An expert system for ensuring the reliability of the technological process of cold sheet metal forming

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Abstract. In order to exclude periodic defects in the parts manufacturing obtained by cold sheet metal forming a method of automated estimation of technological process reliability was developed. The technique is based on the analysis of reliability factors: detail construction, material, mechanical and physical requirements; hardware settings, tool characteristics, etc. In the work the expert system is presented based on a statistical accumulation of the knowledge of the operator (technologist) and decisions of control algorithms.

Cold stamping allows obtaining parts with complex shapes, manufacturing of which by other treatment methods are either impossible or difficult: body parts, frames, amplifying elements of car body, airplanes, etc. [1] However, the periodic appearance of defective goods in the production of the phenomenon is not rare. Such defects as dents, creases and tear sheet (or cracks) appear.

In modern market conditions: import substitution, saving material and labor resources, meeting the requirements of quality management, one of the urgent tasks is the problem of ensuring the reliability of technological processes.

In most cases, the cause of periodic defective goods is a negative result of the cumulative impact factors of technological process, which are permissible for a given material and technology ranges.

Therefore, at the stage of development and realization of technological processes of sheet metal forming it is necessary to establish, monitor, and manage their design and technological parameters to ensure their desired consistency.

The paper presents a method of automated estimation of reliability of technological processes, at the design stage allows to identify and correct these critical parameters.

The technique is the following: automated analysis of safety factors – detail design, material from which it is made, mechanical and physical requirements; the equipment parameters, which will be stamping, tool characteristics, etc. The list of factors and their labels are presented in [2,3,4].

The indicators of the chemical composition are denoted by coefficients reflecting the quantitative range of the content of impurities in steel. The coefficients on the content of carbon \( K_{M1} \), sulfur \( K_{M2} \), phosphorus \( K_{M3} \), silicon \( K_{M4} \).

Criteria for characterizing the mechanical properties of the material, presented in the form of private coefficients are the coefficients of the yield strength \( K_{M5} \), tensile strength \( K_{M6} \), relative elongation \( K_{M7} \), relative narrowing \( K_{M8} \), anisotropy \( K_{M9} \).

Indicators that account for the punching technology, are represented by the coefficients of friction between the surface of the workpiece and the working parts of the tool \( K_{T1} \), the permissible deviation
for the thickness of the initial sheet $K_{T_2}$, temperature $K_{T_3}$, permissible deviations on dimensions of the original sheet $K_{T_4}$ and limit the elongation factor $K_{T_5}$.

Characteristics of the instrument are indicated by the following coefficients: coefficient reflecting the hardness of the material from which the working parts of the instrument are made $K_{W_1}$, a coefficient reflecting the roughness value of the surface of the working parts of the instrument $K_{W_2}$, a coefficient taking into account the wear of the working parts of the instrument $K_{W_3}$, a coefficient taking into account the misalignment of the upper and lower parts of the stamp $K_{W_4}$, the coefficient taking into account the irregularity of the clearance between the working parts of the stamp $K_{W_5}$.

An important element affecting the reliability of the technological process of sheet metal forming is forging equipment. Its characteristics are presented by coefficients reflecting deviations of a nominal force $K_{Ob_1}$, stroke $K_{Ob_2}$ and shut height of the press $K_{Ob_3}$.

Information on listed indicators ($K_{M_i}$, $K_{T_j}$, $K_{Ob_k}$, $K_{W_l}$) is represented graphically in the reliability profile on figure 1, where conditions of three comparable technological processes are conventionally displayed: * reliable technological process; • the process with the periodic occurrence of defective goods; □ – process with systematic defective goods.

As for some indicators the implementation of the process without occurrence of defective goods will contribute to their minimum value and some maximum, the profile of indicators of reliability of technological process of sheet metal forming is divided into three areas:

1) hatched – area in which the values of reliability indicators of sustainable technological process are desirable to be;
2) white, no fill – area in which reliability indicators for sustainable technological process are allowed to appear, starting from the middle line until the middle of the yellow area;
3) grey, with fill – area in which the values of indicators of reliability are undesirable because the probability of obtaining a defect-free process is far below (or equal to 0) than when injected into the area of green or yellow. [5]

Reliability profile is built based on the "radar" or "profiles" methods, which allows to combine different process parameters into a single dimensionless rate – integral coefficient of reliability and to objectively evaluate and compare processes. [5]
Expert system was developed based on a statistical accumulation of the knowledge of the operator (technologist) and decisions of control algorithms. The scheme of the expert system is presented in figure 2.

![Diagram of the expert system of the technological process reliability of sheet metal forming](image)

**Figure 2** – Schematic diagram of the expert system of the technological process reliability of sheet metal forming

The core of the system is the knowledge base, which stores information about the dependencies between different safety factors. Knowledge is stored in the form of mathematical dependences and technological expertise, formalization of this knowledge is in the form of rules. The knowledge base is initially formed at the expense of formalized knowledge of experts. Further replenishment takes place either by the expert or on the basis of precedents.

The system operates on the base of the operation type and the corresponding parameters of the technological process (material grade, gauge, type of workpiece, lubrication, tool options, etc.) that are injected at the first stage.

Then goes the selection of defective goods which occasionally occurs in the stamping process. In the database in accordance with the type of defective goods the corresponding algorithm for calculation of technological parameters is chosen. The next step consists of calculation of technological parameters for selected algorithm, in the case of a successful calculation, the output is a technological process with the new settings. In case of impossibility of parameters calculation due to
the algorithm, the technologist manually develops new process and approves it by means of simulation (for example, in the program AUTOFORM, PAMSTAMP, etc.).

In the "Expert" technological process with estimated parameters is checked by a specialist, who eventually accepts one of decisions: to send the process into the following stages: assessment of feasibility; return to the technologist for completion, send to the knowledge base, as a technology process with options that allow to obtain a defect-free stamping.

Feasibility assessment is an assessment of the reality and economic feasibility of implementation in specific production conditions.

After assessing feasibility, the data is entered into the database of precedents, from which it is transferred to the knowledge base and database.

The development of an intelligent system summarizing knowledge in the field of cold sheet metal forming, allows the calculation of rational parameters of technological processes excluding the possibility of periodic defective goods.

Thus, by adjusting the value of one or more reliability indicators, effect of interdependence "adjust" other indicators, can be explicitly or indirectly, to control the technological process based on intelligent systems. [6]

References:

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