Математическое моделирование физико-технических процессов и систем

Simulation of the deformation process taking into account the elastic comeback effect

E.G. Demyanenko[1], A.N. Epifanov[1], I.P. Popov[1]

[1]Samara National Research University, Moskovskoe Shosse 34A, Samara, Russia, 443086

Abstract. In this paper the simulation of the method, which combines the deformation and the investigation of elastic comeback effect during forming of the thin-walled shells, is presented. The springback value on the edge of the part after removing of the deforming force is also evaluated.

Keywords: Flanging, Forming, Model, Wall thickness, Springing, Pam-Stamp 2G (ESI Group).

1. Introduction
In the rockets and aircraft manufacturing the thin-walled axisymmetric shells, such as nozzles, fairings, deflectors etc., take the special place. Identification of the forming mechanism and its major parameters, including elastic comeback, which influences the quality of part and the applicability of improved methods to thin-walled axisymmetric shells, allows intensification of manufacturing, since lowering the volume of mechanical treatment also improves the part quality due to preservation of the deformed metal structure.

2. The object of the study
Modern investigations of the elastic comeback and springback effects are conducted in several directions [1], which depend on the method and the way of applying force and obtaining empirical dependencies or comparing empirical data to the calculated numbers. We conduct the investigation of elastic comeback mechanism [2, 3] during forming the thin-walled shells, by the new method, combining processes of flanging and forming. We compare several numerical models during the finite-element analysis, which allow us to estimate the influence of parameters of the simulated processes and predict the elastic comeback for the experimental studies.

3. Methods
The proposed method is implemented using the device (figure 1), in which the conical blank is set in the die with the same cone angle as in the blank [4]. The blank then is clamped with the conical holder in the area of its larger edge. In this portion, during the downward movement of the punch the flanging takes place at first. The blank is intensively thinning in the area of the larger diameter, until the moment then in the side of the smaller edge it touches the surface of the punch and the surface of the elastic element. As the punch continues its downward movement, the lower portion of the blank is

squeezed between the punch and the elastic element, whose inner surface corresponds to the surface of the punch. The process evolves to forming in the situation close to plane-strain-conditions, when tangential deformation tends to zero.
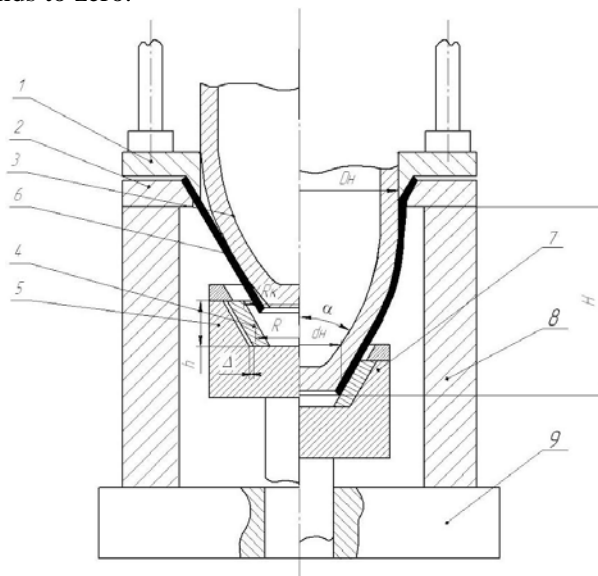
1 - Upper conical holder; 2 - Conical die; 3 - The punch; 4 - Elastic element;
5 - Lower holder; 6 - The blank; 7 - Support ring; 8 - The casing; 9 - Stamp plate
Figure 1. Scheme of the action of the friction forces on the barel-shaped part.

Let us analyze the possible springback of the edge in the processes of flanging and forming. [5]. We estimate the springback of the edge after flanging by the known formulas (figure 2), when the stress-strain conditions is close to the linear scheme: $\sigma_S \approx \sigma_\rho = 0$, $\sigma_\theta \neq 0$, $e_\rho = e_S$, $e_\theta = -2e_\rho = -2e_S$.
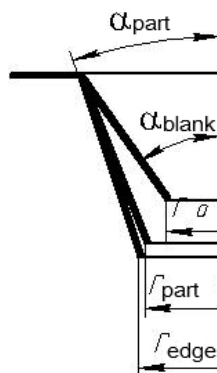

Figure 2. Cheme of the springback calculation in the flanging process.

