Data Management for Solving the Problem of Sequential Shaping Simulation

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Abstract. The publication presents the results of a study of the process of investing in the innovation of the Russian manufacturing industry (sample 2009-2017). Factors of economic efficiency of investment projects of the industry are revealed. It is proved that the efficiency of investment is determined by external factors, primarily by the level of economic concentration (CR3) of the market of innovative products. The coordination of the scientific result with the industry consolidation dynamics model (A.T. Kearney) is presented.

1. Introduction

Sheathing of aircrafts is the most large-sized and thin sheeted parts. The sheath itself is subject to increased demands on the quality of the enclosing surface associated with the shape of the shell of double curvature. The most characteristic property of this type of parts is their low stiffness [1,2]. Thin sheet shell under the influence of its own weight changes its shape and can not be a carrier of dimensions for linking the units and parts of the aircraft. At the same time, their bearing capacity and strength are determined by the thickness of the sheet preform. Significant overall dimensions of the skins, as well as their relatively small number on the aircraft, determined special requirements for data management in the construction of the model of sequential shaping and to automated means of their production [3].

The hood refers to the forming operations associated with an increase in the area of the sheet blank and subsequent localization of the tension in the dangerous section of the part, as a result the sheet stock quickly becomes thinner and collapses, which is the cause of high rejection and large technological waste [4, 6]. The reason for the localization of the stretching of the sheet blank is, first of all, the unevenness of the deformation due to the complex shape of the shell and the influence of frictional forces.

Many manufacturers of aircraft traditionally collect aircraft with a large amount of refinement of parts. This introduces new requirements to the tightening processes and leads to the need to develop a new method for geometric modeling of surfaces of various shapes, as well as a new method for forming an equal thickness shell of double curvature.

2. Principles for the formation of a shell surface model of more complex geometric shapes

In reality, the geometric model of elliptic shells of double curvature describes the relationships between the aerodynamic properties of the skin contours in the aircraft's reference frame and the
characteristics of the geometric shape of the shell. The data of this model in the form of a description of the guiding and forming surfaces are used for graphical representation of the design object, as well as for the development of technological equipment and programs for their processing on machines with numerical control (CNC) [5,7].

A method is proposed for constructing a mathematical model of the surface of enclosing shells, which can be designed as a document containing directions of the guiding and generating surfaces in a certain coordinate system [9]. In addition, to determine the geometric parameters of the shell-forming shells, the direction of the skin is compatible with one of the orthogonal planes of symmetry \( F_1 \), which determines the longitudinal shaping contour of the section of the shell surface passing through the point \( O \). The second plane of symmetry \( F_2 \) orthogonal to the first determines the position of the central transverse contour of the section of the shell surface, also passing through the point \( O \). The point \( O \) in this case is considered as an elliptic point and represents the pole of the surface. The shell of a double curvature of a biconvex form [10,12].

To determine the geometric parameters of a double-curvature shell, it is necessary to build it into a 3D model on a computer. The direction of the cover is compatible with one of the orthogonal planes of symmetry \( F_1 \), which defines the longitudinal shaping contour of the section of the shell surface passing through the point \( O \) [13]. The second plane of symmetry \( F_2 \) orthogonal to the first determines the position of the central cross section of the shell surface also passing through the point \( O \). Figure 1 shows the surface of a biconcave double curvature shell having a ratio of the length (L) to the width (B) of the selected sheet blank is less than one and the double angle Pulling the grip of the punch work piece in a direction stitched equal to 1800.

As a result, conditions are created for the geometric linking of the conjugate surfaces of the envelope-forming shells and the conical punches according to the symmetry principle, determined by the symmetry planes and. Then, under the mathematical model of the surface of shells, we mean a set of algorithms and numerical data that are necessary and sufficient for unambiguous determination of differential-geometric parameters of characteristic sections and points of the analysed surface [14-16].

The accuracy of the formation of the contours is achieved through the use of a computer, which in the calculation process selects an analytic contour curve and compares it with the original data set. Automation of calculations and transformation of geometric parameters into digital information allow applying the processing of tightening punches on CNC machines [17]. However, the achieved accuracy of processing the tightening punch does not solve the problem entirely, it is necessary to provide a regulated tolerance for thickness variation when the sheet blank is tightened. All this introduces new requirements to the technology of production of encapsulating shells of aircraft and leads to the need to develop new technical and technological solutions that ensure the production of shell-forming shells with minimal variability [4, 5].

The initial stage in modelling the sequential forming scheme of the cover is the preparation of geometric models of the elements participating in the process, the sheet blank, the punch, and the part to be obtained - double curvature shells. The double curvature shell has a rather complex geometric shape, which is difficult to describe with the standard ANSYS / LS-DYNA surface modelling tools [18-20].

For this purpose, it is advisable to use a specialized CAD system, such as Compass-3D. The model of the part is the prototype of the punch model, taking into account the dimensions of the straight sections of the latter. Also, given that one of the features of LS-DYNA is the need to break down into finite elements and absolutely rigid bodies, the punch was presented in the form of a surface (shell) directly in contact with the work piece. When constructing the model of the work piece, the dimensions of the clamping areas - sections of the sheet billet, which are in the process of shaping in the clamps of the tension press, are also taken into account. An important part of the sequential forming scheme of the tightening is the movement of the clamps of the tensioning press along the necessary trajectory [21]. All motion trajectories are approximated by a sufficient number of points, which we will call steps.
For the convenience of modelling the process throughout its length, a step-by-step numbering of steps is used, which breaks the entire process into 84 steps.

