Application of multi-agent system for control of parameters of precision stamping process of bevel gears

K N Gavarieva\textsuperscript{1}, L A Simonova\textsuperscript{1}, D L Pankratov\textsuperscript{1}, V G Shibakov\textsuperscript{1} and R V Gavariev\textsuperscript{2}

\textsuperscript{1}Kazan Federal University, Naberezhnye Chelny Institute, 423812, Russia, Naberezhnye Chelny, Prospekt Syuyumbike 10A, 
\textsuperscript{2}Kazan national research technical university named after A.N. Tupolev-KAI, Gavarievakn@mail.ru

Abstract. The article deals with the possibility of using an intelligent control system for the parameters of the technological process of precision stamping and mechanisms of crank hot-stamping presses.

1. Introduction

Modern metal-saving technologies are aimed at increasing the utilization factor of the material and obtaining high-quality products. Thus, the production of bevel gears (BG) corresponding to the 5-6 accuracy class is possible only by precision stamping. The products obtained this way are, by their shape and dimensions, extremely close to the finished part and have minimal allowances, or do not need further mechanical treatment at all [1].

To ensure high accuracy of parts manufacturing, it is necessary to eliminate as much as possible the negative impact of random errors affecting the technological process, which is achieved by automation [2].

As it is known, the most appropriate way to automate the process of precision stamping of bevel gears (BG) is to create and implement a multi-agent intelligent control system for process parameters (billet temperature) and the mechanisms of crank hot-stamping presses (Figure 1).
Figure 1. The structure of a multilevel control system for the precision stamping process of bevel gears BK-knowledge base, DB-database, BR-rule base, MAS-multiagent system.

2. The main body

The system is divided into 3 levels. The upper level is organizational, it is an intellectual superstructure of the system and is based on the knowledge of the organizational subsystem with the functions of reasoning, planning and decision-making in organizing the problem-solving process.

The middle level is coordination one. This level corresponds to the coordination subsystem, which is carried out through the interaction of the upper and lower levels of intellectualization. The task of this level is to plan the work of the lower level and the implementation of operational management.
Process information is displayed on the control panel display. The operator is necessary in the system in case of emergency situations, to debug the coating mode, as well as in the preparation and loading of blanks, and in unloading of processed products.

The lower level is executive. It is a hardware management system that solves a specific task with specific requirements for precision and functions. In order to obtain complete information about the process, sensors are added to the automatic control system. The information from the lower-level equipment is transferred to the remote in/out modules, and then to the controller. The system can be extended by adding measuring equipment and actuators.

This multi-level system as a basis has a knowledge base, which stores information about the parameters of the technological process of precision stamping of bevel gears (BG). The knowledge base is formed on the basis of practical experience, and formalized in the form of production rules, taking into account the rules of logical inference [3].

All new dependencies from the precedent base are analyzed in the block of checking rules for compliance with generally accepted ones. After adding new dependencies to the knowledge base, the system more accurately diagnoses the state of the installation nodes, which leads to a decrease in marriage.

On the basis of the presented structure of the technological process of precision stamping system of bevel gears (BG) we can represent agents of the process in the form of a single multi-agent system (MAS) (Figure 2).

Figure 2. The structure of the MAS for a process of precision punching the bevel gears (BG)

In the presented system the whole spectrum of technological process tasks according to certain rules are distributed among all agents, each of which is a member of the group.

As it is indicated in papers [4-6], interaction of the agents entering into MAS with external environment is provided by the agent - external sources. Interaction between agents occurs through a coordinating agent, which is designed to coordinate the work of agents at all levels. It contains a repository of all the technological functions of the MAS and a knowledge base with rules for building the system.

The proposed control system generates control actions based on the knowledge base [7,8]. In the process of analyzing knowledge representation models, a product based on rules model was preferred. It has a high modularity of rules: when adding or changing a rule, everything that was created earlier, remains relevant. Ability to self-explain: the system explains the chain of rules that was used to obtain the output. In the course of the technological process, the precedent base and the knowledge base are developed.
To determine the production rules, according to papers [9,10], let us consider the fuzzy derivation by the example of the force-agent for stamping the first transition. The following signals from the sensors are available (Table 1).

