Research paper

Explosive forming techniques for making a copper plate relief

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Abstract

On the explosive forming process, a metal plate is formed by colliding with a die at a high velocity, so that the delicate figure of the die surface can be formed on the metal plate as it is. This excellent forming performance is considered to be very suitable for creating art works. The authors tried to form a copper plate into fish as it is, by means of explosive forming process. The present report represents the explosive forming process and shows some experimental results. In order to succeed in the explosive process, it is important to make the die skillfully. The important point of the die used for the explosive forming is as follows :

(1)The die must have adequate strength against impulsive loading so that the die may not be destroyed with the collision of the metal plate.

(2)The whole shape and the delicate scale figure of fish are precisely reproduced on the die surface.

(3)The shape of the die must be designed in order to prevent the breakage of the metal plate.

After several tries and errors in the experiment, successful results were obtained. In this paper, experimental results were presented including the failure experiments.

Keywords : explosive forming, underwater shock wave, underwater explosion

1. Introduction

In the explosive forming process, a metal plate is formed by colliding with a die at a high velocity, so that a delicate figure of the die surface can be formed on the metal plate as it is. The excellent forming performance is considered to be very suitable for creating art works. Asahi Chemical Industry Corporation Limited made Al panels with several geometrical figures by means of explosive forming technology to decorate surfaces of buildings[1]. Fujita et al. tried to made artificial work pieces with plane figures by means of explosive forming[2]. They proposed the method using printing paper for photograph and cutting sheet as material of the die. The paper or sheet was made hole in shape of figure to create and the die for explosive forming was made by pasting it on a stainless steel 304 plate. Several metal panels were produced for memorial services by their method.

In this investigation, it is tried to make three dimensional art works by means of explosive forming process. The objects of production are fishes which have delicate figures of suck as scales.

In the present paper, we propose a method to make the figure of fish on a copper plate and discuss experimental results.

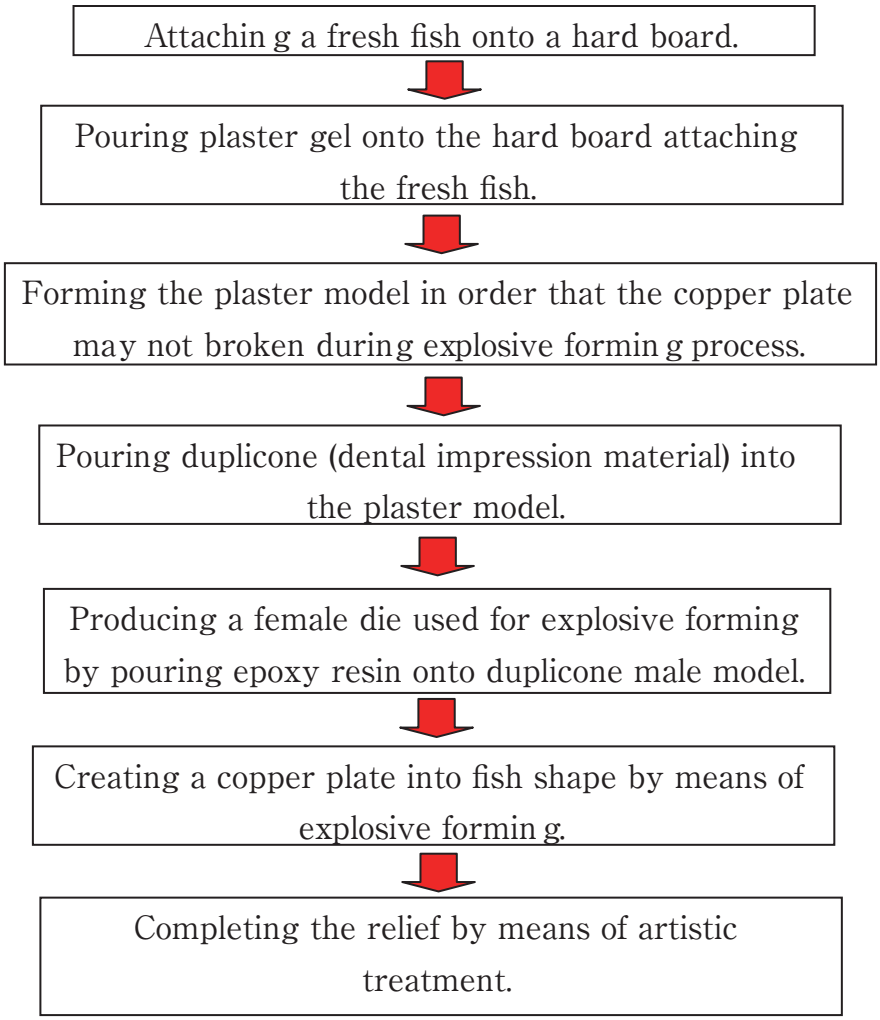


Figure 1 A series of processes for creating a copper plate into a relief of a fish shape by means of explosive forming technology.

