

**METHODOLOGY OF CREATING MANAGEMENT PROGRAMS
FOR CASE PRESSES USED IN THE AVIATION INDUSTRY**

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The article is devoted to the optimization of the technological process for the manufacture of aircraft parts by the tightening method on CNC presses (Computer numerical control). The aim of the work is to create a control program that provides the manufacturing of the details-sheaths of the required accuracy and quality according to the control program in an automated mode. The method of creating control programs proposed in the article takes into account the shortcomings of the S3F software, which is the apparatus for forming control programs for the equipment considered. The method is based on the choice of the optimal loading scheme, under which the deformation program is created, the values of the control coordinates of the press are calculated in accordance with the kinematic model of the press and, as a result, a control program is formed. The mathematical module for creating control programs includes several computational units using modern CAD/CAM/CAE programs. Calculations, analysis and visualization of the tightening process were carried out using software-computational complexes MathCAD, ANSYS, T-LEX, NX, etc. As a result, we obtain a control program that provides more accurate production of the part with a minimum amount of finishing work. The presented method of calculation of the tightening process makes it possible, on the basis of the details of the part, to determine the shape of the tightening punch, and also, if necessary, to adjust the existing tightening punch in order to ensure a more precise manufacturing of the part.

Keywords: tensioning press, CNC, control program, deformation scheme, loading history.

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**МЕТОДИКА СОЗДАНИЯ УПРАВЛЯЮЩИХ ПРОГРАММ ДЛЯ ОБТЯЖНЫХ ПРЕССОВ,
ПРИМЕНЯЕМЫХ В АВИАЦИОННОЙ ПРОМЫШЛЕННОСТИ**

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Рассмотрен вопрос оптимизации технологического процесса изготовления деталей летательных аппаратов методом обтяжки на прессах с ЧПУ. Целью работы является создание управляющей программы, обеспечивающей изготовление деталей-обшивок требуемой точности и качества по управляющей программе в автоматизированном режиме. Предложенная методика создания управляющих программ учитывает недостатки программного обеспечения S3F, которое является аппаратом формирования управляющих программ для рассмотренного оборудования. Методика основана на выборе оптимальной схемы нагружения, под которую создается программа деформирования, рассчитываются значения управляющих координат пресса в соответствии с кинематической моделью пресса и в результате формируется управляющая программа. Математический модуль создания управляющих программ включает несколько вычислительных блоков с применением современных CAD/CAM/CAE-программ. Расчеты, анализ и визуализация процесса обтяжки проводились с применением программно-вычислительных комплексов MathCAD, ANSYS, T-FLEX, NX и др. В результате получается управляющая программа, обеспечивающая более точное изготовление детали, с минимальным объемом доводочных работ. Представленная методика расчета процесса обтяжки позволяет на основе данных о детали определить форму обтяжного пуансона, а также при необходимости скорректировать имеющийся обтяжной пуансон с целью обеспечения более точного изготовления детали.

Ключевые слова: обтяжной пресс, ЧПУ, управляющая программа, схема деформирования, история нагружения.

Introduction. Implementation in production of the equipment with the computer numerical control (CNC) is the main objective of scientific and technical progress in aircraft manufacturing industries. More difficult the process of implementation and management of automation systems is being solved in procuring and forming production [1]. Control of any technological process proceeds by means of change of parameters and the modes of processing. Incorrectly selected modes can result in irreversible defects (tucks, gaps) and, as a result, spoilage of details. Therefore, to find the best solution of the task of manufacturing aircraft details with the lowest expenses providing the given quality, optimization of technological processes is necessary. This task is very important, however a question of optimization of technology is very difficult both from mathematical and practical point of view.

Problem statement. To manufacture aircraft parts from sheet procurement by the tightening method at aircraft factories, the presses of cross (Loire T 600, Loire FET 1500/6000) and longitudinal (Loire FEL 2x500) tightening of the French firm ACB are used (fig. 1).

