

# CAD system of design and engineering provision of die forming of compressor blades for aircraft engines

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**Abstract.** The articles provides the calculation algorithms for blank design and die forming fitting to produce the compressor blades for aircraft engines. The design system proposed in the article allows generating drafts of trimming and reducing dies automatically, leading to significant reduction of work preparation time. The detailed analysis of the blade structural elements features was carried out, the taken limitations and technological solutions allowed forming generalized algorithms of forming parting stamp face over the entire circuit of the engraving for different configurations of die forgings. The author worked out the algorithms and programs to calculate three dimensional point locations describing the configuration of die cavity. As a result the author obtained the generic mathematical model of final die block in the form of three-dimensional array of base points. This model is the base for creation of engineering documentation of technological equipment and means of its control.

## 1. Introduction

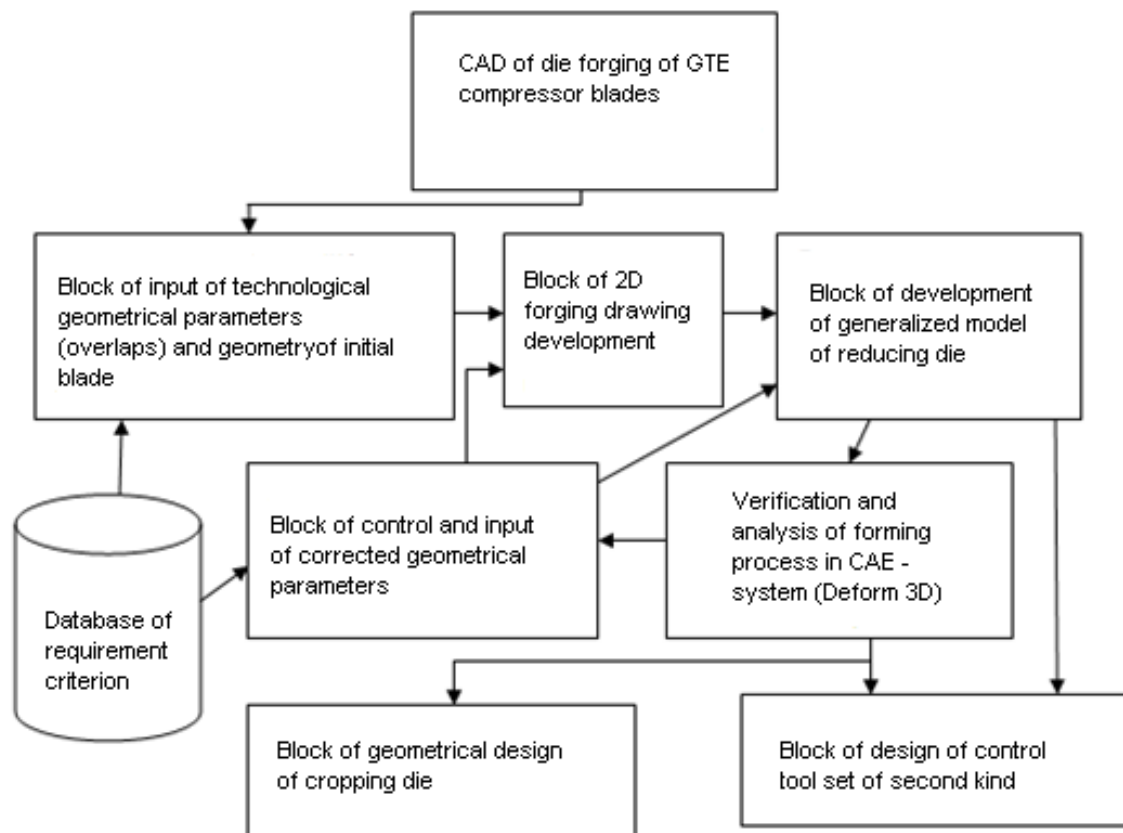
At present, a significant range of blanks for GTE compressor blades from titanium alloys is stamped by hot stamping [1-3]. As practice has shown, despite the considerable allowance (over 1 mm) on profile surfaces, this traditional technology has a number of competitive advantages in comparison with technological processes of pressure processing, which ensure minimum allowances (isothermal stamping, high-speed stamping, milling) [4-6].

Advantages consist in higher productivity and durability of die equipment, the possibility of using unified forging for a number of sizes of blades.

