observation by SEM. The samples are set in the molding jig and gold coating are performed on the jig with samples by vacuum deposition method to make the conductive film between jig and samples.

The secondary electron image of fracture surface is shown in figure 9. Small changes of form were occurred on the jigs surface, when direct irradiation of electron beam to the jig. This phenomenon shows, the PLA resin is weak against heat.

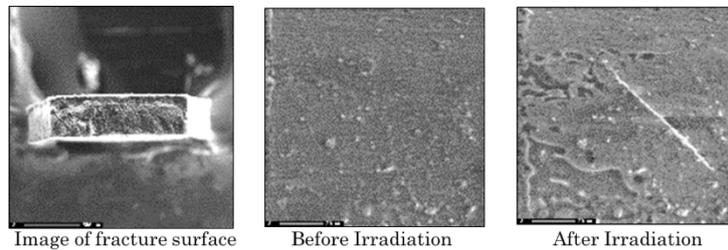


Fig.9 The secondary electron image

In the metallographic examinations of spent fuels and TMI-2 debris, several samples should be mounted together in the same acrylic tube for saving the preparation time of grinding and polishing process. It is difficult to make the equalizing mount of samples in the acrylic tube only using the manipulator. The jig for metallographic examination was molding by 3D printer and dummy samples mounted in the acrylic tube to verify the adaptabilities of the jigs for the metallographic examination. The figure 10 show the results of metallography before and after etching. The photograph of after etching shows the PLA resin was not encumbered the etching process. According to these results, the PLA resin is suitable for the metallographic examination.

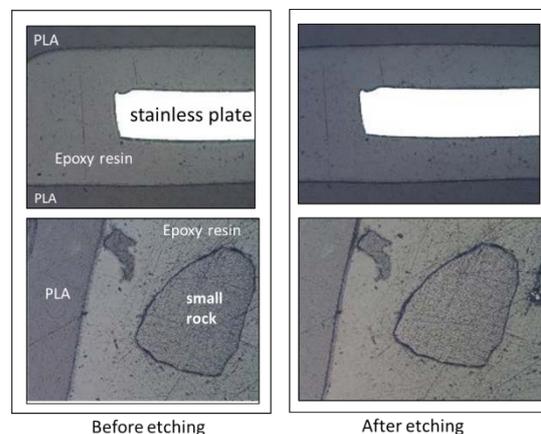


Fig.10 the results of metallography

In the other example of use, the observation tool for penetration tube between control room and hot cell was designed and molded by the 3D printer as shown in figure 11. This tool holds the endoscope type USB connectional camera and light at the top side of the tool and passes through in the penetration tube (diameter as  $\phi 49.5\text{mm}$ ) to check the inner surface condition as scratch mark or contamination of penetration tube. Since this order comes from operation person of hot laboratory, molding time of the jig was only six hours including the design process by CAD.

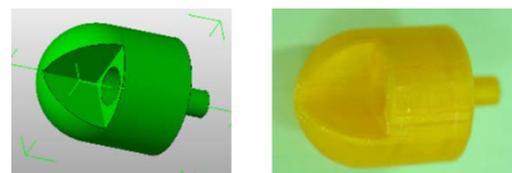


Fig.11 Design and molding result

## **9. Conclusion**

It became clear that the actual dimensions of the 3D-printed jigs were slightly smaller at the concave section and larger at the convex section compared to the plan, therefore, it is necessary to take this into consideration when designing for jigs to be made with 3D printers. Further applications of 3D-printed jigs include those used in SEM observation, for good carbon film deposition, and in metallography, where jigs are applicable without harmful effects on polishing and etching processes.

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