PROPOSAL OF THE FLEXIBLE TOOL FOR THE PRODUCTION OF AEROSPACE PARTS

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The paper is focused on the design of a container tool for forming of sheet metal parts used in the aerospace industry, which is based on a flexible medium. The tool is intended for hydraulic press CBJ 500-6 and it is multi-purpose for a wide range of materials, shapes and sizes. A combination of polyurethane plates Fibroflex and two rubber plates are used as an elastic medium. A punch is made of plywood of 28 mm thick with negative shape of a part. For elimination of a springback during a bending operation, relieving of bending surfaces is performed. The designed tool and its dimensions are verified by using FEM analysis and subsequently also by practical experiment, i.e. verification and debugging functionality for a standard product of aluminium alloy 6061.T6.

KEYWORDS

forming, sheet metal, flexible tool, elastomer, aerospace parts, numerical simulation, aluminium alloy

1 INTRODUCTION

In the production of aircraft parts, unconventional production methods are very often used with respect to a single-part production and a variablility of shapes and dimensions. These methods seems to be optimal for a solved part - the reinforcing rib, see Fig. 1. A sheet metal blank is supplied in a form of circumferentially milled flat pattern of the solved part with thickness of 0.65 mm. It is made of 6061.T6 material, which is aluminium alloy with excellent joining characteristics and good acceptance of applied coatings. It combines relatively high strength, good workability and high resistance to corrosion. The chemical compositions and mechanical properties of material are given in Tab. 1 and Tab. 2. [MatWeb 2016].

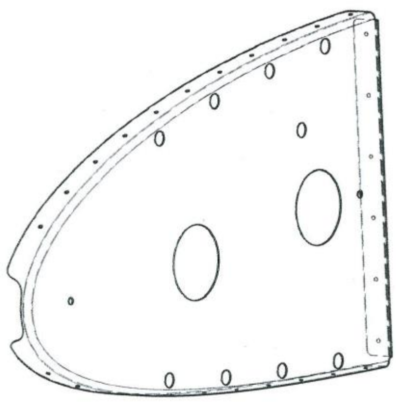

Figure 1. Shape of the part

Table 1. Chemical composition of aluminium alloy 6061.T6

Element	Al	Cr	Cu	Mg	Si
c_{max} (wt. %)	98.6	0.35	0.4	1.2	0.8
Element	Fe	Mn	Ti	Zn	Other
c_{max} (wt. %)	0.7	0.15	0.15	0.25	0.15

Table 2. Mechanical properties of aluminium alloy 6061.T6

Tensile strength [MPa]	310
Yield strength [MPa]	276
Elongation to break [%]	12

In current production, the part is hammering by hand using shaped hammers according to the negative part shape, which is made of plywood of 28 mm thick. The production is very lengthy and surface quality of the part is not sufficient according to conditions of use. Therefore, the aim is to manufacture the component in a press using a forming tool.

2 CHOICE OF PRODUCTION TECHNOLOGY

Due to variability of dimensions, shapes and due to a small batch production, utilization of flexible tools seems to be optimal, i.e. a forming chamber with an elastic medium, where a conventional die, which is expensive to manufacture, is replaced by an elastomer. Main advantages of the flexible forming tool are its versatility and simplicity, low initial costs and simple preparation of a production. [Mrna 2012] [Podany 2008].

The basic design of the closed tool is seen in Fig. 2. [Gore 2016]. It consists of a forming chamber with the elastomer, which moves into the base plate. Elastomer is clamped, which prevent its free flow. The total force increases with a shape changing of a formed part.

The punch is usually made of steel, but it can also be made of plastics, laminated materials, light metal alloys and wood.

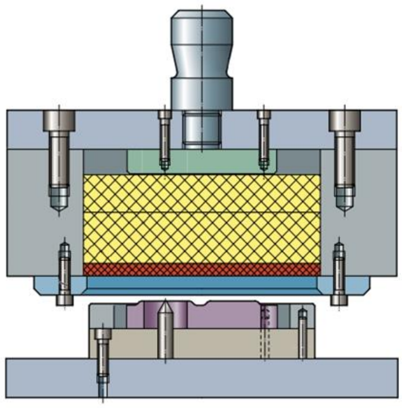

Figure 2. Schema of flexible tool

In view of use, two possible medias are applicable - a rubber and a polyurethane. Due to the component shape, it is preferable to choose the polyurethane, which properties fall into the area between rubber and plastic materials. In terms of price, rubber plate is preferable of course.

2.1 *Proposal of Module Tool*

On the basis of dimensions of manufactured parts and the clamping surfaces of a hydraulic press CBJ 500-6, the container tool was made, see Fig. 3.