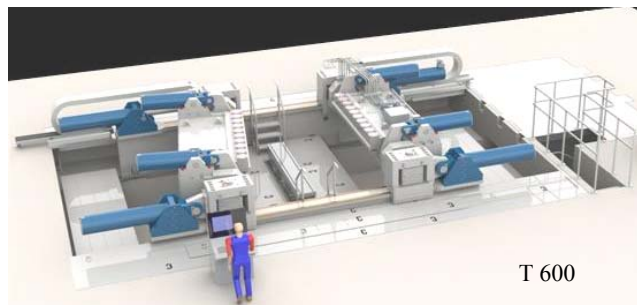
Control of parts of the press can proceed both in manual and in automated (according to the controlling program (CP)) mode. The S3F software which allows to create control program on the basis of geometry of a detail and physicomechanical properties of material which it is made of, is delivered to the enterprises of the aviation industry together with the equipment.

The S3F software is CAM/CAE module which automatically creates control program in the press CNC language on the basis of the built-in kinematic model (KM) of the press. Such method of forming of control program is automated, rather simple and fast. However details formed according to the control program on the basis of the S3F software do not always provide details of the required quality. The reason of such results is a number of restrictions of the S3F software:

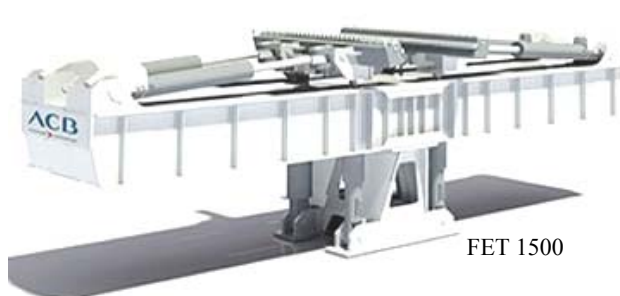
- irrespective of a detail form only one option of tightening according to the scheme И-Р is applied (a bend with the subsequent stretching);
- it is difficult to get control program for aircraft parts having difficult geometry (low technological effectiveness);
- algorithms of search of initial position of the press operating parts and their further movement aren't optimum;
- the deformation model of procurement in use is simplified and doesn't allow to predict puckering;
- the program doesn't help to define necessary deformation (it is set by the user);
- doesn't allow to correct a trajectory of the operating parts of the press movement.

Two versions of the solution of a problem of increase in accuracy of production of the required detail form are possible:

- creation new control program (correction of a trajectory of procurement movement);
- creation new or correction of the available tightening punch.



T 600



FET 1500



FEL 2x500

Fig. 1. Tensioning presses

Рис. 1. Обтяжные прессы

As there is no possibility of correction of KM in the S3F software, development of new KM of the press and the mathematical module for forming control program taking into account complexity of geometrical forms of aircraft parts is required. Such KM will give the complete idea of interconnection of movement of parts of the press [2; 3].

The KM in the form of analytical dependences allows to define a necessary combination of values of movements of controlling parameters of the press which will provide more accurate trajectory of tightening of sheet procurement on a punch surface.

Approbation of a trajectory of tightening, distribution of deformations and tension, identification of dangerous sites (zones of possible gaps, formations of folds and puckering) allows the use of CAE software products – ANSYS, MARK, etc.

The KM, realized geometrically in CAD system, allows to define by a graphic method a trajectory of the parts of the press movement on trajectories described by an evolvent. A graphic method is effective to apply only to simple forms of details (an ellipse, the cylinder, a circle). However such search of a trajectory of the movement does not guarantee exact production even for simple forms. Therefore it is convenient to use a graphic method

as addition to analytical methods and as means of visualization of a tightening process. To increase accuracy of production of aircraft parts it is necessary to create control program by use of various schemes of loading and optimization of process of tightening. In fig. 2 the scheme of possible ways of realization of process of creating control programs for tensioning presses with CNC is presented.

In fig. 2 the solid lines show an option of control program creation using the S3F software. The dash lines show an option of creation of control program based on a combination of analytical calculations and finite and element modelling. The second option includes several computing units. The dotted lines show an option of creation of control program using graphic programs which is approved by means of finite and element modelling [4].

The analysis of schemes of loading when tightening.

As it was stated above, the program of deforming according to the diagram of И-Р is used in the S3F software. The process of B-S is characterized by the fact that a procurement is initially bent on a punch and then in a curved status is exposed to stretching. The frictional forces between a procurement and a punch which appear in the course of stretching reduce the calibrating deformations and exert the negative impact on the process of forming as the detail springing increases.