It is known that the value of the elastic strain is:

$$e_{elast} = \frac{\sigma_{iedge}}{E} \tag{1}$$

where $\quad \sigma_{iedge} = \sigma_{TO} + \Pi e_{\theta_{iedge}} = \sigma_{TO} + \Pi \ln\left|\dfrac{r_{edge}}{r_{blank}}\right|$;

σ_{iedge} - stress intensity on the edge of the part;

e_{elast} - the elastic deformation of unloading;

E - the elasticity modulus;

r_{edge} - radius of the edge;

r_{blank} - radius of the blank.

On the other side of the elastic unloading leads to a decrease in the radius of the edge, since:

$$e_{elast} = \ln\left|\frac{r_{part}}{r_{edge}}\right|,$$ (2)

where r_{part} - radius of the part.

Hence, the radius of the part from the equations (1) and (2) is:

$$r_{part} = r_{edge} \cdot \exp\left(-\frac{\sigma_{iedge}}{E}\right).$$ (3)

Then the difference in the radii is:

$$\Delta r_{flang} = r_{edge} - r_{part} = r_{edge}\left[1 - \exp\left(-\frac{\sigma_{iedge}}{E}\right)\right].$$ (4)

It should be considered, that $\sigma_{iedge} = \sigma_{\theta edge}$ for the edge during flanging.

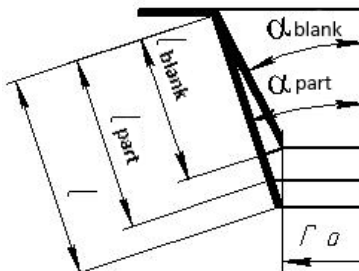Let us examine the process of forming (figure 3).

Figure 3. The springback effect estimation scheme during the forming.

At the similar stress intensities in the separately considered processes of flanging and forming, tangential stresses in flanging process are 2 times larger, that they are during the forming (and reduce of edge radii respectively). During the forming for the isotropic body:

$$\sigma_{\rho edge} = 2\sigma_{\theta edge}.$$ (5)

as $\sigma_{iedge} = \frac{\sqrt{3}}{2}\sigma_{\rho edge}$, then

$$\sigma_{\rho edge} = \frac{2}{\sqrt{3}}\sigma_{iedge} = 2\sigma_{\theta edge},$$ (6)

$$\sigma_{\theta edge} = \frac{1}{\sqrt{3}}\sigma_{iedge} = 0,5\sigma_{iedge}.$$ (7)

Even if we suppose that the springback depends only from tangential stresses, then the difference in the radii is:

$$\Delta r_{form} = r_{edge}\left[1 - \exp\left(-\frac{\sigma_{iedge}}{2E}\right)\right].$$ (8)

By analyzing the expressions (4) and (8) we see, that the springback value during the forming is lower than that during the flanging:

$$\Delta r_{form} \le \Delta r_{flang}.$$ (9)

Using modeling techniques in different kinds of program complexes allows getting the idea of stress-stain condition and technological features of the processes. Our choice of Pam-Stamp 2G (ESI

Group) is justified by its ability to simulate thin shells and to analyze deformation» processes of sheet metal stamping.

4. Simulation results

By replacing the real process scheme by the simplified one we could achieve an adequate and precise model for the numerical simulation [6, 7]. We expand our search of the influence of the elastic comeback during the two processes by using the punch of conical and spherical shape, since its shape could also influence the springback.

