

Substantiation of the need to create the technology of stretch forming shells double curvature shell using new alloys

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Abstract. The technology of stretch forming shells doubly curved shell should take into account the kinematic features of the stretching press and the plastometric characteristics of the sheet blanks when performing a sequential scheme of stretch forming. The technology is characterized by some parameters. They include the following groups: material properties; friction conditions; dimensions of the sheet blank; heat treatment conditions of the sheet material; the placement parameters of the stretch die on the bed of press; technological conditions of the process of obtaining shell details of the minimum thickness variation on stretching press with program control.

1. Introduction

At present, the development of aviation and rocket transport depends on the creation of technology, aimed at developing methods and means of producing double curvature shells of complex spatial forms using new alloys. First of all, these are the high flight speeds of modern aircraft, which impose strict requirements on the geometric shape of the elements and the accuracy of the aerodynamic contours of the air frame. In addition, the double curvature shells of complex spatial forms perform the carrier functions of the details of the aircraft covering and the segments of the spherical bottoms of the fuel tanks of rockets, which should ensure the strength and non-destructibility of structures.

In turn, the trend of reducing the weight of the aircraft requires the use of sheet skin elements and segments of spherical bottoms of fuel tanks made of new aluminum alloys, despite the popularity of aluminum-based composite materials. Most often, these are thermally or dispersively hardened aluminum alloys of complex phase composition, including an aluminum-lithium alloy of the Al-Mg-Li system. However, it is related to deteriorating system. They are distinguished by the complexity of phase and structural transformations in the process of deformation and heat treatment. Since aluminum alloy Al - Mg - Li is the lightest (density 2.47 g/cm³), corrosion-resistant, weldable, with an increased modulus of elasticity and sufficiently high strength, it should become the main structural material of modern and advanced aviation equipment.

However, the analysis of the existing schemes of stretch forming made it possible to establish the presence of limiting factors affecting the deformability of aluminum sheet blanks. These include uneven stretching due to the influence of friction forces and shear deformations due to the complex shape of the shells of double curvature. Also, they include unacceptable localization of deformation, which leads to the predominant development of thinning of the aluminum sheet blank. In addition, the maximum difference in thickness in certain areas of the shell, as well as in the output location sheet



blank of the press clamps, are areas of increased danger, where the probability of localization of deformation and rupture of the aluminum sheet is the highest.

Therefore, in order to reduce or completely eliminate the limiting factors, it is necessary to create isometric conditions for a symmetrical stretch forming. It is realized only on curved presses with program control [1]. At the present day, custom equipment for stretch forming with programmed control for the Russia aviation industry is almost absent. The equipment of the new generation FET and FEL of the French company ACB is purchased, but it does not always correspond to the specifics of domestic production. This causes many problems:

First, the design of technological problems at the present stage should be carried out using application systems. In this case, the initial information of the sheet material, parts and products will be transmitted in the form of electronic dummy and must be supported by the digital environment of the pre-production. However, they have become hostages of the software that comes with the new generation equipment. This was due to the lack of an information environment in domestic enterprises.

Secondly, it is necessary to conduct a high-quality technological audit to verify the compliance of the domestic principles of testing the plastometric characteristics of aluminum sheet blank, equipment and technology for the new generation equipment for stretch forming.

Not only traditional information on the plastometric characteristics of sheet materials from aluminum alloys is necessary to determine the allowable degrees of deformation, but also hereditary information, which is a consequence of the crystalline structure and dispersity of the hardened phases.

Thirdly, the program control of the stretch forming equipment of the new generation performs the “wrapping” of the stretching die with a sheet blank at differential stretching due to the movement of the clamping devices. This method of stretch forming was tested on the first-generation stretching presses of the type FEKD, previously supplied by the same company ACB. Despite the fact that the production instructions were developed by NIAT, which are based on the principle of “wrapping with stretching,” the wrapping did not take root.

Fourth, the first-generation stretching presses FEKD were designed and delivered to domestic aviation enterprises in 1981 by a special order of our country. However, in 2013, when buying the new generation stretching press FET and FEL, unfortunately, the technological features of domestic production were not taken into account and some requirements of the technical specifications were violated, which are an integral part of the contract.

To solve these problems, it is necessary to produce domestic stretch forming equipment with program control. The government of Russia has already developed a Federal Target Program for the domestic civil aviation sector. This program must be implemented on the existing technological base of Russian enterprises. The creation of Russian stretch forming equipment with program control based on the domestic experience of the recent past is possible through the modernization of domestic aviation production. Import substitution has become a matter of political and economic security for domestic aviation. A new version of the “superjet” SSJ-100R has already been developed, the design of which can be assembled from domestic components and cover made on domestic stretching presses with program control.