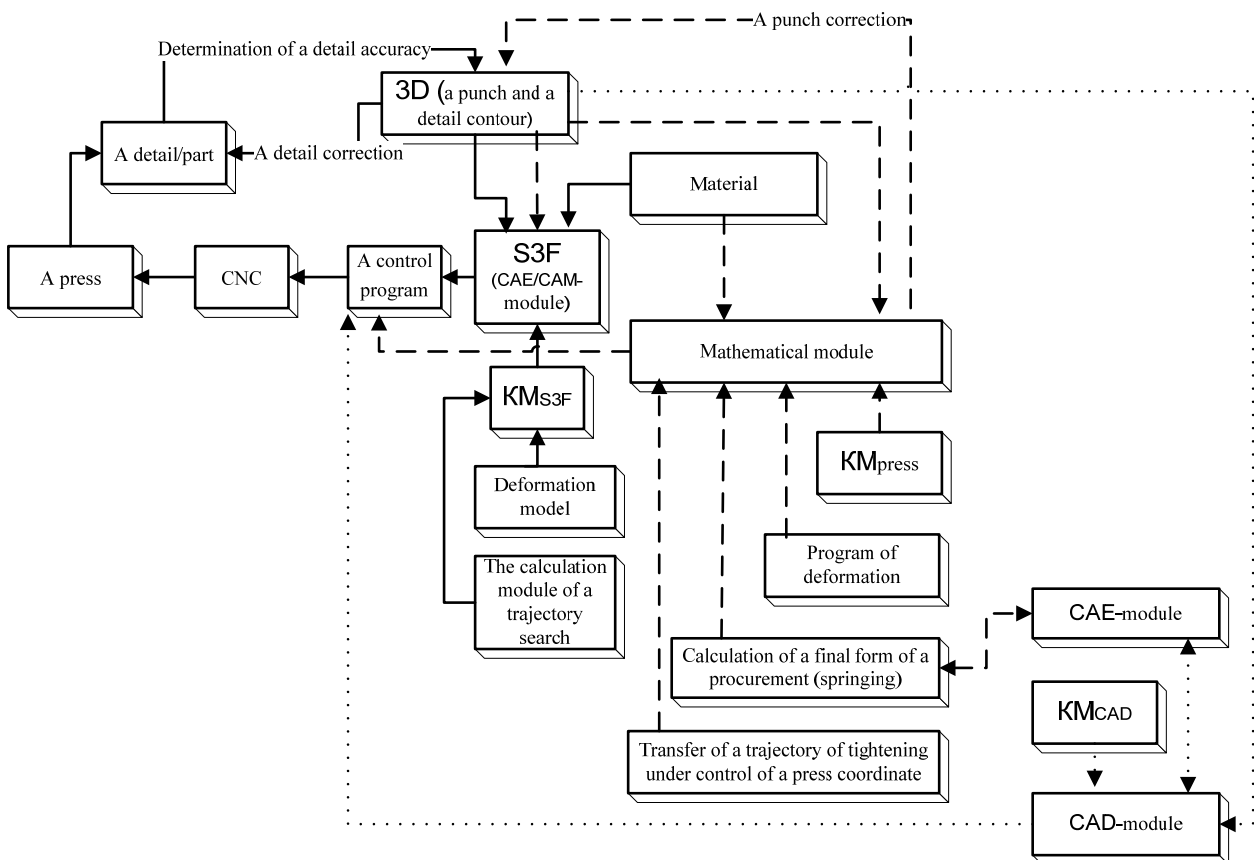


Fig. 2. The diagram of process of creation CP for presses with CNC

Рис. 2. Схема процесса создания УП для прессов с ЧПУ

The choice of tightening scheme depends on a detail form. Also a technologist faces a question of setting values of initial parameters of tightening process. Therefore when developing technological process it is necessary to carry out the analysis of all schemes of deformation and to choose an optimal variant to manufacture a detail with the least error [7–10].

Definition of a terminating form of a detail for various schemes of a loading. The developed mathematical module allows to calculate analytically a terminating form of a detail using various schemes of tightening. The analysis of results of calculation will allow to choose the most optimal variant of a detail manufacture.

