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Numerical Simulation of Maximum Stress in Single Point Incremental Forming of TA1 Sheet based on Original Sheet Thickness

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Abstract

Titanium alloys are widely used in medical, automotive, aerospace and other fields due to their corrosion resistance, high strength and light weight. Single point incremental forming technology has been applied to titanium alloy processing to meet the demand of customized titanium alloy products. The maximum stress produced in the process of single point incremental forming has an important influence on the formability. In this paper, ABAQUS finite element simulation software is used to study the influence of different original sheet thickness on the maximum stress in the process of single point incremental forming. The results show that large stress is produced at the corner of the part; The smaller the original plate thickness is, the easier the stress concentration is; With the increase of the original plate thickness, the maximum stress is smaller.

Keywords

Single Point Incremental Forming; Simulation Experiment; Maximum Stress.

1. Introduction

Single point incremental forming technology has the characteristics of short production cycle, low processing cost, high digital intelligence and high degree of flexible processing. It meets the requirements of green processing and manufacturing in the current era, and can meet the increasingly personalized, diversified and complex needs of people [1]. It has been applied in medical, automotive, aerospace, shipbuilding and other fields. However, because the technology is to extrude the sheet metal through the tool head, and there is no die support in the forming process, the processed parts will produce a certain accuracy error [2]. In recent years, this technology has been paid more and more attention by many scholars, and a lot of researches have been done on formability and forming accuracy.

Industrial pure titanium has been used in aerospace and other fields due to its high strength and low density. G. Hussain [4] and others evaluated the feasibility of cold forming of industrial pure titanium TA1 sheet, and studied the influence trend of layer spacing, tool head diameter and other process parameters on the formability of pure titanium sheet. Zhang Bin et al. Used the single point incremental forming process to process the plates with different thickness into square cone parts. The results show that the greater the thickness of the plate is, the smaller the springback is [5]. Titanium and its alloys are considered to be the most commonly used materials in aerospace, plastic surgery, dentistry and marine applications because they have better strength to weight ratio and stronger corrosion resistance than steel and aluminum alloys [6].

Most of the above researches take the sheet metal forming circular cone as an example to study the influence of different process parameters on the forming accuracy and forming quality of single point incremental forming, and some research results have been obtained, but the research on square cone

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is still less. In this paper, the influence of original sheet thickness on the maximum stress of single point incremental forming is studied by ABAQUS finite element simulation software, with TA1 titanium alloy sheet as the raw material and square cone as the forming target. It has important reference value for the application of single point incremental forming technology in the processing of titanium and its alloys.

2. Experimental scheme

The principle of single point incremental forming is shown in Figure 1. The upper and lower clamps clamp the sheet metal to make it fixed; The tool head extrudes the sheet metal layer by layer along the forming track of the expected contour shape of the forming part. The forming track is shown in Figure 2. Through the continuous extrusion of the tool head on the sheet metal, the deformation of the sheet metal increases, and finally the sheet metal is processed into the expected shape of the forming part.

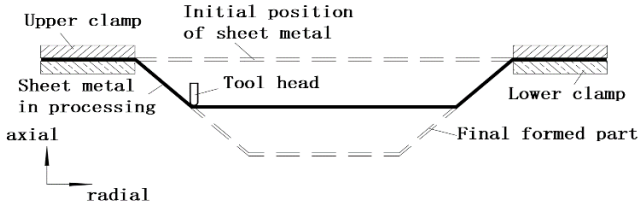

Figure 1. Schematic diagram of single point incremental forming

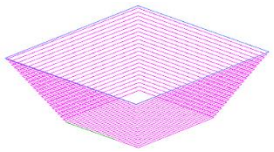

Figure 2. Spiral trajectory in square cone space

The original sheet thickness is one of the important parameters in single point incremental forming. The maximum stress produced in the process of single point incremental forming is an important evaluation index of formability. The greater the maximum stress is, the easier the sheet is to crack and the worse the formability is. Therefore, this paper takes the original plate thickness as the research object, and takes the maximum stress as the evaluation index to explore the relationship between the two.

3. Tensile test

In the finite element simulation, we need to use the material property parameters of the plate. In this paper, we obtain the material property parameters of TA1 through tensile experiments.

Under the condition of room temperature, the tensile test of TA1 plate tensile specimen was carried out with electronic universal tensile testing machine at the tensile rate of 1 mm / min. the size of tensile specimen was determined according to the tensile test method for metallic materials at room temperature (GB / T 228.1-2010) [7], as shown in Figure 3. Figure 4 (a) shows the intact tensile specimen of TA1 plate, and Figure 4 (b) shows the tensile specimen of TA1 plate broken.

