Influence Of Nozzle Caliber on Rapid Forming Discipline

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Abstract

The theories of jet electroforming (JEF) were introduced. The several copper specimens with simple shape were fabricated by the developed device under the optimum procession parameters. Microstructure evolution of copper layer was examined by means of the scanning electron microscopy (SEM) and x-ray diffraction (XRD). Nozzle caliber influence on electroforming rate, formed precision, scanning interval were studied. The result shows that nozzle caliber has basal the linear relation with the electroforming rate, the electroforming rate increases with increasing nozzle caliber; nozzle caliber has great effects on the precision of electroforming spot, the well precision of electroforming spot can be gained with the small nozzle caliber.

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1. Introduction

The traditional rapid forming technique primarily focuses on processing of metalloid whose inherent characteristics confine the application of the technique in industrial. Hence direct manufacturing of metallic components and parts with high accuracy and mechanical property has become the research orientation of rapid manufacturing technique[1]. for example, multiphase structure deposit method[2], direct metal sintering forming[3], selective laser sintering[4], laminated object manufacturing etc. By reviewing these methods, it is found out that they are mostly conducted under high temperature and high

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pressure, for which the crafts are complex. The jet electroforming rapid manufacturing technique recommended by our research group incorporates preceding research results and is based on electrochemistry principle, can accomplish direct manufacturing of nano-crystalline parts under normal temperature and pressure. The craft is relatively simple, the cost is low and has some practical significance. The influence of relevant technological parameters including electroforming voltage, electrolyte jet distance, jet velocity on jet electroforming rapid formation has been elaborated in the documents and is not repeated here. The paper lays special stress on analysis of the influence of nozzle caliber on electroforming speed, forming accuracy and casting distribution characteristics and the prototyped metal copper sample workpiece with nano-crystalline structure.

2. Experimental Procedures

A initially device was designed for the fabrication of accurate nanocrystalline nickel parts, depending on the functional requirement. A electrolyte was used to deposition on the flat stainless steel substrate under the following composition(g/L): CuSO₄·5H₂O-250, H₂SO₄-40, Electrodeposition took place in the bath at a temperature 30 °C.

The nickel depositing layer’s ingredient and microstructure was measured by using a Rigaku XRD D/Max-IIA diffractometer with scanning electron microscope. Prior to measure, EDX samples were vibrated by ultrasonic vibrator and washed in distilled water and alcohol. Using the scherrer's equation to calculate the average size of the specimen assembled on the substrates.

3. Analysis and Discussion

Fig.1 respectively shows the casting plaque obtained under the condition of different d and the graph of relation between the casting plaque and nozzle caliber where the electroforming voltage is 70V and jet distance is 3mm. It can be learned from the figure that the caliber of casting plaque exhibits arithmetic growth along with the augment of nozzle caliber. The increment is notable and the diameter is approximately 2 times of nozzle caliber. For example, the diameter of casting plaque in case of 4mm nozzle caliber is approximately 8mm, whereas the diameter of casting plaque obtained in case of 1mm nozzle caliber is less than 2mm. The results show that the smaller nozzle caliber brings about less relative error of casting plaque when the rest technological parameters remain constant and the dimension accuracy for forming parts is high. Otherwise it goes oppositely.

![Fig. 1 Effect of nozzle caliber on precision of electroforming spot: (a) electroforming spot; (b) relation of nozzle caliber with electroforming spot diameter](image-url)
Fig. 2 shows the formed square metal dies where nozzle caliber is respectively 1mm and 2mm. It can be visually seen from the figure that radius of rounded corner of metal die is larger when nozzle caliber is 2mm, approximately 1mm, whereas the radius of rounded corner of metal die is notably small when nozzle caliber is 1mm, just 0.5mm. Evidently the smaller nozzle caliber results in higher forming accuracy when the rest parameters remain constant.

Fig. 2 Electroforming layer with the different nozzle caliber: (a) $d=2\text{mm}$; (b) $d=1\text{mm}$

Fig. 3 shows the distribution characteristics of casting thickness prepared when nozzle caliber is respectively 1mm and 2mm. It can be seen from the figure that casting thickness is maldistribution, relatively thicker in the center of casting whereas thinner in borderline, exhibiting exponential function distribution. It illustrates that the current intensity for the center of sediment is top and that the current intensity for the borderline is lowest during the course of electrodeposit. Higher current density results in faster deposit speed and thickness for sediment is larger within the identical duration; otherwise the electrodeposit speed is slow. In the meanwhile the thickness and width of casting obtained through nozzle with smaller caliber is evidently lower than that of casting obtained through nozzle with large nozzle, which further justify the experimental conclusion that larger nozzle caliber results in faster electroforming speed.

(a)  

Fig. 3 Effect of nozzle caliber on electroforming depth: (a) $d=1\text{mm}$; (b) $d=3\text{mm}$
Fig. 4 manifests the surface contour and appearance of casting center and borderline, the microstructure for these two locations is also completely distinctive. Along the casting borderline the current density is low, deposit speed is slow, surface of sedimentary layer is leveling, granula is fine; In the location closer to center the current density goes up and the consumption speed of deposited metallic ion at cathode is fasten. Where the transfer speed of metallic ion in electrolyte towards cathode is insufficient, thick diffusion layer is generated. The sediment is prone to from cellular and expand prominently, thus turns rough and gross cellular granula appears.

![SEM micrograph of the different section in electroforming layer: (a) center; (b) edge](image)

The forming of metallic parts is accomplished by scanning of layers and lines successively in line with rapid forming principle. Therefore the appropriate scanning interval $L$ should be determined in relation to the distribution condition of electric field to ensure leveling casting surface with low roughness is obtained. Perform scanning experiment on caliber of nozzle between 1~3mm respectively where electroforming voltage is 70V, jet distance is 3mm, scanning speed is 1mm/s. The result demonstrates that preferable surface smoothness of casting can be obtained where the scanning interval $L$ is equal to or less than 0.5d, which can be explained by that the mutual superimposition of edges of two sediments makes up the detect of thin edge of single sediment, and results in the thickness across the whole sediment approach uniform. Where the scanning interval is larger ($L>0.5d$) apparent peak and valley will appear on the surface of casting, this is because the distance of two sediments is far and lap joint between two scanning line is limited (Fig. 5), sediment along the borderline hasn’t superimposed completely, thickness for location of superimposition is limited and fails to reach the thickness of sediment center. Where the scanning speed is excessive ($L>d$) it can’t shape up intact sediment and the middle of two adjacent sediments exists disruption. This is because just scattered or no electrical field is distributed at all along borderline of sediment, reducing ability for ion is weak, the nozzle has stopped before metallic ion is deposited, on this account consecutive casing plaque hasn’t achieved.

![Electroforming layer with the big scanning interval](image)
4. Conclusions

The nozzle with large caliber can increase the electroforming speed. The nozzle with heavier caliber results in a larger dimension of casting plaque which is 2 times of that of nozzle. This explains why the forming accuracy of parts is greatly going in the down side. The practically formed casting thickness is not just simple superimposition between layers. It is also influenced by electrical field distribution in the deposition process. During the course of electroforming the thickness distribution of casting is not equal, reach maximum in the center and gradually turn thinner while far apart, exhibiting exponential function distribution. For the sake of obtaining smooth deposited layer the scanning interval of $L \leq 0.5d$ (nozzle caliber) is preferable.

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