Input data for calculation is the geometrical amount of sheet procurement: H – thickness of a sheet and B – sheet width; R_{0nar} – the external radius of a bend; E , σ_B , σ_{02} and δ – mechanical characteristics of material; ε_{pact1} – the relative deformation of preliminary stretching and ε_{pact2} – the relative deformation of the calibrating stretching (fig. 4).

For implementation of calculations we break a sheet section by height into a set of elementary strips: M – number of elementary strips in 1 mm; N – quantity of elementary strips by section height; Δh – height of an elementary strip (a step of splitting section of a sheet).

For each elementary strip we determine y_k coordinate, width b_k and radius ρ_k . We calculate tension σ_{p1} and effort P_{p1} of preliminary stretching. We define the intense-deformed state (IDS) of a sheet after preliminary stretching σ_{p1} , we calculate deformations of a bend ε_n and the sheet IDS at a bend after stretching ε_{p1n} and σ_{p1n} .

Using a bisection method we find the radius of R_0 and the position of a neutral layer H_0 . We calculate the moment of inertia of J_0 relating to neutral axis. We define the IDS of a closing stage of the process of P .

$S1-B-S2$ – the calibrating stretching after a sheet bend with stretching – ε_{p1up2} and σ_{p1up2} . We calculate the bending moment of M_z and the calibrating effort of P_{p2} . We find change of the layer curvature passing through the center of gravity $\Delta\chi_{ct}$, we determine residual tension σ_{ost} after unloading and the moment of residual tension relating to the center of masses Mz_{ost} . We calculate a layer curvature χ_{ct} passing through the center of gravity after unloading and then we get detail radius after unloading of R_{nar} [11].

In fig. 5 the algorithm of definition of a detail form after tightening is presented.

The algorithm in fig. 5 is the solution of a problem of definition of terminating position of procurement – detail form. However, if the detail form the complicated (non-technological) then to get a detail without deviations, without completion due to change of the loading scheme only, is not always possible. In such cases it is possible to increase accuracy of manufacture of a detail for the account of a punch correction. Searching for the anticipated form of a punch is the solution of the inverse task presented in fig. 5. The unit of the program of calculation of a punch form correction enters the mathematical module of searching for optimum parameters of technological process of tightening [12–15].

Formulas of determination of resultant tension

Scheme	Calculated formulas
B-S	Zone of the stretched fibers
	$\sigma_{n-p} = K_n \cdot (\varepsilon_{n-p})^n$ $\varepsilon_{n-p} = \varepsilon_n + \varepsilon_{pact}; \quad \varepsilon_n = \frac{\rho_i - R_{nc}}{R_{nc}}$
	Zone of the compressed fibers
	$\sigma_{n-p} = \begin{cases} E_n \cdot \varepsilon_{akt}, & \text{if } \varepsilon_{akt} \leq \varepsilon_n, \\ K_n \cdot (\varepsilon_{akt})^n, & \text{if } \varepsilon_{akt} > \varepsilon_n, \end{cases} \quad \varepsilon_{akt} = \varepsilon_{pact} + \varepsilon_{nac}; \quad \varepsilon_{nac} = \frac{\sigma_n}{E_n}$ $\sigma_n = \begin{cases} E_n \cdot \varepsilon_n, & \text{if } \varepsilon_n \leq \varepsilon_n \\ -K_n \cdot \varepsilon_n ^n, & \text{if } \varepsilon_n > \varepsilon_n \end{cases}$
S-B	Zone of the stretched fibers
	$\sigma_{p-n} = \begin{cases} E_n \cdot \varepsilon_{p-n}, & \text{if } \varepsilon_{p-n} \leq \varepsilon_n, \\ K_n \cdot (\varepsilon_{p-n})^n, & \text{if } \varepsilon_{p-n} > \varepsilon_n, \end{cases} \quad \varepsilon_{p-n} = \varepsilon_{pact} + \varepsilon_n$
	Zone of the compressed fibers
	$\sigma_{p-n} = \begin{cases} \sigma_p + E_n \cdot \varepsilon_n, & \text{if } \varepsilon_n \leq \varepsilon_{nac} + \varepsilon_n, \\ -K_n \cdot (\varepsilon_n - \varepsilon_{nac})^n, & \text{if } \varepsilon_n > \varepsilon_{nac} + \varepsilon_n, \end{cases}$ $\sigma_p = \begin{cases} E_n \cdot \varepsilon_{pact}, & \text{if } \varepsilon_{pact} \leq \varepsilon_n, \\ K_n \cdot (\varepsilon_{pact})^n, & \text{if } \varepsilon_{pact} > \varepsilon_n, \end{cases} \quad \varepsilon_{nac} = \frac{\sigma_p}{E_n}$

