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Issue Article

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MODELING AND ANALYSIS OF THE ALUMINUM PLATE DRAWING PROCESS

Abstract: *The analysis of the calculation of the deformed state of a sheet metal blank during its drawing into the die with a rigid punch was performed in the article. It is determined that for the formation of a thin-walled plate, the punch force increases in proportion to the depth of pressing the blank into the die. Constant force indicates the achievement of full contact between the surfaces of the punch and the blank. At the bending points of the blank, maximum deformations are observed, causing a decrease or increase in the part thickness and an increase in the hardening of the material.*

Key words: *deep drawing, blank, thickness, strain, stress, material.*

Language: *English*

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Introduction

It is cost-effective to manufacture simple body parts of small dimensions with a small wall thickness using the method of deep drawing of a sheet metal blank [1-2]. In production conditions, deep drawing can be accompanied by various defects, for example, a significant thinning of the wall thickness of the part, wrinkles on the surfaces, the formation of cracks in the material, partial rupture of the material, etc. The causes of these defects are incorrectly selected process modes, small or large thickness of the sheet blank, lack of a blank holder, etc. Therefore, in order to reduce production costs, process engineers optimize the deep drawing process depending on the material of the blank and the complexity of the contour of the part. The deep drawing process is often optimized using special computer programs [3-5]. Computer calculations were carried out to determine the stress and strain state of the material of the parts, depending on the change in the thickness of the sheet blank, the applied load, and the punch force [6-10]. These calculations make it possible to optimize the plastic deformation operations of thin-walled parts before their introduction into real production.

For a qualitative assessment of the plastic deformation of thin-walled aluminum blanks, a computer simulation of the deep drawing process was performed, followed by an analysis of the results of the stress and strain state of the part.

Materials and methods

To form a plate by deep drawing, two-dimensional models of a circular disk (blank), a die, a punch and a blank holder were created. The model of the blank on the plane was a strip with a thickness of 2 mm and a length of 350 mm. Tool steel with the properties of an absolutely solid body was chosen as the material of all the elements of the drawing die. Aluminum with the following properties was adopted as the material of the blank: density – 2700 kg/m^3; Young's modulus – 70 × 10^9 Pa; Poisson's ratio – 0.33; Murnaghan third-order elastic moduli – -2.5 × 10^{11} Pa, -3.3 × 10^{11} Pa, -3.5 × 10^{11} Pa; Lamé parameter λ – 5.1 × 10^{10} Pa and Lamé parameter μ – 2.6 × 10^{10} Pa. The blank was drawn into the die to a depth of 40 mm. The loading parameter for the implementation of the deep drawing process was adopted in the range from 0 to 1.0 with a step of 0.1. The state of the blank material during the drawing process was tracked along the flat surface of the disk.

Results and discussion

The results of calculating the stress and strain state of the blank material during plate drawing were shown in the Fig. 1. The changes in the punch force, the thickness of the blank and its displacement into the die, the hardening of the deformed material of the blank and the contact pressure on the surface of the blank, shear and equivalent stresses of the material were subject to consideration. The degree of plastic strain of the blank material during deep drawing was also presented.

The punch force of 460 kN is required to perform the aluminum plate drawing process. At the same time, a gradual increase in force was created when the punch was vertically moved to a distance of 25 mm. Further, the drawing process took place at a constant value of force. At the time of the final plate profiling, the punch force increased by another 150 kN.

It is noted that the bottom of the plate does not change in thickness. At the bending points, both an increase and a decrease in the initial thickness of the sheet blank is observed, depending on the value of the loading parameter. On average, the change in the thickness of the blank is up to 5% of the initial thickness. Significant thinning of the blank (up to 50% of the initial thickness) occurs on the flange. This is due to the clamping of the blank with the blank holder mounted on the right side.

The profile and dimensions of the drawn blank were shown in the Fig. 1, *C*. The finished plate profile is shown by the dependence of the displacement of the blank on the length of the blank with a loading parameter of 1.0.

The hardening function determines the hardening of the material after exposure to variable loads. It is noted that the material of the blank is subjected to significant hardening from the side of the blank holder. In the bending zone, the degree of hardening of the material is maximum.