The combination of polyurethane sheets Fibroflex of 25 mm thick with hardness of 70 ShA and two rubber plates of 40 mm thick were chosen as a forming medium. Thus, the forming layer was comprised of three plates, where in the surface, in a contact with a component, resilient polyurethane was placed.

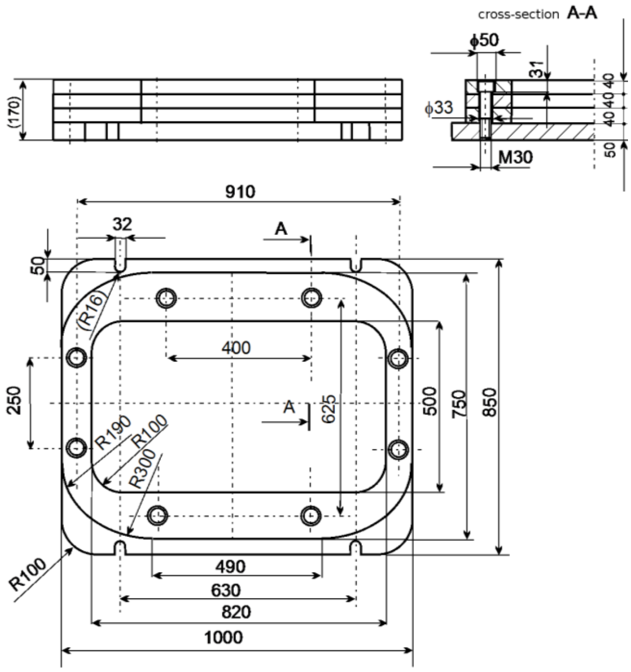

Figure 3. Proposal of the flexible tool

3 VERIFICATION BY USING NUMERICAL SIMULATION

In this study, the finite element analysis was subsequently performed for the designed shape and tool dimensions by using simulation software ANSYS Workbench Static Structural with implicit approach, which is suitable to solve static or quasi-static nonlinear problems. In this case, a final shape of formed part is not necessary to be considered for forming chamber stress analysis, i.e. only simulation of elastomer pressing is sufficient. Therefore, a simulation of forming process without formed part was realized.

3.1 Geometrical Data

Preferably, possibilities of symmetry and simplified model of screw connection using bonded contact were used. With above mentioned simplification, the geometrical model of the module forming tool was created in software Autodesk Inventor Professional 2010 and it was imported into the simulation software in *.iges format, see Fig. 4.

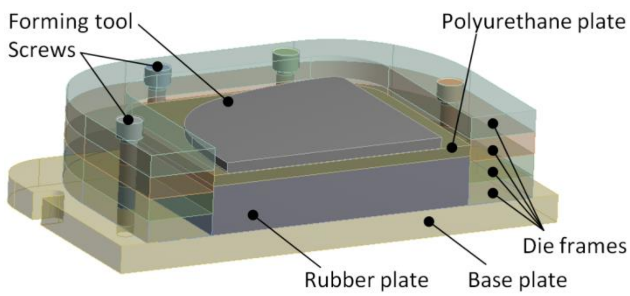

Figure 4. Schematic representation of geometrical model

Based on above considerations, the finite element mesh model was generated as it is shown in Fig. 5. Polyurethane and rubber plates were modeled by using twenty-node hexahedral solid elements with edge length of 10 mm. For other geometric components (forming chamber), 20-node hexahedral solid elements were also used with main edge length of 20 mm. In areas where using of hexahedral elements is problematic, 10-node tetrahedral solid elements were used. Geometry of the forming tool (punch) was considered as rigid, without impacts of material description. Therefore, only contact elements were applicated here.

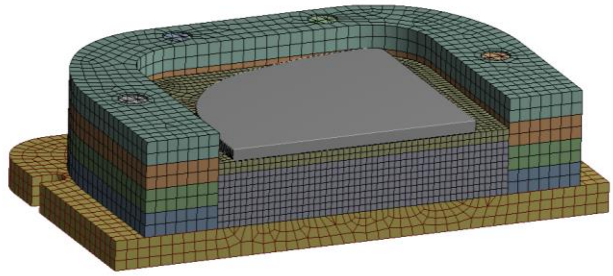

Figure 5. Finite element mesh model

3.2 Material Data

One of the main requirements for numerical simulations is the description of material properties through material models. As mentioned prievously, the combination of the rubber and the polyurethane was considered as an elastic medium. In this case, incompressible two-parameter Mooney-Rivlin hyperelastic material model was used, which is described as follows:

$$W = C_{10} \cdot (I_1 - 3) + C_{01} \cdot (I_2 - 3) \qquad (1)$$

where W is the strain energy, I_1 and I_3 are the strain invariants and C_{10} and C_{01} are the hyperelastic material constants.