## 2. Description of problem and solution method

It is known that the design of 3-D models of reducing and cutting dies for volumetric punching of blades is not a fully formalized process, which in many ways stands on the experience of the designer and technologist depending on the applied practice in production, and is not always amenable to automation. In this connection, the purpose of this work is to generalize the experience of developing CAD die tooling, which would implement a balanced approach to the combination of a formalized automated process of die geometry determination with the possibility of its interactive correction based on production experience and the possibility of geometry optimization, for example, using CAD-systems (Deform 3D , Qantorform et al. [7-10]).





**Figure 1.** Information flows in CAD die forging of GTE blades

The system (fig. 1) consists of three consequential calculations of blocks: development of die forging, calculation of generic mathematical model (GMM) of final reducing die and block of technological equipment engineering of the second kind (test pattern and others).

The first block involves the creation of a typical forging drawing without a 3-D model with the possibility of output in paper form. Such presentation of the calculation results allows one, without violating the tradition of enterprises, to agree on the shape and dimensions of the forging with all interested services and industries. In order to increase the versatility of the program, the size of the allowances on all surfaces of the scapula is not related to normative documents, which differ markedly at different enterprises. Therefore, allowances can vary within the wide limits and are set by the user in the initial data. The required overall dimensions and coordinates of the points of the blade cross-sections are entered according to the design drawing of the blade in manual and automatic modes. To increase the visibility of input and reduce subjective errors, the system provides a series of slides. Appointment of allowances, stamping inclinations, technological boss (block), and creation of drawing forgings with all sizes is performed automatically.

The received dimensions of the forging design in automatic mode are transferred to the block for calculating the generic mathematical model of the final stamp. The CAD system has an "input control" block, which allows us to apply manual input, excluding the forging design block, change any work size after automatic input, and additionally enter the missing parameters.

The described principles of CAD design of volumetric stamping of GTE blades are implemented in software, which was technically tested at OJSC Kuznetsov.

### 3. Discussion of obtained results

According to the results of the practice of using the system and its technical approbation, it is possible to single out several key points concerning the processes of formalized determination of the die geometry and construction of its GMM.

1. Selection of gutter geometry. The form of a flash gutter linker of the blade edge in the system under consideration is accepted as a natural extension of profile in each cross-section. In this case the linker is converging and does not have any pips at the border-line with die forging, which enhances the stamp durability. The width of a linker and its final thickness are variables and set in manual mode.

2. The solution of the problem of choosing a line of die connector around the blade shank and technological boss (block) is the most complex and multivariate. The analysis of a great number of forging showed that depending on the blade construction it is possible to point out three main variants of blade intersection with path surface of shank end. There are algorithms and programs for realization each of these variants.

In practice, three types of connector dies are used: parallel, stepped, inclined. Inclined and stepped connectors allow one to adjust the depth of the die cavity in the upper and lower liners. The stepped connector simplifies the manufacture and control of the stamp. The gradient of the step levels is carried out at a small angle of 5-7 degrees. However, this connector complicates the setting of the stamp and worsens the quality of the burring. A small gap in the vertical section of the connector (0.1 ... 0.3 mm) often leads to a collision of dies with a slight displacement.

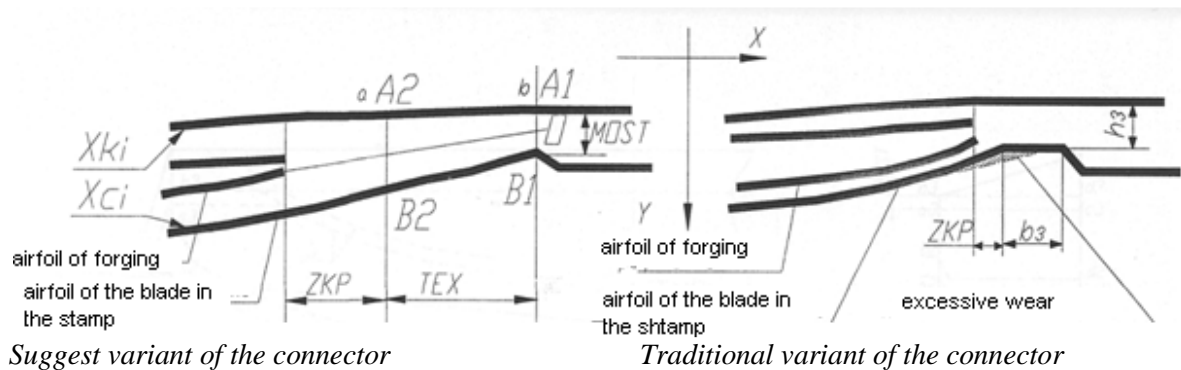
The proposed algorithm provides for the use of only two kinds of connectors: parallel or inclined.

