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FEATURES OF THE DEFORMED STATE OF THIN-WALLED PARTS OBTAINED BY DEEP DRAWING

Abstract*: The analysis of the deformed state of brass, bronze, duralumin and steel hollow parts after deep drawing of blanks was performed in the article. The analysis was performed on the basis of the obtained forming limit diagrams and the graphs of the change in the resultant force during drawing vs. the execution time of the process. It is noted that the risk of cracks of the steel sheet is possible with major engineering strain of 28%. Non-ferrous alloys have a higher threshold of major engineering strain, at which material is destroyed.*

Key words*: drawing, the forming limit diagram, deformation, the blank.*
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Introduction

The manufacturability of forming plastic materials, using the example of drawing of hollow parts, is provided on the basis of the selection of rational modes of plastic deformation and the configuration of forming tools of the die, which will help to minimize the rejection of finished products, the permissible level of material thinning, reduce the downtime of technological equipment, etc [1-10]. Drawing of the metal sheet of the small thickness has the number of features, one of which is the determination of the most deformed local sections of the blank, which cause the formation of cracks and destruction of material. Inadequate stretching and severe thinning of material and the wrinkles formation on the blank flange during drawing contributes to the occurrence of these critical deformations. Control over the deformation degree of the blank during drawing can be carried out according to the special forming limit diagrams after computer modeling the process. In the future, the experimental data are compared with the calculated data of material deformation according to the diagram and the conclusion is made about the rationality of performing drawing under these conditions.

Materials and methods

The computer calculation of the deep drawing process of the sheet was implemented in the LS-DYNA program, since after modeling, the forming limit diagrams, contours of the stress and strain state of material, etc. were available. The deep drawing process of the blanks made of brass, bronze, duralumin and steel was modeled. In each case, the thickness of the blank (disk) was adopted 1 mm. The blank holder was used to reduce the wrinkles formation on the blank flange. The output product after deep drawing was the thin-walled cup of circular cross-section. The blanks models had the properties shown in the table 1.

Table 1. The properties of materials of the blanks models.

Parameter	Material			
	Brass	Bronze	Duralumin	Steel
Mass density, kg/m^3	8600	7500	2650	7800
Young’s modulus, GPa	95	80	74	200
Poisson’s ratio	0.36	0.35	0.34	0.3
Strength coefficient, GPa	0.58	0.8	0.205	0.64
Hardening exponent	0.34	0.45	0.2	0.15