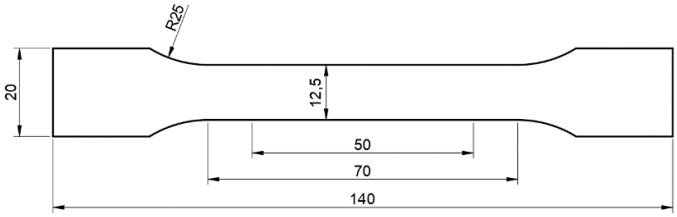

Figure 3. Tensile specimen size

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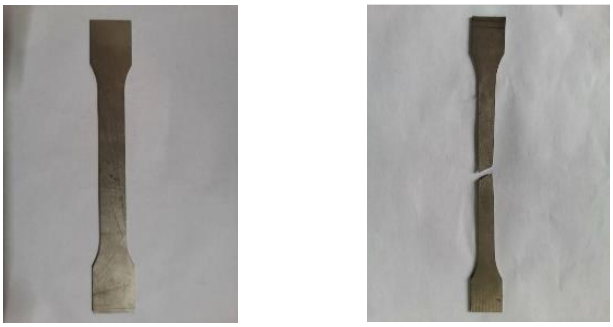

(a) (b)

Figure 4. Tensile specimen

The performance parameters of TA1 obtained by tensile test are shown in Table 1.

Table 1. TA1 plate material parameters

Material name	Young's modulus E(Gpa)	Poisson's ratio	yield strength δ_s(Mpa)	tensile strength δ_b(Mpa)	Density ρ(g/mm^3)
TA1	105	0.34	187	463	4.5

4. Numerical simulation experiment scheme

The plate material TA1 has a size of 160mm×160mm; The diameter of tool head is set to 10 mm; The outer dimension of the upper and lower clamps is 160mm×160mm, the inner dimension is 140mm×140mm and the thickness is 2mm.

The dynamic explicit algorithm is used in the simulation. There are three contact pairs in the simulation model, which are tool head and plate contact pair, upper fixture and plate contact pair, lower fixture and plate contact pair. Each contact pair is set as surface to surface contact. The plate mesh is divided into S4R shell elements.

To sum up, the established finite element simulation model is shown in Figure 5.

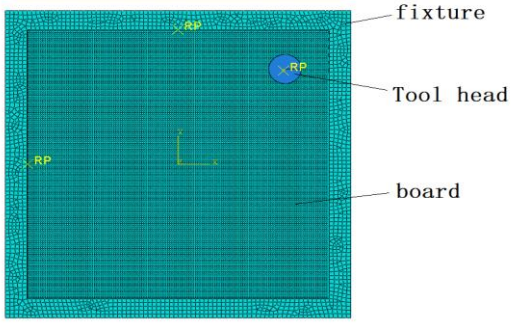

Figure 5. Simulation model of single point incremental forming

In this paper, the numerical simulation experiments with different original plate thickness (t_0 = 0.6 mm, 0.8 mm, 1 mm, 1.2 mm) are designed by using the single variable criterion.

5. Experimental results and analysis

Fig. 6 (a), (b), (c) and (d) are the stress nephogram of the formed part corresponding to the original plate thickness t_0 = 0.6 mm, t_0 = 0.8 mm, t_0 = 1 mm and t_0 = 1.2 mm respectively. Figure 6 shows that the larger stress distribution area is mainly located at the junction of the side wall area of the forming

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part and the bottom area of the forming part, and at the diagonal of the four side walls of the forming part. This is because, in the actual processing process, each corner area of the forming part is easy to produce stress concentration, so the stress in this area is large, and it is easy to produce fracture phenomenon. It can be seen from Figure 6 that from the original plate thickness t_0 = 1.2mm to t_0 = 0.6mm, with the decrease of the original plate thickness, the stress distribution gradually tends to concentrate.

Figure 7 shows the effect of original plate thickness on the maximum stress. When the original plate thickness t_0 = 0.6mm, the maximum stress is 463.059Mpa; when the original plate thickness t_0 = 0.8mm, the maximum stress is 448.812Mpa; when the original plate thickness t_0 = 1mm, the maximum stress is 438.651Mpa; when the original plate thickness t_0 = 1.2mm, the maximum stress is 436.878Mpa. Therefore, the smaller the original sheet thickness, the greater the maximum stress in the process of sheet single point incremental forming.