Table 1. Examples of sensor signals

| No | Signal                              | Denotation       | Variant of origin                  | Denotation       |
|----|------------------------------------|------------------|------------------------------------|------------------|
| 1  | The temperature of the workpiece   | $t^\circ_{\text{workpiece}}$ | Agent the heating temperature of the workpiece | A-1              |

For "workpiece temperature" the linguistic variable workpiece temperature is 1100-1200°C, where up to 1100 °C and its surroundings (0-50°C) is "low", the temperature is more than 1200°C is high temperature [11].

Therefore:

- if the temperature of the workpiece is low, then an increase in the yield stress is by 13% and there is an increase in the deformation force, consequently, an overload of the crank hot-stamping press (CHSP) appears and a press jam may occur;
- if the temperature of the workpiece is "high", then the plasticity of the metal decreases, which is the result of significant grain growth and subsequent burn of the metal (oxidation of grain boundaries).

3. Conclusion

Thus, the creation and implementation of a multi-agent intelligent system for controlling the parameters of the technological process (volume and temperature of the workpiece) and the mechanisms of crank hot-stamping presses makes it possible to increase operational, quality, and technical and economic indicators by reducing the number of errors in the development of the control system; reducing the time to identify and eliminate the causes of the malfunctioning of the system; reducing the probability of failure of expensive equipment.

References

[1] Bertheev M M and Zalyaev I A 1988 Fundamentals of Computer Aided Design Systems (Ucheb. Posobie pod redakciej Yu. V. Kozhevnikova. — Kazan: izd. KGU) p 253
[2] Makarov I M, Lohin I M, Manko S V and Romanov M P 2006 Artificial Intelligence and Intelligent Control Systems (M.: Nauka) pp 214-17
[3] Morozov V K and Rogochev G N 2011 Modeling of information and dynamic systems (M.: Akademiya) pp 127-129
[4] Gavariev R V, Savin I A and Leushin I O 2016 Impact of the functional coating on service durability of injection molds for the zinc alloys pressure casting (Tsvetnye Metally) p 66–70 DOI: 10.17580/tsm.2016.01.11
[5] Gavariev R V, Savin I A and Leushin I O 2017 Improvement of zinc castings surface quality by laminated protective coating (Tsvetnye Metally) p 84-88 DOI 10.17580 / tsm.2017.05.13
[6] Gavariev R V and Savin I A 2017 Improvement of surface quality of casting produced by casting under pressure (Solid State Phenomena) p 988-993 DOI: 10.4028/www.scientific.net/SSP.265.988.
[7] Pankratov D L, Gavariev R V and Gavarieva K N 2016 Influence of multilayer coatings on the operational stability of molds for injection molding IOP Conference Series: Materials Science and Engineering Vol 134 No 1 012031
[8] Gavarieva K N, Simonova L A, Pankratov D L and Gavariev R V 2017 Development of expert systems for modeling of technological process of pressure casting on the basis of artificial intelligence IOP Conference Series: Materials Science and Engineering V 240 No 1 012019
[9] Shaparev A V and Savin I A 2017 Calculation of joint plastic deformation to form metal compound in cold condition (Solid State Phenomena) pp 313-18 DOI:10.4028/www.scientific.net/SSP.265.313

[10] Shaparev A V and Savin I A 2016 Calculation of the amount of the reduction required for the formation of compound layers during cold rolling of bimetals (Materials Science Forum) pp 328-333 DOI: 10.4028/www.scientific.net/MSF.870.328

[11] Safronov N N, Mingaleeva L B, Savin I A 2018 Optimization of charge material composition in shs process with ferrosilide fabrication from gaseous wastes of metallurgical production (Chernye Metally) pp 53-59