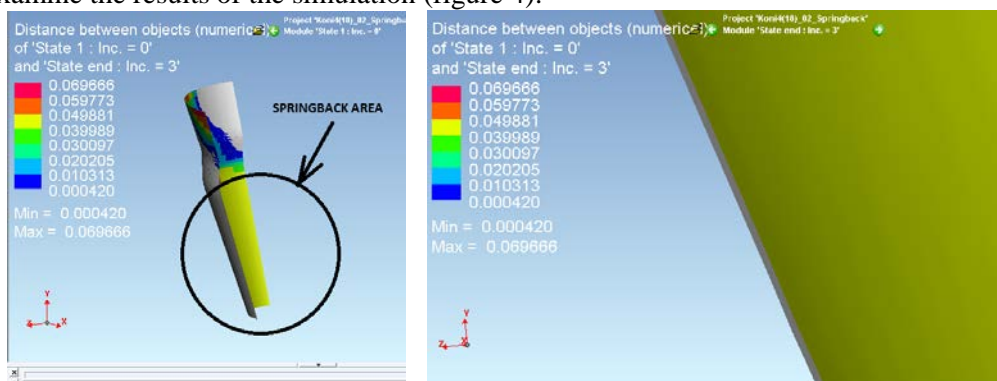Let us examine the results of the simulation (figure 4).

Figure 4. The area of the springback during flanging using conical punch.

For more accurate estimation of the springback let us compare the corresponding points on the average diameter of the parts before and after the release of the deforming force (figure 5).
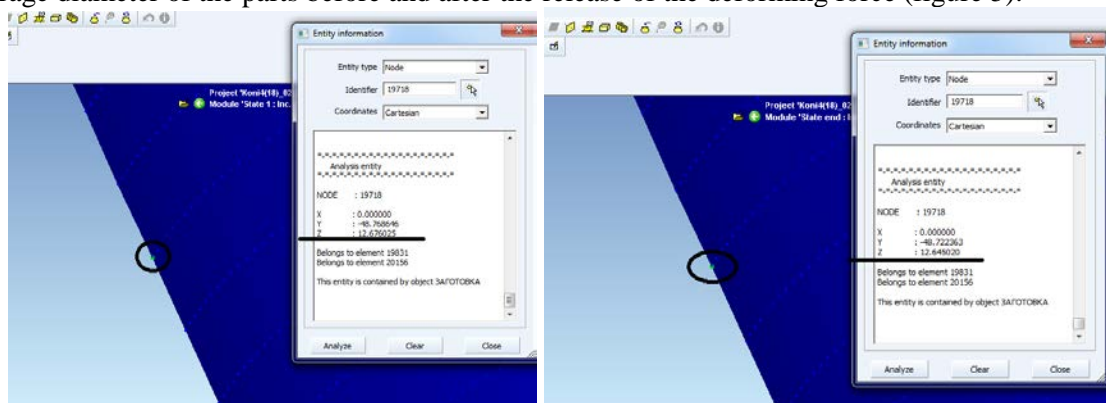

Figure 5. The coouidinates of the investigated point (on the left the part before springback effect, on the right- the part after springback).

Attention should be paid to the distances along the Z axis, since this is the axis, along which the edge of the part moves (Fig 6).
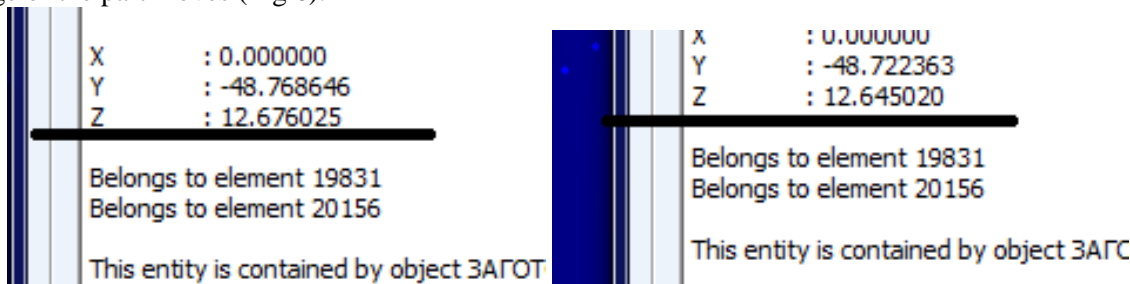

Figure 6. The value of the Z coordinate for the part before (left) and after (right) springback.