![Figure 1](image_url)

**Figure 1.** The shell of a biconvex form of significant double curvature (an element of the cladding of the outer surface of a motor nacelle engine)

The compass-3D geometry created earlier in the surface modelling module of the Compass-3D system is imported into the Ansys environment using the IGES format. It is also necessary to take into account that the dimension of the imported model is millimetres, while the dimension used in the Ansys environment is meters. To reconcile the dimension, the geometry must be scaled based on the ratio 1: 1000, representing it, thus, in meters. The finite element mesh is constructed using the constructed surfaces. When the physical model was divided into finite elements, an ordered partition into quadrangular elements was used [22]. The longitudinal and transverse lines of the curvatures of the surfaces of the shell, punch, and also the work piece itself were broken into 100 segments each, which corresponds to a breakdown into 10,000 elements.

3. **Numerical experiments**

In the course of the work, a large number of numerical experiments were carried out, as a result of which an optimal kinematic model of the sequential formation pattern of the skin was obtained and a series of final numerical experiments were performed in which various external and internal parameters varied. External parameters include the coefficients of friction of the various facing of the punch and the coefficients of the anisotropy of the properties of the sheet material.

For the initial analysis of the results of numerical experiments, the values of the effective deformation and shell thickness were considered along the sequence of the sequential circuit at the characteristic points and in the corresponding elements (Figure 2):

- element A with the serial number 4991 is a characteristic point on the edge of the part;
- element B with serial number 4951 is a characteristic point at the pole of the shell;
- element C with the serial number 9551 is a characteristic point on the descent of the shell.
Internal parameters include the kinematic angular values associated with the angle of coverage of the tightening punch and the angle of extension of the shell between the cladding operations created by the movement of clamps of the blank. The choice of angular parameter values is realized due to understanding of several reasons:

• The localization of deforming forces in the vicinity of the pole of the tight punch at the first tightening operation due to the redistribution of the load from the flat sections of the punch is taken into account;

• The features of the formation of the central part of the shell at the initial stage of the first hanging operation are taken into account, where the localization of the deforming forces in the vicinity of the pole of the tight punch is preserved.

• The features of the double curvature shell are taken into account, due to the fact that when the surface of the surface is bent it remains unchanged, as does its Gaussian curvature, although the principal curvatures vary inversely.

Figure 3 shows a "symmetric" palette of distributions of the values of deformations and thickness along the average surface of the shells. This indicates, first of all, the possibility of controlling the process of shaping the shell and its thinning. With regard to the quantitative evaluation of the obtained values of deformations and thickness, for this purpose there are characteristic elements A, B, C.
extension (b, e), at the end of the molding operation (c, f); a, b, c - distribution of effective deformations along the middle shell surface; d, e, f is the shell thickness distribution

Full-scale quantitative information is carried by the graphs of the change in effective deformations along the average surface of the shell and the thickness of the shell at its characteristic points, depending on the time vector of the combined operations according to the sequential scheme (Figure 4).

![Graph a](image1)

**Figure 4.** Graphs of the change in effective deformations along the average shell surface (a) and shell thickness (b) at its characteristic points

In quantitative terms, this numerical experiment is the best. This is due to the fact that the values of the shell thicknesses at the end of the circuit take the following values: A - 1.903 mm; B - 1.823 mm; C - 1.795 mm. Correspondingly, the transverse thickness difference (between points A and B) is 0.080 mm, and the longitudinal difference in thickness (between B and C) is 0.028 mm.

4. **Model of the analysis of quality indicators**

   To analyse all values of the thickness of the shell, the Minitab software complex was designed to process statistical data. Minitab is often used in combination with the Six Sigma technique. To build the diagrams in the Minitab software, we used the procedure for analyzing the reproducibility for normal playback (Capability Analysis Normal). In the construction, the tolerance for the thickness of the work piece mm was set. On the abscissa axis, the thickness values of the shell are plotted, and the frequency of their recurrence along the ordinate axis. When constructing a histogram, the program automatically determined the number and width of columns with a base equal to the width of the interval along the thickness. The height of the column corresponds to the frequency of the data on the thickness in this interval. Then on the histogram the upper and lower limit values of the norm were determined, and the program automatically has constructed a curve of distributions of data on frequency. As a result, you can easily understand the type of histogram distribution.
The analysis of the Six Sigma diagrams includes the calculations of the following statistical parameters: the average thickness value over the shell surface, the standard deviation of the thickness and the efficiency factor. In addition, for each numerical experiment, the lower and upper tolerance limits were defined, the so-called control norms and. With the known numerical value of the coefficient of validity, an analysis was made of the reproducibility of the shaping process by the skin. For this, 5 intervals were considered. In particular, six numerical experiments were detected in the range, of which only two were performed without corrugation, including the one given, which is the best.

5. Conclusion
Information technology without analysing the quality of the information provided will not be able to solve the problem of reducing the cost of production of aircraft. The authors, having experience in constructing a model of the surface of shells of complex geometric shapes, should note that errors occur not only related to the calculation of curvature and loads, but also to the data management model. Therefore, in this paper, the principles of constructing planes of complex geometric shapes are considered in detail.

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