2. Experimental procedure

Figure 1 illustrates a series of processes for making a relief of copper plate in a shape of fish by means of explosive forming.

A die used for explosive forming must be made of Ren Cast MEZ200, which is commercial name of a kind of epoxy resin and is sufficient strength for impulsive loading. The die of Ren Cast cannot, however, be obtained directly from a fresh fish and the die must be reformed to improve unsatisfactory results, so that a plaster model must be at first made.

Therefore a plaster female model is made by pouring plaster gel onto a fresh fish fixed on a sheet of hard board. The plaster female model is reformed to prevent the breakage of the copper plate during explosive forming. The method reforming the plaster model is mentioned in the following section.

Explosive forming process was performed using the experimental equipment shown in Figure 2 which was designed by researchers in Sojo University. After a specimen (an annealed copper plate of 0.3 mm thick) is pressed against gum packing set on the flange of the die holder, air in the die cavity is removed by a vacuum pump. Detonating code of 500 mm long is attached on the ceiling face of a pressure vessel with gum tapes in the shape of a circular ring as shown in Figure 3. After the pressure vessel is put on the die holder, the equipment is submerged. As soon as the detonating code is initiated, underwater shock wave is generated. The shock pressure arriving at the plane of the specimen is heightened by adding the direct shock wave to the reflecting one from the ceiling face, and the pressure of detonating gas bubble is kept at high level during forming process because the vessel is closed just after initiation. Since the vessel is not connected with the die holder, the vessel only flies up along guide ports and too large stress is not generated in the vessel structure in spite of high pressure in vessel. The flying velocity is largely reduced by resistance of water, so that impulsive stress is not so high when the vessel collides with stopper.

3. Experimental results

The copper plate collides the die at high velocity obtained by high shock pressure and is deformed into the shape along the die. When the curvature radius of the outline edge in the die is too small, the extension strain is concentrated at the part next to the outline edge, and the plate is broken there. Figure 4(A) shows an example of such a broken part. According to the numerical simulation by Fujita et al., the curvature radius of the edge must be

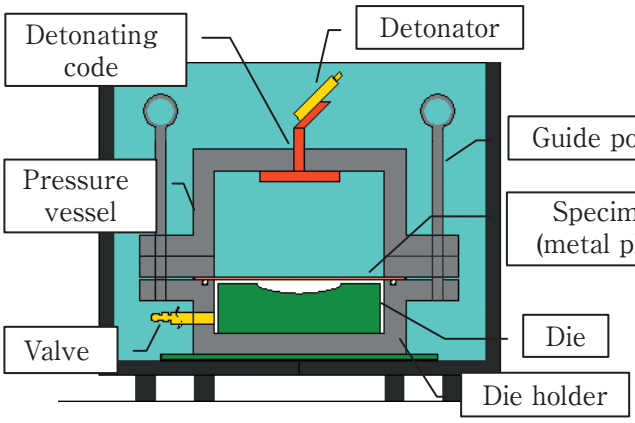


Figure 2 The experimental equipment for explosive forming.

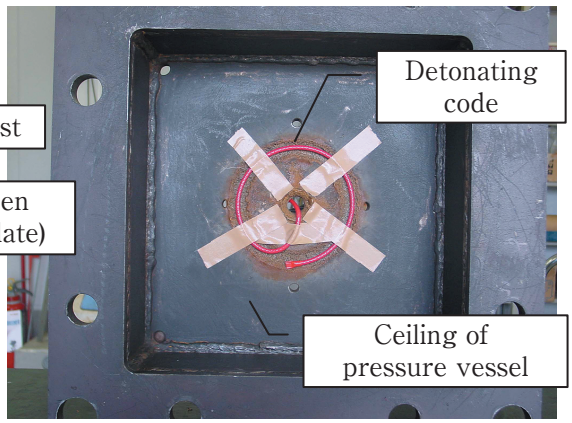
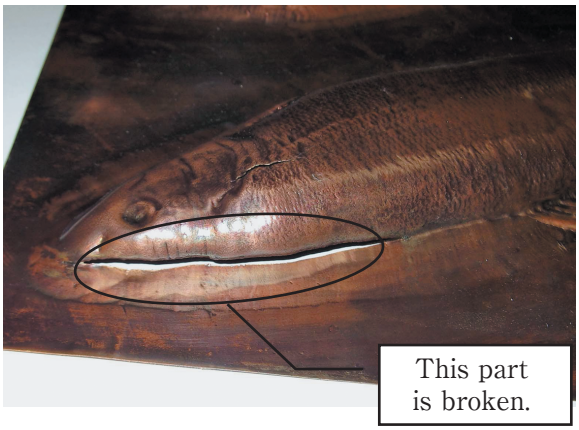


