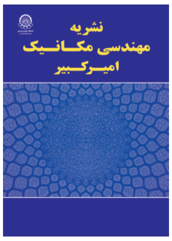

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Experimental and Numerical Investigation of Forming Force of Ti6Al4V Sheet in Electric Hot Incremental Forming Process of a Conical Part

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ABSTRACT: Ti6AI4V sheet, has poor formability in room temperature. In the recent years, different works have been performed to analyze manufacturing of lightweight materials using ISF process. Due to wide use of Ti6Al4V titanium sheet in aeronautics and astronautics industries, electric hot incremental forming of Ti6Al4V sheet has been investigated in this study. The results showed that the material can be suitably formed by EHIF in a range of 400–500°C with a slight oxidation. In the current work, performance of electric hot incremental forming process is investigated on the Ti6Al4V sheet using experimental and finite element modeling. The effects of processing parameters, such as wall angle, step size and tool diameter were investigated on the incremental forming force of samples. The results demonstrated that the incremental forming force increases with increasing the step size and decreasing the tool diameter. In addition, the finite element modeling was used to compare the experimental and numerical results. The numerical prediction of forming force was obtained and compared with experimental results, showing a good agreement.

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1- Introduction

Incremental Sheet Forming (ISF) process is one of the dieless methods to produce 3D sculptured sheet metal parts [1, 2]. Because of good formability at room temperature, the process mainly focuses on the steel and aluminum alloys [3-5]. Because of hardness of titanium alloy, a few researches have been focused on the titanium alloy. The Ti6AI4V sheet has poor formability at the room temperature. So, the superplastic forming at 750-950°C temperature is usually used [6].

In this study, experimental and numerical investigation of electrical hot incremental forming process of Ti6Al4V was performed.

2- Methodology

The main equipment of experimental setup in the current study are composed of five parts: forming tool, sheet blank, blank holder, DC power source to develop the EHIF process and a 3-axis CNC mill machine as a platform. A simple tool with hemispherical end forms the sheet at high temperature; range of 400–500°C. Also, a thermometer was used to control the temperature at the interface of tool and sheet (Figure 1).

A dynamometer was employed under blank holder, clamped to the table of milling machine to measure the incremental forming force. Positive current cable of DC power source (transformer) is connected to the forming tool, and negative current cable to the blank holder. According to the Joule's law, when DC current flows from the tool to sheet, the high-current density generates heat.

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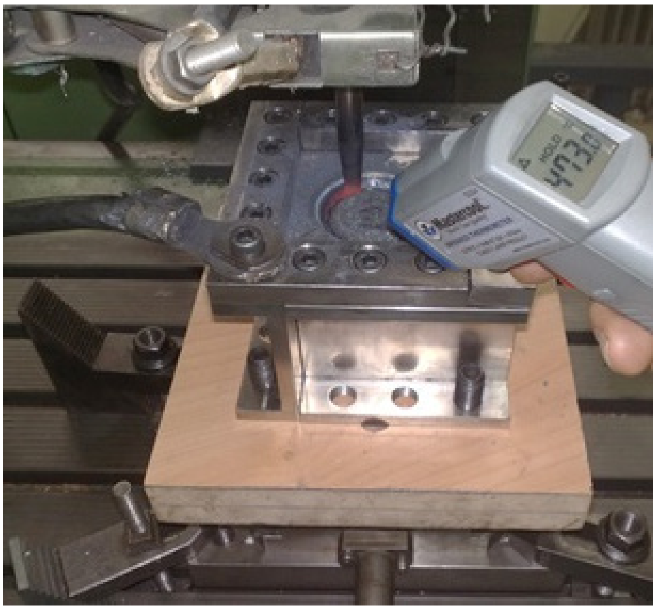

Figure 1. The experimental setup

3- Results and Discussion

The experiments were carried out on the Ti6Al4V sheets. The size of the sheet blanks corresponds to 90×90×1 mm. The required object modeling and tool path programming were carried out in the commercial CAD/CAM software POWERMILL. The spiral path has been used as the forming traveling approach. In this study, the feed rate value was equal to 1000 mm/min and current was kept at 400 A to obtain a temperature range of 400-500 °C at the interface of tool and sheet. Measurement of F_x, F_y and F_z forming forces were performed in this study. Also, the magnitude of forming force was extracted as F. The F_z is the maximum forming force applied in the vertical direction. The F_x and F_y are the in-plane forces exerted on the sheet blank. All results are based on the resulting total vector sum of these three forces. In this section, the influence of the mentioned parameters will be discussed on the incremental forming forces. Three conical frustum with diameter of 60 mm at the bottom and wall angles of 45°, 56° and 64° were selected to evaluate the forming force. The magnitude of force decreases with increasing the wall angle (Figure 2).

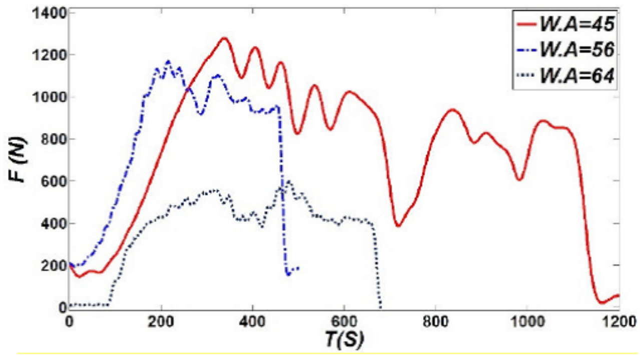

Figure 2. Variation of forming force with wall angles

The variation of vertical step size on the forming force has been presented in Figure 3.