2. Automatized stretch forming

Our specialists have extensive experience and knowledge: in the construction of the stretch forming equipment, including foreign ones; in the kinematics of the process of stretch forming; in automatization and control of stretching presses. The method of increasing the degree of deformation achieved almost in one transition without localizing the tensile deformation and leveling their values in different areas of the sheet blank was tested [2,3,4]. The method has been developed for uniformly changing the thickness in various areas of the sheet blank to obtain a shell of minimum thickness variation.

At present, the design of processes of stretch forming is carried out without jointly taking into account the requirements for the properties of sheet blanks and the structural and phase state of the deformable sheet material. In manufacturing practice, it is known that the properties of finished

products are interconnected. However, this fact is taken into account very weakly.

Successful and long-term operation of the domestic stretching presses (PO and OP type) due to their modernization and automation, as well as the stretching presses FEKD, showed the technological continuity of our aircraft structures (Tupolev Tu334, Antonov An140 and An148, Beriev Be200, Ilyushin Il103 and Il114, Il112 and Irkut MC21).

Automated stretch forming shells on stretching press with program control requires special training, starting with processing the electronic model of the stretching die and ending with the calculation of the control program. In order to successfully implement the methods, stretch forming of shells of various geometric shapes using new alloys, it is necessary to solve the problem of the design study of the stretching die. The method of increasing the degree of shape change provides for the expansion of the form-forming stage of the middle part of the sheet blank in the central cross section area. After reaching the deformation of the geometric shape of the shell, it is necessary to stretch the remaining parts of the sheet blank while maintaining the position of the biggest deformation in the middle part, but without localizing it in the area along the contact boundary with the stretching die surface to the press clamps. This scheme of stretch forming was called a sequential scheme, including preliminary and repeated stretching, separated by unloading the sheet blank and its extension to a new position for repeated stretching [5].

One of the requirements for the separate stages of the sequential scheme of stretch forming is their separate implementation under conditions of a symmetrical stretching with appropriate parameterization of the surface of the stretching die. The design engineering of the stretching die determines its correct positioning on the bed of press. It provides a constant position of the forming contour in one of the vertical planes of the stretching press and the conditions of axial symmetry during the deformation of the central cross section of the shell. The coordinate system of the press is tied to the plane of the table and the vertical axial line passing through the pole of the surface of the stretching die. The corresponding parametrization of the surface of the stretching die is characterized by two orthogonal lines of curvature. They mutually intersect at the pole of the surface, where the radii of the lines take the maximum and minimum values, and their product characterizes the value of the Gaussian curvature [6].

Further, the value of the Gaussian curvature is used to estimate the deformation in the region of the surface pole. It characterizes the obtaining of a given geometric shape of the shell of double curvature and the finding of its metric properties. A certain quadratic surface is also close to the surface of the shell in the vicinity of the pole. This makes it possible to divide the process of stretch forming into separate forming operations and to determine, when unbending, a new position of the double curvature shell, which will be isometrically located with respect to the surface of the stretching die.

However, the control system of FET, FEL and FETL presses is equipped with a subsystem of automated generation of control programs developed at the Voronezh Technical University. It allows, by computer modeling of the process of stretch forming, to form a control program and to carry out adaptive control of the stretching press. The result of this is the control programs for the CNC press, for the calculation and the formation of which, the ACB company supplies the S3F software through its representative office in the city of Voronezh.

This program requires an electronic model of the working surface of the stretching die. Next, it is necessary to orient it relative to the press coordinate system, so that in the coordinate system of the S3F program it was possible to simulate the process of stretch forming. However, it is impossible to track the distribution of plastic deformation and thickness over the surface of the sheet at any time using the S3F program. S3F does not provide tools for analyzing the plastometric characteristics of a new alloy. To this end, it is necessary to additionally build a simulation of the process of stretch forming shells double curvature shell using a new alloy using the finite element method, which allows for a more accurate analysis of this process.

To develop new designs of aviation technology, it is necessary to have new production technological solutions that should ensure the unity and consistency of the organizational and technological environment of an enterprise based on CALS technologies. Tasks such as the exchange

of information on the identification of sheet material properties, the corresponding parametrization of the surface of double curvature shells, the design of volumetric circulating tooling and the preparation of control programs for stretching presses must first be solved using CALS technology.

The software for the Computer Aided Manufacturing of stretch forming shells double curvature shell using aluminum sheet material is supplied along with the stretching equipment of the new generation. The control program of the stretching press performs the “wrapping” of the sheet blank of the stretching die in case of differentiated stretching by moving the clamping devices. This method of coating was tested on the first-generation stretching presses FEKD, supplied by ACB. However, despite the fact that production instructions were issued by NIAT, which are based on the principle of “wrapping with stretching”, wrapping wraps did not take root for a number of reasons.