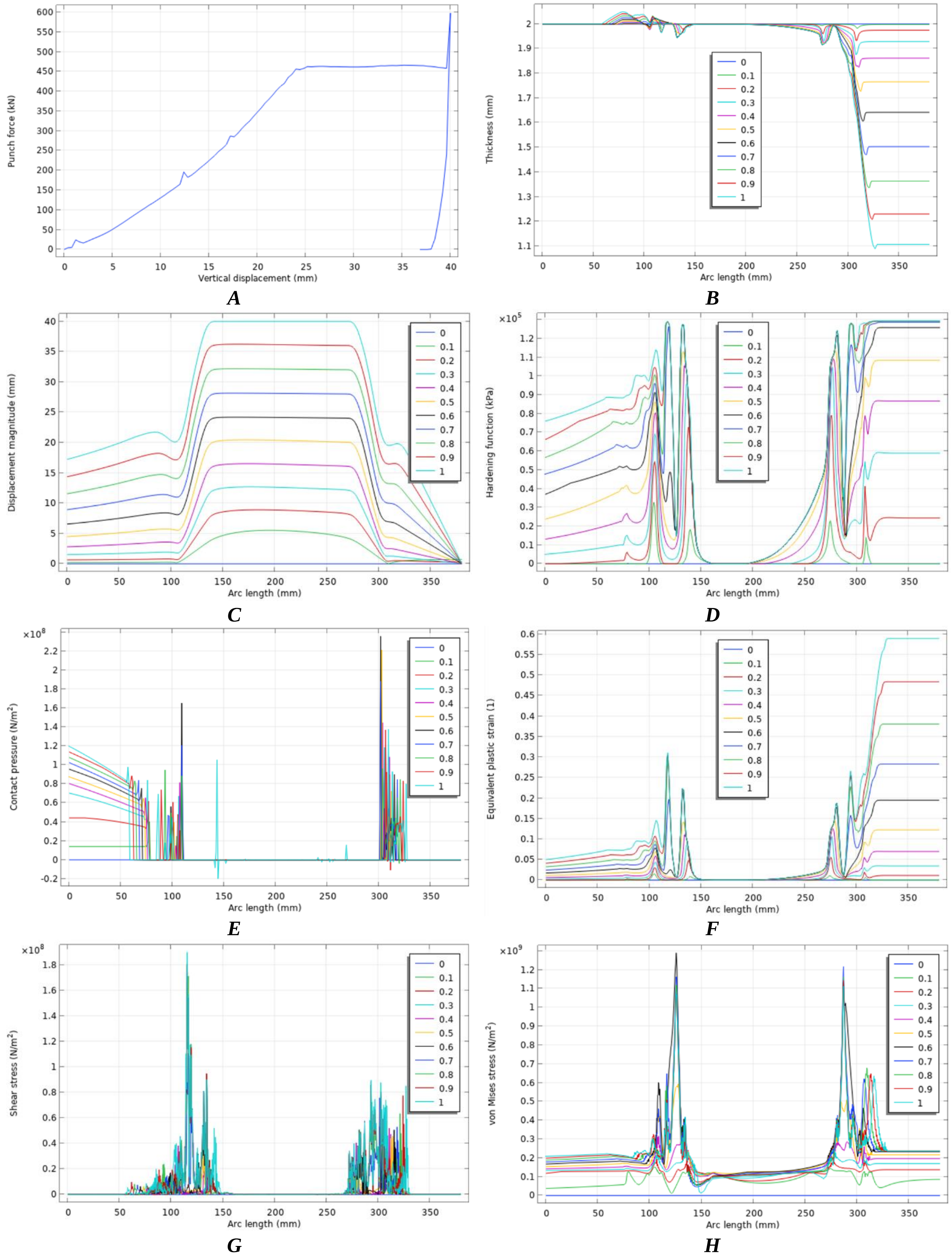

Figure 1. Calculation results: *A* – the dependence of punch force on vertical displacement; *B* – the dependence of thickness on length of blank; *C* – the dependence of displacement on length of blank; *D* – the dependence of hardening function on length of blank; *E* – the dependence of contact pressure on length of blank; *F* – the dependence of equivalent plastic strain on length of blank; *G* – the dependence of shear stress on length of blank; *H* – the dependence of von Mises stress on length of blank.

The contact pressure of the punch on the sheet blank prevails from the side of the blank holder and can reach 2.28 × 10^8 N/m^2. This pressure occurs at the bends of the sheet blank during the contour formation of the plate. The side walls and bends of the plate are subjected to plastic strain of up to 0.3 (a plastic strain coefficient of 1.0 corresponds to the material destruction). However, clamping the blank flange with the blank holder plastically deforms the material to 0.6 at a loading parameter of 1.0. The nature of shear and equivalent stresses of the material is almost the same. The largest values of these stresses are determined in the bend zone on the side of the blank holder.

Conclusion

Thus, based on the analysis of the state of the plate material during deep drawing of the sheet blank, the following conclusions can be drawn:

1. Due to the small thickness of the blank and the use of the blank holder, the value of the punch force during deep drawing varies in proportion to the volume of material pulled into the die. The completion of the part formation is characterized by the constant value of the punch force from almost the middle of the drawing depth of the blank and a sharp jump in force to the maximum value before the effect of a rigid spring of the material.

2. The change in the thickness of the finished part from the initial thickness of the blank is no more than 5% in the bend area. The thinning of the material can reach up to 50% of the initial thickness of the blank on the side of the blank holder.

3. The greatest values of stresses and strains are also observed in the bend area of the sheet blank material. At the same time, the maximum stresses are calculated on the left side, where the blank holder was not used. The coefficient of plastic strain can reach 0.6 from the side of using the blank holder.

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