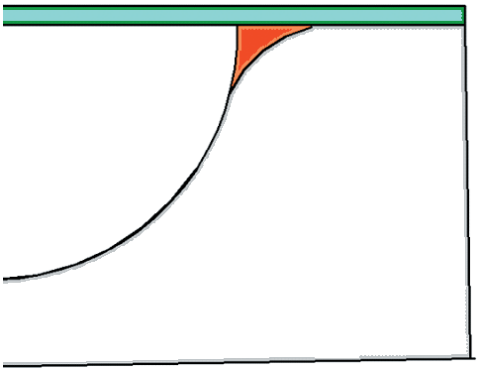
Figure 3 Detonating code attaching on the ceiling face of pressure vessel.



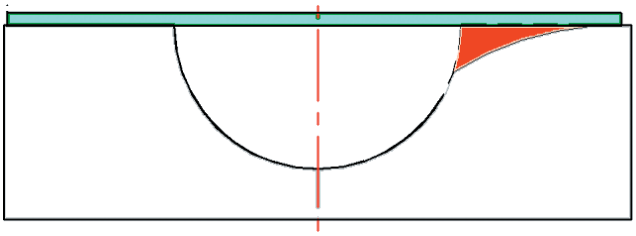
(A) The copper plate is broken at the outlined edge of the fish.

(B) The copper plate is broken at the central part of the abdomen of the fish.

Figure 4 Failure examples



(A) Making round the outlined edge.



(B) Shaving off the flat surface outside of fish outline into a little inclined surface in case of deep female die. (The part of hatching line in this figure is shaved off.)

Figure 5 The important point of the operation reforming the plaster model.

more than 5 times of the plate thickness for no strain concentration there, when the coefficient of friction (COF) is 0.3[3]. When such a broken part was generated as shown in Figure 4(A), the outline edge of the plaster model was reformed a little more round with a cutter knife as shown in Figure 5(A). Further when a thin metal plate put on a female die subjected to uniform impulsive pressure, the largest extension strain is generated at the central part of the plate as suggested by Hudson's analysis[4]. Figure 4(B) shows an example that the plate was broken at the central part of the abdomen. Such a breakage is generated when the female die is deep. When such a broken part was generated, flat plane outside of the outline edge was shaved into a little inclined one as shown in Figure 5(B). By making a little inclination, the inward flow of material is caused in the part outside of the outline edge and the die becomes a little shallow with decreasing to the height of the outline edge. On account of these effects, the extension strain at central part was expected to decrease.

Such reformations of plaster model must be performed as taking care of very little spoiling the image of the original fish. The die of Ren Cast was remade using the reformed plaster model by such method. Successful relief were obtained by using the remade die as shown in

(A) A kind of bream

(B) A flatfish

Figure 6 Examples of successful relief.

Figures 6(A) and (B). Both pieces were formed into the shapes of fishes as they are. The breakage made in the relief is found only at the part of opening mouth of the bream and other breakage cannot be found in both relief. The pattern of scales clearly appears on the relief of the bream as shown in Figure 6(A) and the skin figure of the flat fish's own clearly appears as shown in Figure 6(B).

4. Conclusions

The following conclusions are obtained by the consideration of the results.

(1)When the copper plate was deformed by shock pressure using a female die, the plate was apt to be broken at the part next to the outline edge and at the central part of the die. Relief with no breakage were obtained by making a little round at the edge and making flat plane outside of outline edge into a little inclined plane.

(2)Successful relief were obtained by explosive forming process using the reformed die. They were formed into the shapes of fishes as they are. Further the pattern of scales and skin figure of fishes clearly appear on the work pieces.

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爆発成形法による銅板レリーフの制作

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爆発成形プロセスにおいて，金属板は高速で型と衝突することのよって成形されるため，型面の繊細な形状がそのまま金属板の上で成形することができる。この優れた成形技術は，芸術作品を制作することに非常に適しているとものと考えられる。

筆者らは，爆発成形法によって，銅板上に魚拓を作ることを試みた。魚拓を銅板上に爆発成形法を用いて制作する方法を報告し，いくつかの実験結果を示す。爆発成形を成功するためには，技術をもって型を製造することが重要である。爆発成形のために使われる型の要点は，次の通りである：

(1)型が金属プレートの衝突で壊れないように，型は衝動的な負荷のために強くなければならない。
(2)魚全体の形と繊細なうろこ形状は，正確に型面で複製されなければならない。
(3)金属板は成形間壊れないよう，型の形状を設計しなければならない。

いくつかの試行錯誤の後，良好な結果が得られた。失敗した実験結果を含みながら発表する。

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