A Method for Increasing the Efficiency of Assembling Non-detachable Products by Plastic Deformation Using Artificial Intelligence

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Abstract. The way of achievement of the given parameters of quality of assembling of one-piece products, such as accuracy of geometrical sizes of a product and durability of non-detachable joints at stages of technological preparation and management of technological process with application of an artificial intellect is studied.

Composite metal products obtained by assembly into non-detachable joints by plastic deformation are widely introduced into machine building. The main advantage of their application is the possibility of combining in one single product the technical properties of various steel grades. For example, by using such products, it is possible to solve the problem of saving expensive alloyed steels while maintaining the performance characteristics of the die tool [1].

Among the known ways of assembling non-detachable joints, methods of plastic deformation are the most important, when non-detachable joint is obtained at a temperature below the melting point of the metals to be joined [2, 3]. At the same time, there are practically no zones of structural and chemical heterogeneity which inherent in the methods of obtaining composite parts by means of fusion welding.

Achieving the specified quality indicators for assembly of non-detachable joint, such as the accuracy of the geometric dimensions of the product, the strength of an integral connection, depends on the decisions made, both at the stages of technological preparation and at the stage of management of the technological process itself. The system of technological preparation and management should provide a scientifically justified choice of technological assembling modes, also accurate calculation of the parameters of the connected elements of the product, which allows to take into account their shape change during assembly by stage-by-stage deformation localization in the connected elements of the product in real time.

The solution of the task to improve the efficiency of assembling non-detachable products by plastic deformation is possible only with the use of an automated system for modeling and controlling the technological process using artificial intelligence elements.

Figure 1 shows a structural model of a multilevel automated system of modeling and control of the technological process of assembly of non-detachable products by plastic deformation, which provides both automated preparation of the technological process and control of the process of assembly of the product in real time.
Figure 1 - Structural model of the automated system for modeling and controlling the technological process of assembling non-detachable products by plastic deformation

The initial data of the developed system is the CAD-model of the finished non-detachable product, as well as information about the materials of the connected elements.

According to the initial data, the information system searches for a similar precedent in the database. The database stores ready-made solutions in the form of CAD-models of shaped workpiece and rod, and also in the form of decisions on the choice of equipment and tooling design, formed by the management teams. In the case of absence of a fully coinciding precedent, either a new precedent is created or the closest one is chosen, which is further adapted. When developing a new precedent in the module for analyzing the manufacturability of the product, an analysis is made: on the applicability of the technology according to the size; on the compatibility of strength properties; on the compatibility of metals in heat treatment. Next, the user is offered an alternative for choosing the material of the workpiece. The necessary information for the analysis on rheology and thermal properties of materials, size limitations of the technology, as well as the parameters of hydraulic presses is stored in the database.

In the module for modeling workpieces and process parameters, the geometrical parameters of the shaped workpiece and rod are calculated, process parameters are assigned, recommendations for the selection of equipment and tools are given, information is generated for the tool shop (site) in the form of CAD-models of the shaped workpiece and rod, and input data are generated for the operation of the automated process control system. The module for modeling blanks and process parameters is based on the method for selecting the geometrical parameters of the shaped workpiece.
The automated process of control system (APCS) consists of the upper, middle and lower levels. At the lower level, the sensor signals are coordinated with the inputs of the control device, and the generated commands with the actuators with the help of communication devices with objects. At the middle level, the PLC (Programable Logic Controller) receives information from the sensors about the state of the process and issues control signals to the actuators. The upper level is an intelligent add-in that analyzes and processes information coming from the lower layers and the level of the automated process of control system of technological preparation of production (ASTPP), and also controls the technological process. The intelligent add-on is a fuzzy output module for correcting the control based on the data received from the sensor effort using fuzzy rules.

Input variables characterizing the real state of the control object are subjected to fuzzification and are used directly in the formation of control at the lower level, as well as in the system of fuzzy high-level output. In the system of fuzzy output of the upper level there is the base of fuzzy production rules of the form IF "real state of the object", THEN "correction of the lower level control", which in fuzzy form presents the knowledge of experts to adjust the control parameters of the lower level in order to ensure the gradual localization of deformation in the connected elements of the product in real time.

Approval of the developed system for the production of a compound tool for punching holes was made, which is an integral product of steels X12M (rod) and U10A (shaped workpiece) with \( d = 12 \text{ mm}; \ D = 31 \text{ mm}; \ H = 21 \text{ mm}; \ l = 15 \text{ mm} \). When producing a punch made of steel U10A, its resistance is 40-80 thousand strokes, and from X12M - 150-200 thousand strokes.

The rationale for using a compound tool instead of a one-piece of X12M is to maintain the performance of its operational durability with a lower cost of 3-4 times the costly tool steel X12M.

According to the results of mechanical tests of samples, the tensile strength of an integral joint for tearing was 241-265 MPa (MegaPascals) per unit of area of the contact surface of the joining elements of the product. The analysis of geometrical accuracy of the obtained one-piece product is carried out, as a result of which the value of the deviation by weight of the product is equal to 7.57%. Thus, an integral product with a deviation of geometric parameters within the range of accurate hot forging is obtained, which is 5-25% by weight (volume) of the forging.

References

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