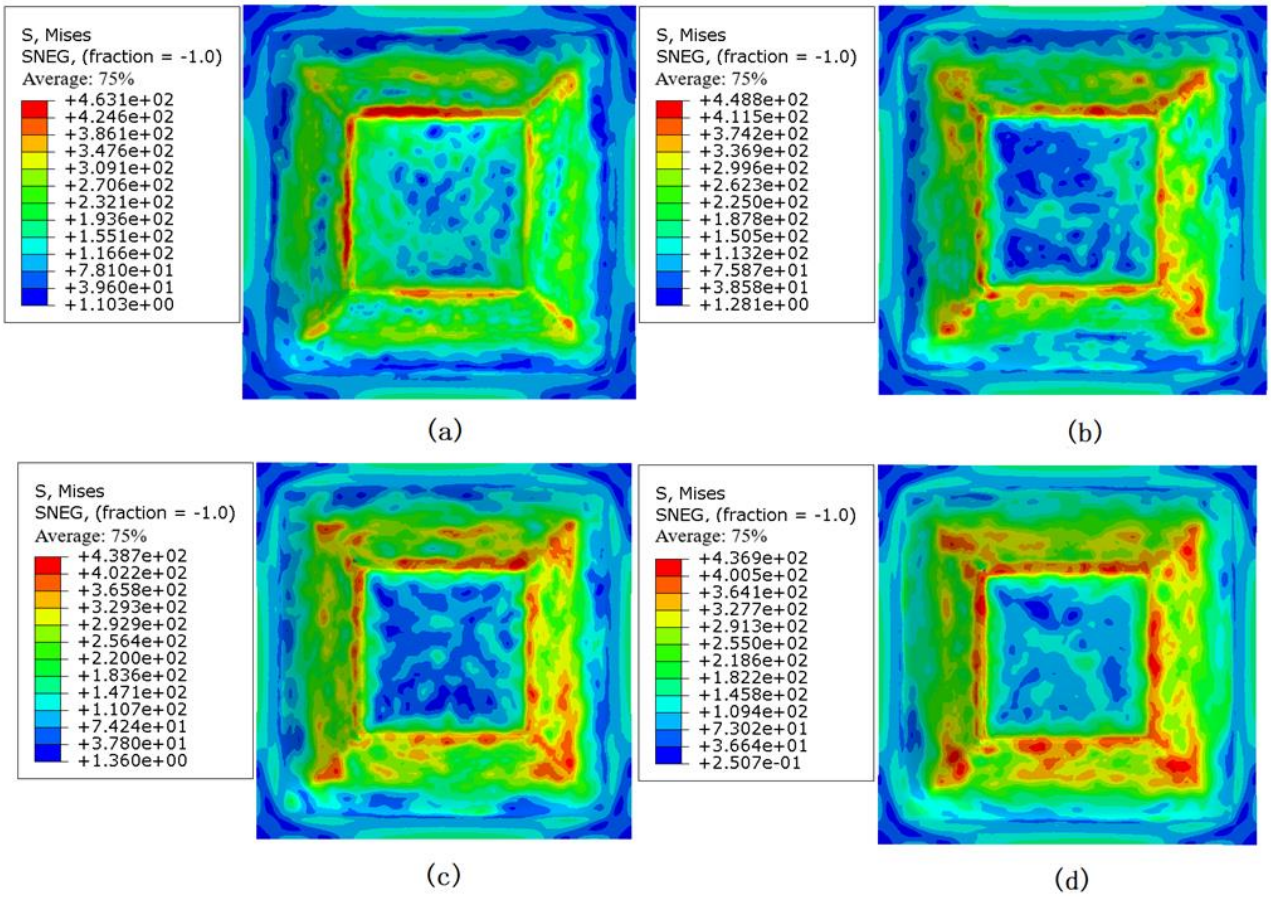

Figure 6. Stress nephogram of forming part

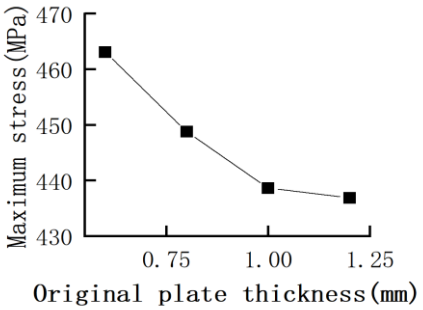

Figure 7. Effect of original plate thickness on maximum stress

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6. Conclusion

In this paper, the single factor simulation experiment is carried out by using ABAQUS finite element simulation software to study the influence of different original sheet thickness on the maximum stress of single point incremental forming

(1) In the process of sheet metal forming, the larger stress is mainly distributed in the corner area of the forming part.

(2) The smaller the original sheet thickness is, the larger the stress distribution is.

(3) With the increase of the original sheet thickness, the maximum stress in the forming process is smaller.

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