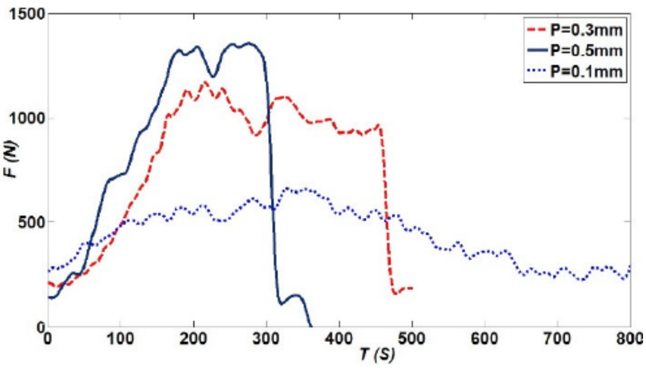

Figure 3. Variation of forming force with vertical step

Increasing the pitch causes reduction of the current density and the generated heat. Therefore, the ductility of the sheet decreases, increasing the required force to form the samples. Similar to the wall angle, an increase in tool diameter causes reduction of the amplitude of required forming force. In fact, the tool-sheet interface and current density are increased by increasing the wall angle or tool size. This phenomenon increases the temperature at the localized zone at the tool-sheet interface. Therefore, the ductility of the material at the contact zone increases and the magnitude of forming force decreases (Figure 4).

In this study, the numerical results have been obtained to compare the process parameters. The behavior of the stress-strain of Ti6Al4V alloy is simulated by the Johnson-Cook model. The numerical results of thickness variation have been presented as Figure 5.

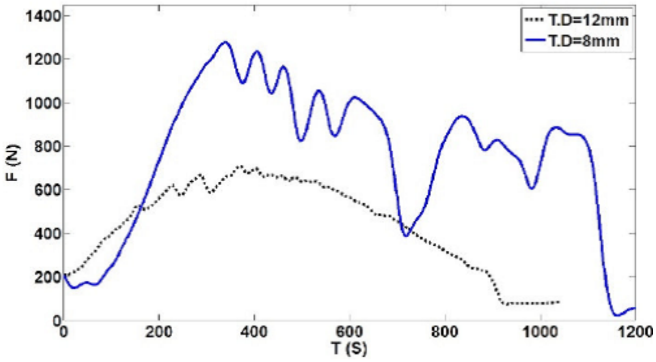

Figure 4. Variation of forming force with tool diameter

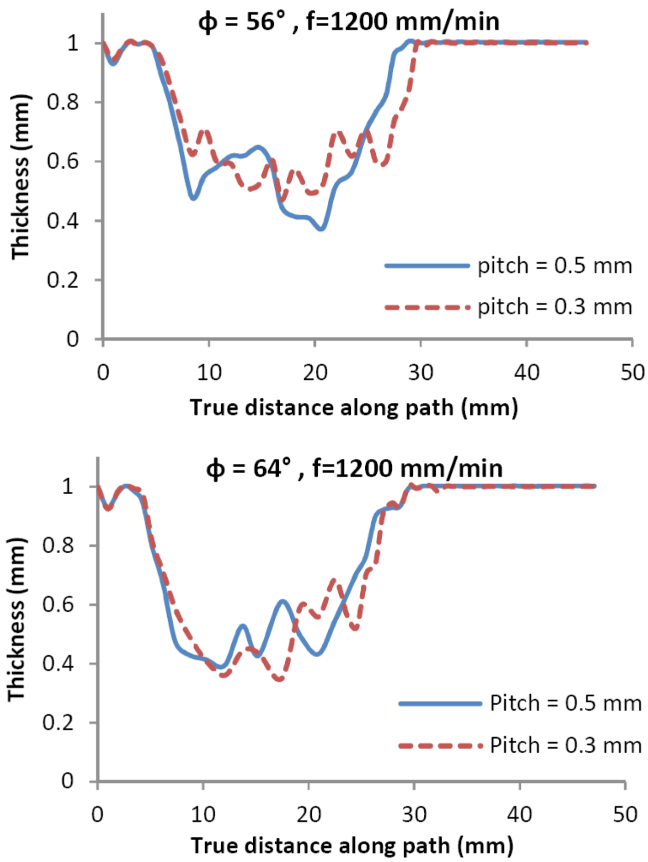

Figure 5. The numerical results of thickness variations

4- Conclusions

The results of the study can be summarized as follows:

1. The measured forces in the EHIF show that with increasing the tool diameter and wall angle, the current density and generated heat are increased. Therefore, the ductility of sheet is increased and the forces will decrease. Also, the forming force can be increased with increasing the step size.
2. In the case of wall angle of 56° and tool diameter of 8 mm, for step size of 0.3 and 0.5 to 0.1 mm, the amount of forming force was increased 37.8 and 47% in average, respectively.
3. In the case of wall angle of 45° and step size of 0.3 mm, for tool diameter of 12 to 8 mm, the amount of forming force was decreased 47.3% in average. Also, In the case

of wall angle of 56° and step size of 0.3 mm, for tool diameter of 12 to 8 mm, the amount of forming force was decreased 40.6% in average.

4. The main and most important parameters in this process include: electrical current, tool feed rate and step size. So that with correct regulation and proper control of these three effective parameters, forming perfect of a part with wall angle larger than 45° may be feasible.

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