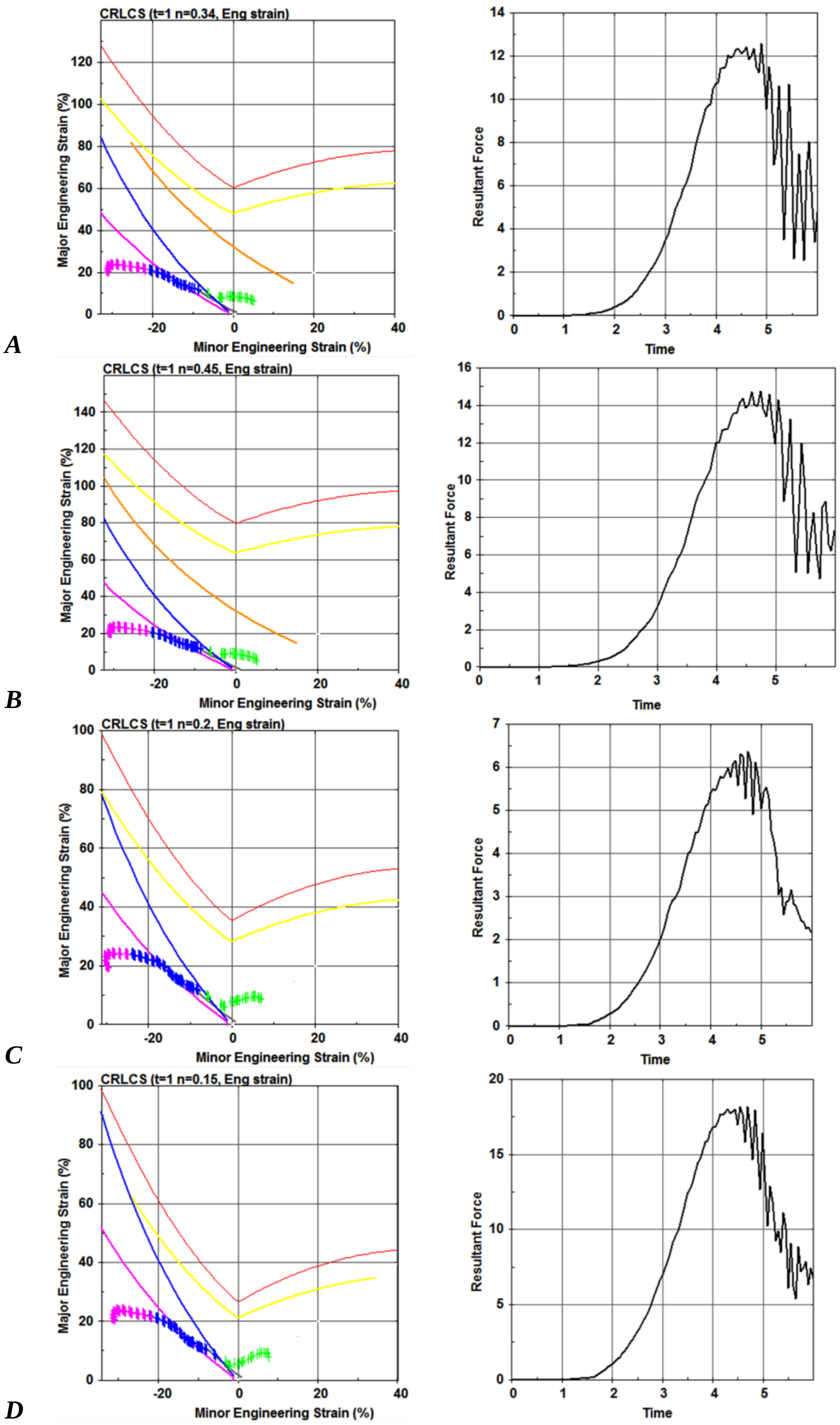

Figure 1 – The forming limit diagrams (left) and the graphs of the change in the resultant force during drawing vs. the execution time of the process (right): *A* – brass; *B* – bronze; *C* – duralumin; *D* – steel.

Results and discussion

It took 6 ms to form the hollow cup (by means of the punch and the die). The deformation process of the blanks was displayed on the forming limit diagrams and the graphs of the change in the resultant force vs. the execution time of drawing.

The forming limit diagram shows the level of critical engineering strains of the blank. In the diagrams, t is the blank thickness, n is the hardening exponent. The zone under the red curve characterizes various combinations of material deformation without destruction. The zone above the red curve characterizes material destruction. The values of minor engineering strains in percentage terms are plotted along the abscissa axis. The negative values of strains correspond to uniaxial stretching of material, the positive values correspond to biaxial stretching. The values of major engineering strains in percentage terms are plotted along the ordinate axis. The diagram also shows the following zones of deformation: between the red curve and the yellow curve is the risk of destruction (cracks), the orange curve is severe thinning, the blue curve is wrinking tendency, the pink curve is wrinkles, the gray curve is inadequate stretching and the green curve is there are no defects. On the graphs of the change in the resultant force during drawing vs. the execution time of the process, the values in ms are plotted along the abscissa axis, and the values in kN are plotted along the ordinate axis. The results of the computer calculation are presented in the Fig. 1.

Let us compare the obtained forming limit diagrams and the graphs of the change in the resultant force during drawing vs. the execution time of the process.

For all cases, possible destruction (the cracks formation) of the blank material is characteristic both during tensile deformation and compression deformation. At the same time, with an increase in compression and tensile deformations and major engineering strain, material shows the higher threshold for destruction. The bronze blank is subject to destruction at the higher values of strain than the rest blanks. Destruction of the steel blank can occur at major engineering strain of 28%. The curve of the destruction risk and the curve of material destruction have identical forms. The transition between these phases of deformations during drawing of the steel blank is minimal. Severe thinning is observed only in copper alloys. This type of deformation is absent for steel and duralumin. Wrinking tendency and wrinkles are observed during compression deformation. These damages (in all cases) occur at the same values of major and minor engineering strains. The part is formed without damage at the small values of compression and tensile deformations (up to 10%). The absence of damages is observed at the bottom of the thin-walled cup.

The dynamics of materials resistance during deep drawing can be traced by the graphs of the change in the resultant force vs. the execution time of the process. Gradual increasing the resultant force during the punch movement indicates increasing the contact area between the blank and the forming tools of the die. The active formation of wrinkles on the blanks flange is described by the decreasing part of the dependence. At the same time, it is noted that the less force is spent to smooth out wrinkles during drawing of the duralumin blank than during drawing of the brass and bronze blanks. For drawing of the steel blank with the thickness of 1 mm, the maximum force of 17.5 kN is required, which is 1.2-3 times greater than the force for drawing of brass, bronze and duralumin.

Conclusion

Drawing of the steel blanks of the small thickness should be carried out with caution, since with the average degree of deformation, cracks may form with subsequent destruction of material. The most optimal option is deep drawing of the sheet made of duralumin, since minimal energy is spent on the forming process of the part and smoothing wrinkles on the blank flange. Wrinking tendency on the flange of the steel blank is combined with the risk zone of the cracks formation in material. Severe thinning is characteristic only for drawing of brass and bronze and is observed both during compression and during tensile.

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