Scheme	Calculated formulas
S1-B-S2	Zone of the stretched fibers
	$\sigma_{p1-n-p2} = K_n \cdot (\varepsilon_{p1-n-p2})^n;$ $\varepsilon_{p1-n-p2} = \varepsilon_{\text{растр1}} + \varepsilon_n + \varepsilon_{\text{растр2}}$
	Zone of the compressed fibers
	$\sigma_{p1-n-p2} = \begin{cases} \sigma_{p1} + E_n \cdot (\varepsilon_n - \varepsilon_{\text{растр2}}), & \text{if } \varepsilon_{\text{растр2}} \leq \varepsilon_n , \\ K_n \cdot (\varepsilon_{p1-n-p2})^n, & \text{if } \varepsilon_{\text{растр2}} > \varepsilon_n , \end{cases} \quad \text{at } \varepsilon_n \leq \varepsilon_{\text{накл}} + \varepsilon_n$ $\sigma_{p1} = \begin{cases} E_n \cdot \varepsilon_{\text{растр1}}, & \text{if } \varepsilon_{\text{растр1}} \leq \varepsilon_n, \\ K_n \cdot (\varepsilon_{\text{растр1}})^n, & \text{if } \varepsilon_{\text{растр1}} > \varepsilon_n, \end{cases} \quad \varepsilon_{\text{накл}} = \frac{\sigma_{p1}}{E_n}; \quad \varepsilon_{\text{растр}} = \varepsilon_{\text{растр2}} + \frac{\sigma_{p1-n}}{E_n}$ $\sigma_{p1-n} = \begin{cases} \sigma_{p1} + E_n \cdot \varepsilon_n, & \text{if } \varepsilon_n \leq \varepsilon_{\text{накл}} + \varepsilon_n, \\ -K_n \cdot (\varepsilon_n - \varepsilon_{\text{накл}})^n, & \text{if } \varepsilon_n > \varepsilon_{\text{накл}} + \varepsilon_n, \end{cases} \quad \varepsilon_{p1-n} = \varepsilon_{\text{растр1}} + \varepsilon_n$