For the polyurethane material model, two parameters C_{10} and C_{01} are 0.736 MPa and 0.184 MPa, respectively 0.232 MPa and 0.058 MPa for the rubber. These constants were determined based on [Altidis 2006] and [Dirikolu 2004].

For material description of the forming chamber, elastic properties are decisive, i.e. the Young´s modulus E = 210 GPa, the Poisson's ratio $\mu = 0.3$ and the yield strength $R_{p0.2}$ = 250 MPa. The friction coefficients at the polyurethane (rubber) – forming chamber interfaces were considered as 0.2.

3.3 Results

Due to the flange height of the formed part, parameters were investigated at the maximal tool stroke of the 25 mm. Fig. 6 shows the tool force – stroke curve, using rubber and polyurethane plates as a flexible punch, with an indication of maximal safe level of the hydraulic press CBJ 500-6, which makes 4500 kN. As can be seen from the diagram, the maximal tool depth, which can be reached by using mentioned hydraulic press is approximately 21 mm.

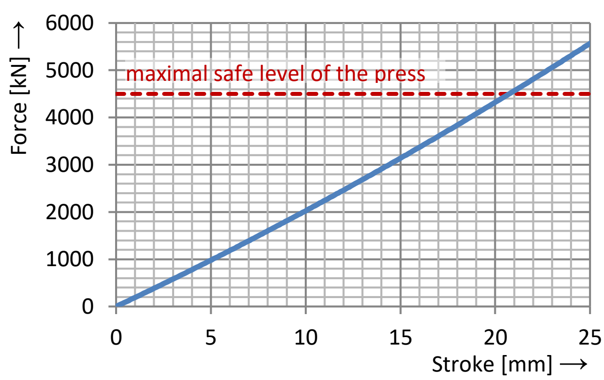

Figure 6. Force – stroke diagram for flexible tool

At this height, other results are obtained, as the equivalent total strain of the solved assembly, see Fig. 7, from which the deformation of the elastomeric block during the forming operation can be seen.

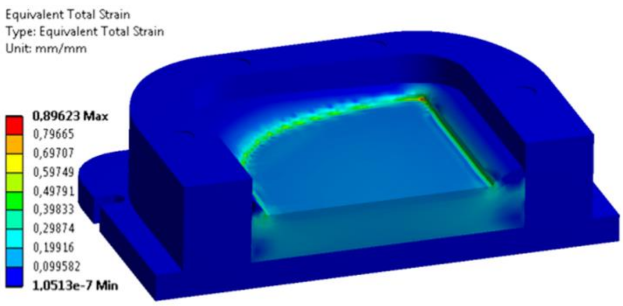

Figure 7: Equivalent total strain of Guerin tool for stroke of 21 mm

However, the main objective is assessing the suitability of the forming chamber design. As illustrated in Fig. 8, the maximal von Misses stress in the forming chamber is almost 98 MPa, which is definitely in a safe region, below the yield strength of chamber material (250 MPa).

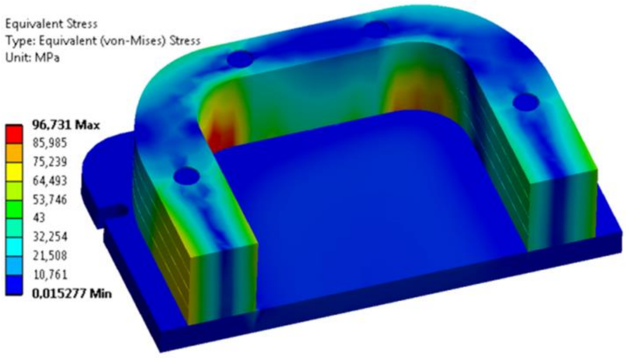

Figure 8. Von Misses stress in the forming chamber

A total deformation of the forming chamber reached approximately 0.5 mm, as it can be seen in Fig. 9, where node displacements are represented in vector format.

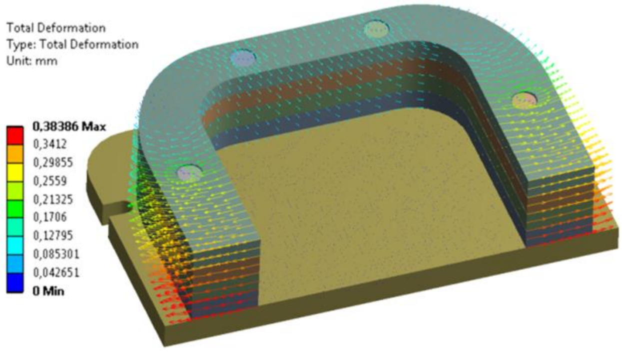

Figure 9. Total deformation of the forming chamber

The individual components of deformation are apparent from Fig. 10, Fig. 11 and Fig. 12. This is the deformation in the X, Y and Z direction, which is the most important.

