Forming a convex flange by pulsed-magnetic field pressure

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Abstract. A large number of parts used in aircraft are D16AM sheet metal flanged parts. Stress plays a role in reducing damage and improving plasticity. Common to such parts is the necessary shaping to increase rigidity and reduce weight. High strain rate forming is a dynamic shaping process that uses the instantaneous impact pressure generated by suddenly released energy to plastically process metal sheets for the numerical study and simulation of the process of magnetic-pulse forming (MPF) of convex flanging. The LS-DYNA program was used, a universal software multi-purpose system of the finite element complex. A computer simulation technique was developed, which allows, in accordance with the required geometry of the die surface and with the selected loading schemes, to take into account the change in load over the deformable area and set the distribution of the pulsed magnetic field (PMF) pressure intensity, vary the geometric parameters of the blanks and the characteristics of the material. In the case of elastic-plastic deformation of a solid, within the framework of the modern approach, it is a cooperative deformation process caused by correlated motion in an ensemble of crystal lattice dislocations. This causes a change in the volume of a deformable body under load by the pressure of a pulsed magnetic field: when the load is removed, the internal stress is almost completely removed and the volume of the body takes the required shape in our case in the form of a convex flange.

1. Introduction
The use of magnetic-pulse loading method makes it possible to reduce the error of conducting experiment process no more than 5%, to determine the parameters of the pulsed pressure which transmitted to the sample, requires no lubrication or stamping and widely using in the aviation industry [1-4]. The unambiguous connection of the parameters of the pressure pulse with the current distribution in the loading equipment justifies the possibility of forming the required load distribution in the sample of the convex flange. The efficiency of high-speed stamping with the use of a magnetic-pulse installation essentially depends on the optimal combination of parameters of the discharge pulse current, such as frequency, damping decrement of discharge current oscillations, etc [5-7]. The mathematical model and the corresponding method of numerical calculations are based on using the variational principle of the theory of plasticity and the technique of the finite element method (FEM). In LS-DYNA, the material behavior model used is implemented in the (Piecewise Linear Plasticity) model.
2. Materials and Methods

2.1. Experiment setup
The calculation of magnetic pulse processing modes is very difficult. The convex flange model which used in this work is a combination of the mechanical and the electromagnetic models, the grid model (section) shown in figure 1. In this case, it is convenient to simplify the real plot of the pressure of the pulsed magnetic field (PMF); it is advisable to bring it to the equivalent [8, 9].

![Image: Cross section of the model at the initial moment of time: 1 – pancake coil; 2 – blank; 3 – hard boundary die.]

2.2. Analysis of the results
A flat helical coil comprising 9 turns with a 1 mm gap was made of 1.6 mm × 8 mm rectangular copper wire. At the end of the simulation, a graph of the voltage on the coil with a value of 2500 Volts with attenuated amplitude is displayed (figure 2).

![Image: Coil voltage graph.]

Figure 1. Cross section of the model at the initial moment of time: 1 – pancake coil; 2 – blank; 3 – hard boundary die.

Figure 2. Coil voltage graph.
Figure 3. Plastic deformations on the workpiece at different stages of forming from time to time: а – 0 sec., b – 1.3e-5 sec., c – 2.5e-5 sec., d – 3.6e-5 sec.

Figure 4. Formed convex flange with control zones.

The thickness calculation, according to the control points, showed that the greatest thinning occurs in the radius zone of the flange (thickness 0.85 mm), along the marginal zone, the thickness is 0.89 mm and along the flat zone of the workpiece is approximately 0.98 mm.
During the deformation, the temperature also rises. The highest temperature is concentrated in the zone of maximum deformation (radius zone) and reaches 95 degrees Celsius.

Calculation of plastic deformations from the control points showed that the deformation is 3% along the flat control point, 15% along the radius zone, and 13% along the marginal zone.
Figure 7. Change in the magnitude of plastic deformation according to the control zones of convex flanging.

The results of numerical simulation of the convex flanging forming process with optimization of the pulsed loading parameters of the workpiece to obtain parts of the required shape were summarized in the form of a nomogram [1-5]. A nomogram for determining the optimal pressure (P) of (PMF) depending on the dynamic yield stress of the workpiece $Y_{ow}$ and the geometric parameters: thickness $\delta_0$ and circumferential deformations $\varepsilon_\varphi$ during convex flanging, which are presented in figure 8.

Figure 8. Nomogram for determining the optimal pressure amplitude (P) of (PMF) for forming of convex flanging at various parameters of the workpiece $Y_{ow}$, $\delta_0$, $\varepsilon_\varphi$.

3. Results
The calculation of the thickness of the convex flange, according to the control points, showed that the greatest thinning occurs in the radius zone of the convex flange by 0.13 mm, less than in the flat zone and by 0.04 mm, less than in the marginal zone.

Calculation of plastic deformations based on control points showed that the greatest deformation occurs in the radius zone and estimated with 15%.

In the process of deformation, the temperature also rises to 95 degrees Celsius, which therefore does not affect on the forming process.

The analog of EM calculation pressure value was estimated 28 MPa at the deformation time 3.6e-5 sec.
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References
[1] Kurlaev N V and Stupnikov V P 2005 Influence of magnetic pulse processing on the structure and properties of aluminum alloys Scientific Bulletin of NSTU 3(21) 180-8
[2] Kurlaev N V and Gulidov A I 2005 Impact of pulse processing on technological defects of workpieces (Novosibirsk: SBRA Sciences) p 168
[3] Yudaev V B, Kurlaev N V and Favorin V M 1989 Numerical solution of problems of pulsed deformation of sheet blanks Proc. of the 11th All-Union Conf. On High Numerical methods for solving problems of the theory of elasticity and plasticity (Novosibirsk: ITAM) 23-6
[4] Kurlaev N V, Gulidov A I and Yudaev V B et al. 2000 Reduction of inhomogeneities of the side shape of sheet parts of aircraft during bending-drawing by pulsed pressure Scientific Bulletin of NSTU 2(9) 91-100
[5] Yudaev V B, Kurlaev N V and Favorin V M 1990 Optimization of loading parameters during pulse stamping of sheet metal parts: J. Mach. Manuf. and Rel. (JMMR) 1 90-6
[6] Kurlaev N V 2003 Reduction of technologically inherited porosity of metals during pulse processing: J. Forge. and Stamp. Prod. Mat. Working by Pressure (KShP) 5 35-9
[7] Gulidov A I, Yudaev V B, Kurlaev N V and Bishev B A 1990 Modeling the processes of stamping sheet parts by the pressure of a pulsed magnetic field, taking into account the impact contact with the tooling: J. Mech. Eng. 5 61-6
[8] Gulidov A I 1982 Numerical simulation of the rebound of elastic-plastic bodies in the three-dimensional case Proc. of the Mat. 7th All-Union Conf. Numerical methods for solving problems of the theory of elasticity and plasticity
[9] Kurlaev N V and Gulidov A I 2005 Influence of pulse processing parameters on material continuity defects: J. Forge. and Stamp. Prod. Mat. Working by Pressure and Metal Form. (KShP-MF) 4 42-6