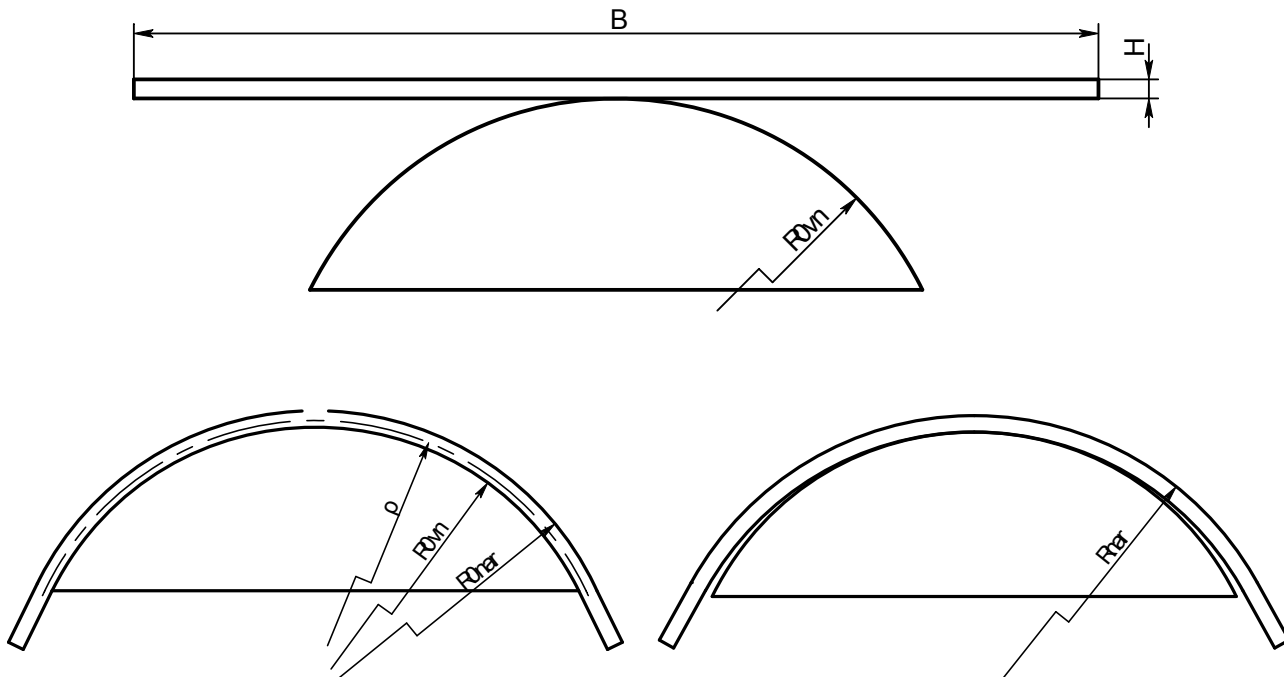


Fig. 4. The position of procurement in the process of tightening

Рис. 4. Положение заготовки в процессе обтяжки

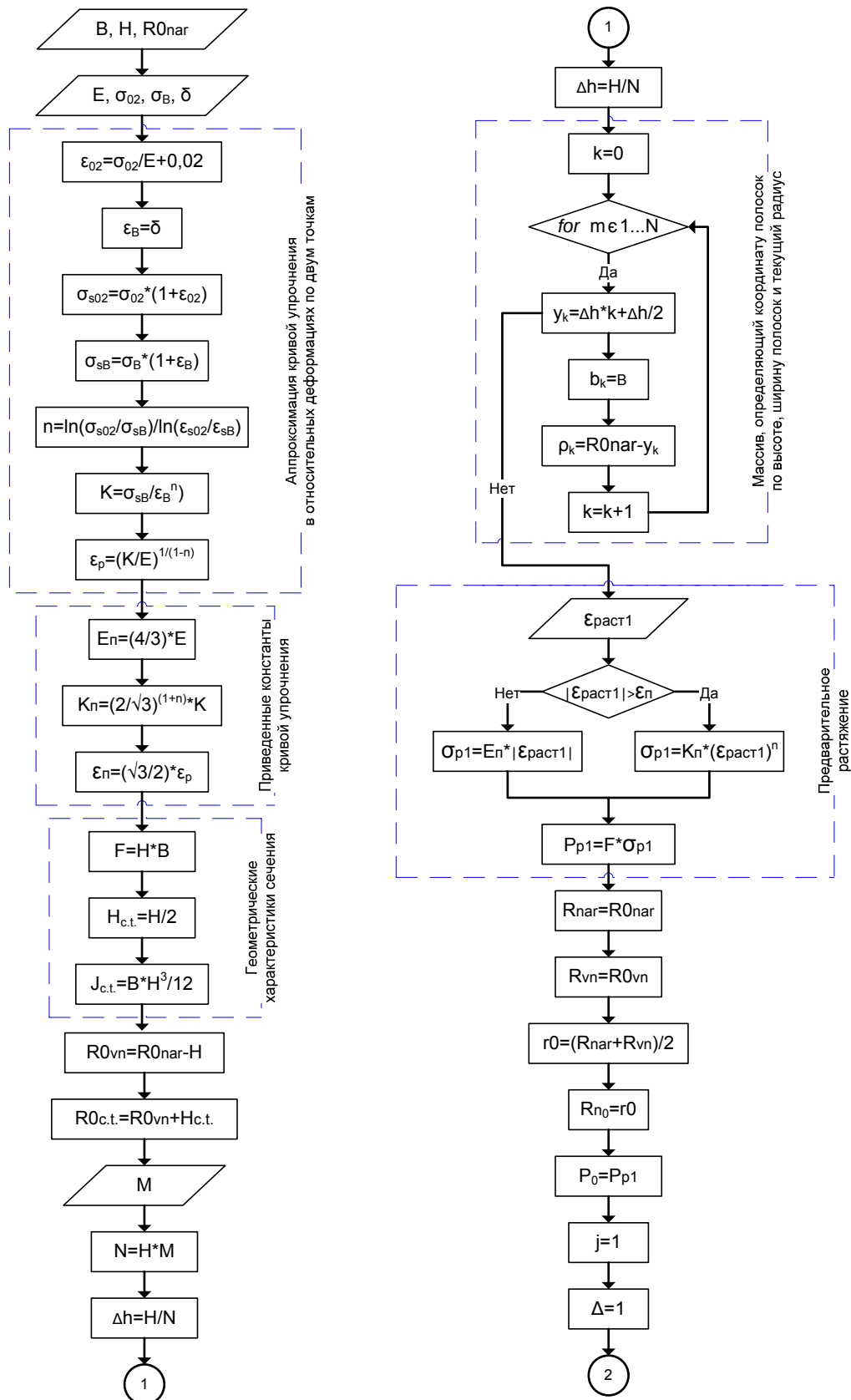


Fig. 5. An algorithm of definition of a detail after tightening (beginning)

Рис. 5. Алгоритм определения формы детали после обтяжки (начало)