According to the achieved data (figure 6) the value of the springback was estimated Z=Z1-Z2=12.676-12.645=0.031 [mm]. This value was calculated for the flanging process using conical punch and it is 10.33% of the workpiece thickness (0.3 mm).

By the analogy, the values of the springback for the flanging using the spherical punch (figure 7), the flanging-forming with the conical (figure 8) and spherical (figure 9) punches was estimated.
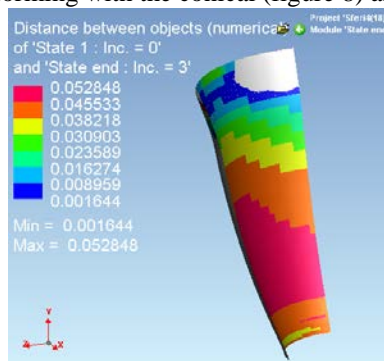

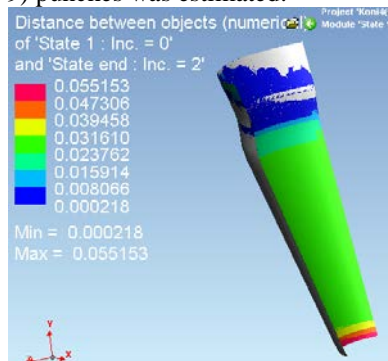**Figure 7.** The springback of the part after the flanging with the spherical punch.

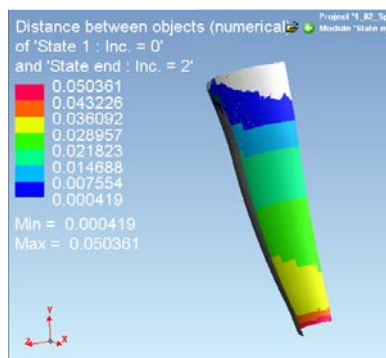**Figure 8.** The springback of the part after the flanging-forming with the conical punch.

Figure 9. The springback of the part after the flanging-forming with the spherical punch.

5. Conclusions

The analysis of the achieved data demonstrated, that the value of the springback effect for the flanging process using the spherical and conical punches is 0.031 mm (10.33% of the wall thickness) and 0.034 mm (11.33% of the wall thickness) accordingly. On the other hand, for the flanging-forming process using the conical and spherical punches this value is 0.004 mm (1.33% of the wall thickness) and 0.003 mm (1.0% of the wall thickness) accordingly. Thus the simulation of the process approved the fact of almost complete compensation of the unwanted springback effect of the flanging process using the combined method of deforming the part by the flanging and forming processes.

6. References

[1]   Yilamu, K. Air bending and springback of stainless steel clad aluminum sheet / K. Yilamu, R. Hino, H. Hamasaki, F. Yoshida // Journal of Materials Processing Technology. – 2010. – Vol. 210. – P. 272-278.
[2]   Tekaslan, O. Determination of spring-back of stainless steel sheet metal in "V" bending dies / O. Tekaslan, B. Nedim Gerger // Materials and Design. – 2008. – Vol. 29. – P.1043-1050.
[3]   Parsa, M.H. Experimental and finite element study on the spring back of double curved aluminum/polypropylene/aluminum sandwich sheet / M.H. Parsa, S. Nasher Al Ahkami, M. Ettehad // Materials and Design. – 2010. – Vol. 31. – P. 4174-4183.
[4]   Demyanenko, E, Popov, I Ru Patent 2580269-2014140637.
[5]   Zvonov, S Peculiarities of the process of hollow conical parts shaping from a ring blank / S. Zvonov, I. Popov, A. Shlyapugin // Russian Aeronautics (Iz VUZ). – 2010. – Vol. 3. – P. 358-361.

[6] Khaimovich, I Improvement of smoothing methods of complex surfaces using interpolation splines / I. Khaimovich, L. Klentak // Fundamental studies. – 2013. – Vol. 10-12. – P. 2634-2638.

[7] Grechnikov, F.V. Effect of anisotropic yield criterion on the springback in plane strain pure bending / F.V. Grechnikov, Ya.A. Erisov, S.E. Alexandrov // CEUR Workshop Proceedings. – 2016. – Vol. 1638. – P. 569-577.