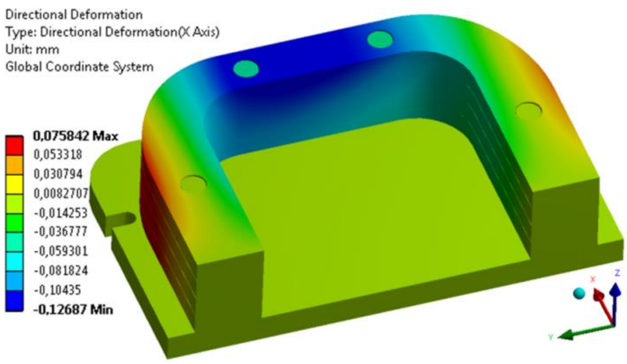

Figure 10. Deformation in the X direction for forming chamber

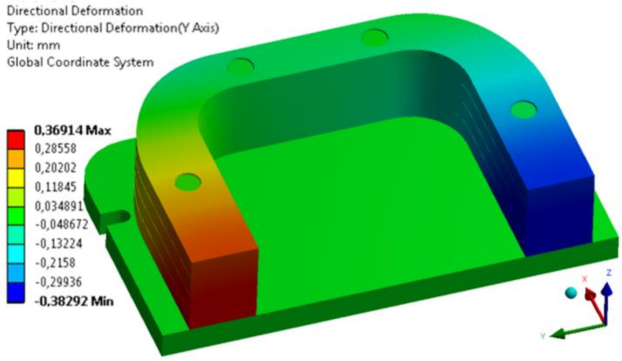

Figure 11. Deformation in the Y direction for forming chamber

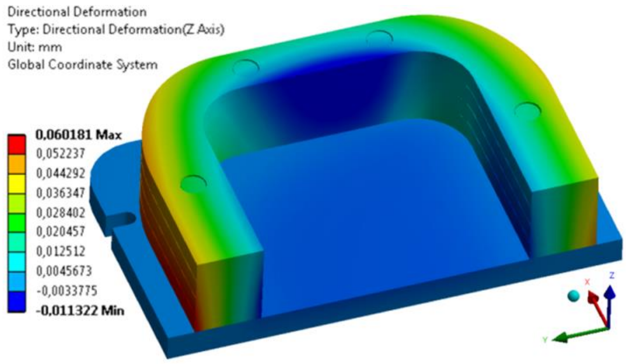

Figure 12. Deformation in the Z direction of the forming

The analysis shows that the instrument will be disturbed only in the elastic range and the proposed design is convenient.

4 IMPLEMENTATION AND EXPERIMENT

The tool was made by water jet cutting, and it was placed into the hydraulic press CBJ, in which a verification part was formed (Fig. 13, Fig. 14). Used tool was made of plywood of 28 mm thick with negative shape of the resulting part, see Fig. 15. For elimination of the springback during the bending operation, bending surfaces were relieved by 10 ° and "recess" was created for an excess material. Sheet-metal pressing with load of 3000 kN (300 tons) was conducted.

Figure 13. Flexible tool in press CBJ 500-6

Figure 14. Detail of flexible tool in press CBJ 500-6

Figure 15. Plywood punch

The production process is shown in Fig. 16 and Fig. 17.

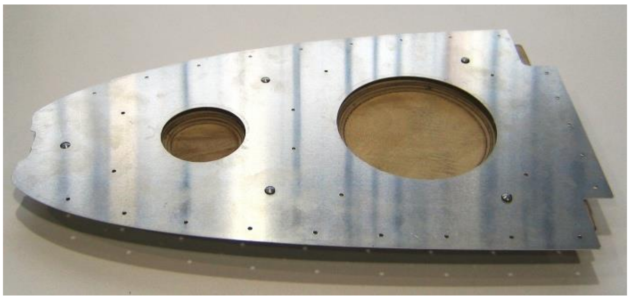

Figure 16. Punch with sheet metal blank

Figure 17. Pressed air rib with punch

Figure 18. Pressed air rib

As the photo of the pressed air rib on Fig. 18 shows that the designed container tool meets requirements for the shape of the produced part.

5 CONCLUSIONS

For a specified group of parts, the structural design and documentation of the container tool suitable for forming by flexible medium in hydraulic press CBJ 500 were elaborated with support of FEM analysis. After construction of the tool and its installation into the press, its functionality was tested. For the chosen part, the tool was successfully validated and owns forming process was debugged.

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