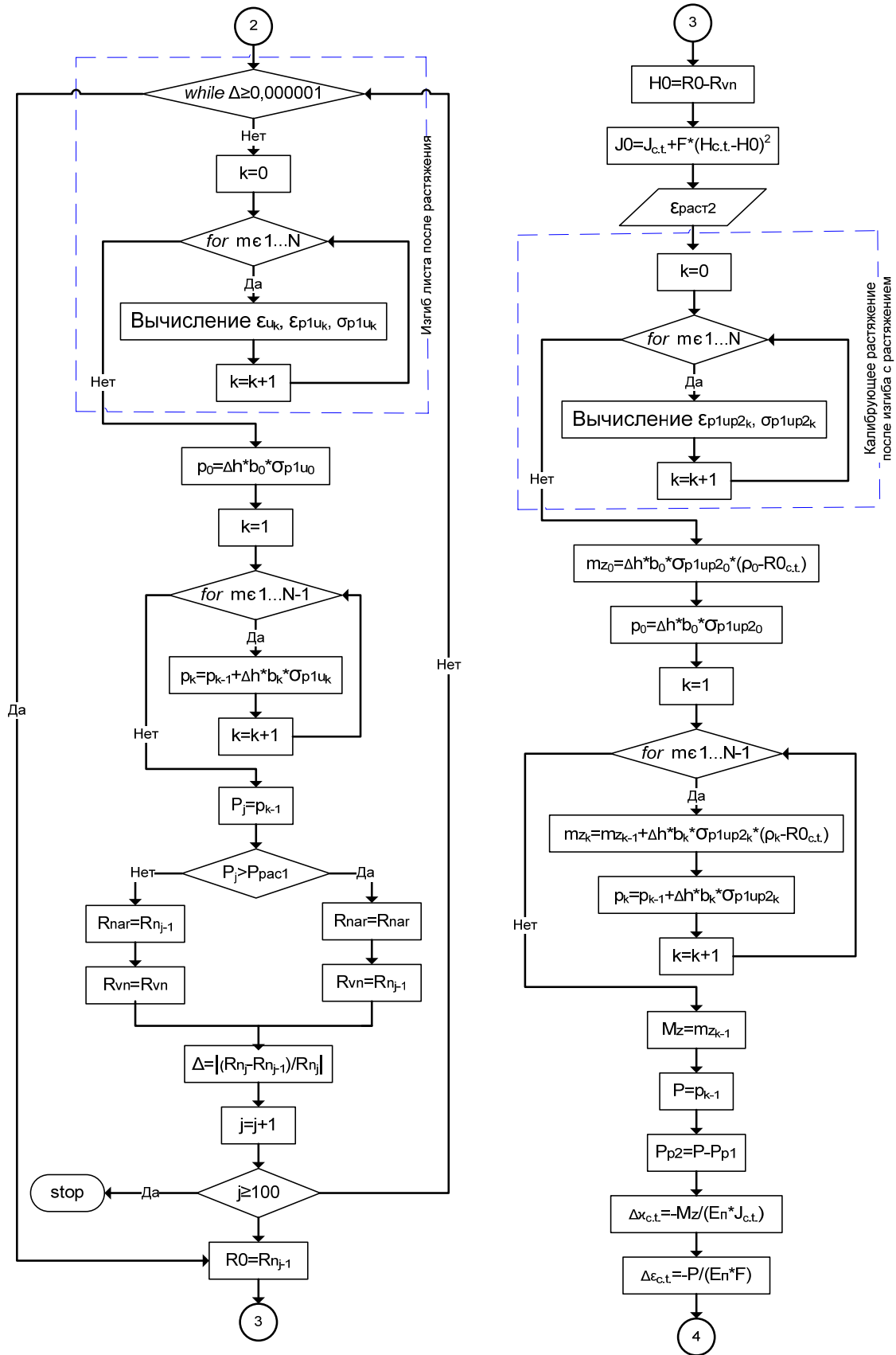


Fig. 5. An algorithm of definition of a detail form after tightening (continuation)
 Рис. 5. Алгоритм определения формы детали после обтяжки (продолжение)

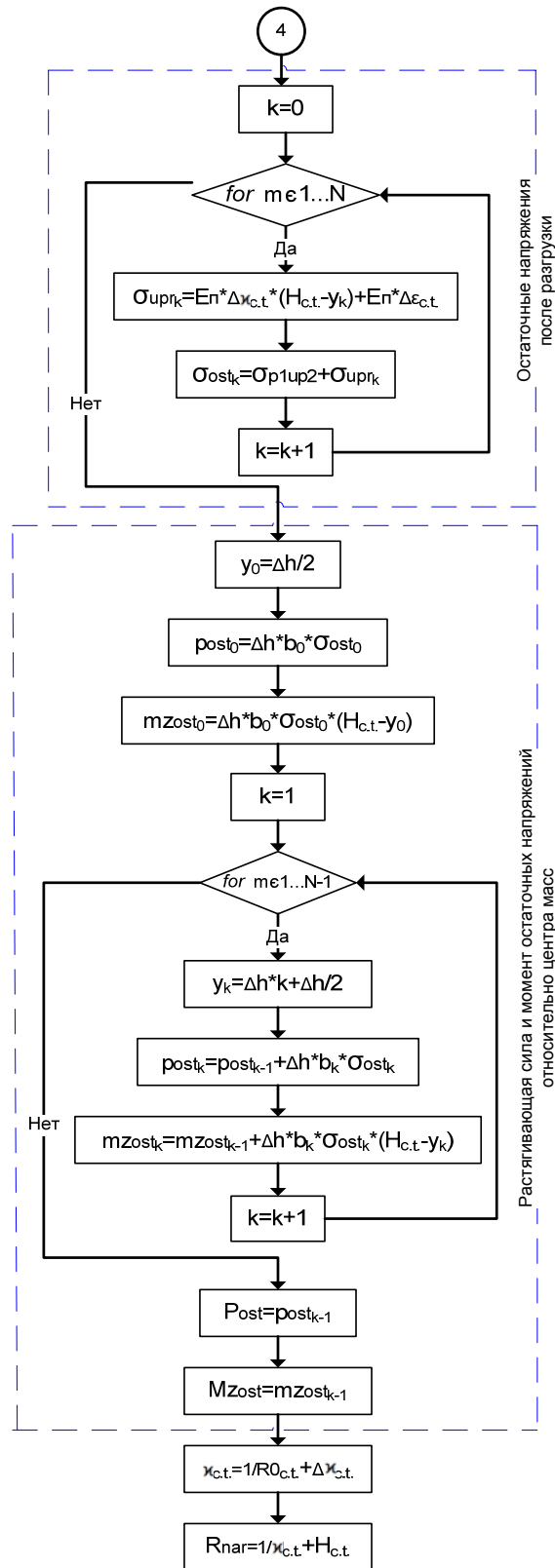


Fig. 5. An algorithm of definition of a detail form after tightening
(end)

Рис. 5. Алгоритм определения формы детали после обтяжки
(окончание)

Conclusion. The offered method of creating control programs is universal for tensioning presses of aviation assignment. The difference are the KM presses by means

of which calculated parameters of process of tightening are transformed to values of controlling coordinates of a press which are reflected in a control program. Creating

such control programs allows to make details of high accuracy in an automated mode and also to exclude or minimize the amount of finishing work.

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