The main reason is the process of stretch forming, which was considered as a forming process with stretching. However, the stretch forming process is a shape-generating sheet forming operation. The main thing in the process of stretch forming is to obtain the geometric shape of the shell along the second curvature (double convex or convex-concave) along the maximum or central cross section in the middle part of the sheet blank with a certain amount of coverage of the shape-generating contour of the stretching die. Moreover, during the process of the stretch forming, localization of the deformation in a narrow region along the interface of the sheet blank with the surface of the stretching die is not allowed. When wrapped with stretching, the deformation of the sheet blank at each moment in time is localized in a narrow region along the contact boundary with the surface of the stretching die. Local necking of the alloy usually leads to breakage of the sheet blank. The high tendency of a sheet aluminum alloy to local necking led domestic developers to abandon the principle of “wrapping with stretching” during the process of stretch forming.

The efficiency of using CNC equipment directly depends on the speed and quality of the preparation of control programs. This is a specific process that consists of a series of sequential stages. The main stages require high qualifications of the developer, as well as modern methods of information processing and electronic computing equipment built on the basis of microprocessors. This level of automation is based on the use of electronic models of parts of components and assemblies, the use of CNC-controlled equipment and technological electronic models that can solve specific technological problems. The design of technological tasks at the present stage should be carried out using application systems. In this case, the initial information of the parts and the product will be transmitted in the form of electronic layouts and must be supported by the information environment of the pre-production.

Objectives of the technology of stretch forming shells double curvature shell using new alloys.

The process of stretch forming of aluminum sheet material remains the main in obtaining details of the skins. Therefore, much attention was paid to the problems of automatizing process. The created stretching equipment is unique, specialized and with program control. In addition, the significant dimensions of the parts of the skins and a relatively small number of them on the aircraft identified special requirements for automated means of their production.

The modern global trend of support for the entire product life cycle should include the development and implementation of a "smart" stretching press using digital twin technology. To create new designs of aviation technology, it is necessary to have new alloys and technological solutions. They must ensure the unity and consistency of the organizational and production environment of the enterprise based on CALS-technologies.

In the conditions of symmetric stretch forming, there are two approaches. The first implements a macroscopic approach to the symmetric development of the boundaries of plastic deformation during weighting due to the symmetry of the properties of the sheet blank and the combination in the process of stretch forming the real axes of symmetry of the sheet blank with the directions of curvatures of the surface of the stretching die. The second method implements a microscopic approach to reducing the tendency of preferential development of deformation in thickness during the stretch forming of sheet material, especially using aluminum alloys, through the development of new heat treatment regimes for new alloys. The way out of this situation is the combination of both approaches. On the one hand,

this will allow us to establish the required properties of the sheet material for specific conditions of stretch forming with the weave, on the other hand, rational plastometric characteristics. As a result, the main tasks of the technology of stretch forming using new alloys were identified:

- Development of the design of processes of stretch forming by using computer simulation by creating conditions for a symmetrical stretching. They provide for the conformity of the axes of symmetry of the properties of the sheet blank and the directions of the lines of curvature, which intersect at the pole of the surface of the stretching die. Also provides for the location of the vertical plane of symmetry of the stretching press, which will pass through the given pole of the surface of the stretching die and the middle of the central clamp of the sheet blank of the stretching press. As a result, it is possible to carry out a parametrization of the surface of the double curvature shell in Gaussian coordinates. A new grid of lines of main curvatures allows you to create an interpolator program, equations for the paths of movement of the cutter. They can form the basis for the development of programs for the treatment of the surface of metallic stretching die made from recycled aluminum.
- Creation of new aircraft structures requires the development of new materials and technological solutions that should ensure the unity and consistency of the organizational and production environment of the enterprise based on CALS technologies. Among the priorities it is necessary to assign the tasks that should be solved using CALS-technologies. These include the following tasks. First, the exchange of information on the identification of properties of sheet material, the corresponding parameterization of the surface of the double curvature shells. Secondly, the design of volumetric contour-generating machine-tool attachment and the preparation of control programs for stretching press.

3. Summary

The use of stretching equipment with program control will require a new approach to the design and testing of the technological process of stretch forming using new alloys. The control of the process of stretch forming is carried out in the "Manual control" mode; in the "Stepping mode" (semi-automatic mode) and in the "Numerical control" mode (automatic mode). The control device of deformations will allow feedback on the absolute value of the elongation during the development of software algorithms for various loading schemes. The movement of the clamping jaws occurs along circular paths with a gradual increase or decrease in the angle of bending and subsequent stretching. At the same time, the search for optimal kinematic conditions for the preparation of CNC control programs of stretching press becomes possible. Along with this, modern tools of imitational modeling of the technological process of stretching using new alloys are used.

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