The end surface of the shank from the side of the input edge of the blade in the lower liner (control base) is formed by turning the forgings in the stamp by an angle of  $TAY3$ . A similar surface in the top insert is at an angle  $(ALNEY + TAY3)$ , where  $ALNEY$  is the selected stamping gradient. In the calculations, this angle is taken as constant. This design of inclines leads to the formation of a "visor" on the forging of a variable width, which is partially removed when burring.

Stamping incline in the bottom insert in the shank end from the side of the trailing edge of the blade is always assumed to be constant ( $ALNEY$ ). To control the displacement of dies in the transverse direction, the stamping gradient in the top insert is assumed to be overestimated.

Here and further all profile surfaces and surfaces of the die connector are calculated taking into account the "hot" dimensions of forgings, which are determined by the coefficient of linear expansion in the range of forging temperatures.

1. Determination of the geometry of the stamp connector surface along the blade edges. The approach adopted for the blade surface formation in a stamp consists in determining the parameters and profile contours of several basic sections, constructing on their basis a simplified model of the stamp blade surface and restoring the necessary intermediate sections with the help of this model. As a basis, the scheme for constructing the blade profile with the formation of edges, used in OJSC Kuznetsov, was adopted. Figure 2 shows a diagram of the connector formation along the trailing edge of the blade profile of the airfoil. The position of the burr trim location along the edge defines the straight line  $a$ , perpendicular to the die axis, and the preset ZKP allowance. On the straight line  $a$  a sharp bend of the blade profile occurs in the plane of parting of a die. This is the most wearable part of the stamp. To reduce its effect on the distortion of the blade cross-section profile, the TEX overlap can be significantly larger than the allowance for ZKP edges. In this case, the overlap serves as a bridging linker. The point O, lying on the diagonal of the profile, is the base when selecting the parting of a die. Similar constructions are performed for the entering edge of the profile.



**Figure 2.** Formation of parting of a die on the blade:  $X, Y$  are the directions of axes in the die block,  $h_3, b_3$  are the height and width of a linker of a gutter,  $ZKP$  is the allowance along blade edges,  $MOST$  is the height of a linker,  $TEX$  is the technological overlap.

#### 4. Conclusion

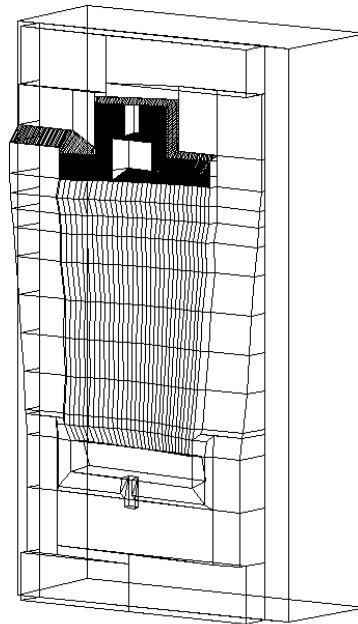
Analysis of the blade structural elements features, taken limitations and technological solutions allowed one to form the surface of parting of a die throughout the engraving contour. Algorithms and programs were developed for calculating the three-dimensional coordinates of points describing the configuration of the die cavity, the base surfaces for the installation of control templates, the shape and overall dimensions of the top and lower inserts of the stamp. As a result, a generic mathematical model of the final stamp was obtained in the form of a three-dimensional array of base points joined by edges in the form of straight lines or splines. This model is the basis for the creation of design documentation for technological equipment and its monitoring tools.

The program module is developed for automatic construction of the final reducing die model. The model consists of a set of carcass-defined surfaces describing the 3-D geometry of the lower and top liners (Fig. 3) of the stamp. The model can be exported to other CAD / CAM or CAE-systems for further technological analysis or for the development of control programs for processing dies on CNC machines.

The program module is developed for automatic construction of the trimming die model. The cutting edge of the stamp is formed from the points of the GMM describing the contour of the cavity in the lower insert.

The module for technological equipment design allows automatically forming standard drawing of final stamp and transferring it to the hard copy.

To finish the stamp and its reconstruction it is provided to create a set of drawings of test patterns. Required dimensions of patterns are obtained from calculation of crossing points, simulating the pattern edge with GMM surfaces.



**Figure 3.** Generic mathematical model (GMM) of lower insert

Thus, the developed structure of GMM is a universal base for the technological equipment design and independent representation of the received structures in the form of drawings and volumetric models.

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