To the question of automation of the injection molding process

D L Pankratov¹ and R V Gavariev²

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

Abstract. The article discusses the features of the injection molding process (IMP) from the point of view of the possibility of process automation. The main factors of the casting process that provide a good opportunity for process automation are indicated. The range of tasks of the injection molding process is determined, for the solution of which it is advisable to use an expert system (ES). The ES model for injection molding is proposed, which provides high-quality castings.

1. Introduction. Injection molding (IM) is one of the most productive and efficient methods for producing blanks with a material utilization rate of up to 95%. Another important advantage of IM is the possibility of producing castings of complex configuration with a minimum wall thickness of 0.6 mm. However, one of the limiting factors is the complexity of the processes that occur in the mold cavity when pouring the melt. The simultaneous influence of temperature and power factors leads to the likelihood of various casting defects, such as: porosity, cold laps, shells, various inclusions, heterogeneity, and others [1]. The elimination of these defects is achieved by optimizing the process parameters based on the experience of a technologist or operator of foundry equipment [2]. At the same time, there is subjectivity of the decisions taken to eliminate defects, which ultimately can negatively affect the quality of the products obtained.

2. Results

One of the possible solutions to this situation is the use of computer systems based on artificial intelligence (AI). There are various approaches to understanding the tasks of AI and creating intelligent information systems: genetic algorithm, neural networks, intelligent agent, artificial neural networks, fuzzy logic (expert system). At the same time, the ES is the most suitable for the injection molding process, since, unlike other artificial intelligence systems, they are designed to solve problems in a specific, narrow area [3].

A correctly selected competent expert can provide ES with unique and valuable knowledge [4]. Consequently, the value of the entire expert system in the form of a finished product is characterized by the quality of the created knowledge base.

Table 1 shows the relationship between the applications of ES and the casting process with pressure application, which confirms the advisability of using ES.

Table 1. The tasks of the injection molding process, for those solution it is advisable to use ES.
| Types of ES application | Explanation | ES objectives |
|-------------------------|-------------|---------------|
| Interpretation          | Description of situations based on observed data. | Recognition, understanding of speech, image analysis, determination of the structure of chemical compounds. |
| Forecasting             | Conclusion of probable consequences from given situations. | Prediction of the state of machines and mechanisms. Prediction of casting quality and probability of defects. |
| Diagnostics             | Conclusion about violations in the system, based on observations. | Hardware troubleshooting. |
| Design                  | Constructing objects with restrictions. | The allocation of resources to support the IMP process. Design of the IMP process. |
| Monitoring              | Flexible management of certain system functioning. | Monitoring the steps of the IMP process. Final result control. |
| Training                | Transfer knowledge of any field to the user or its verification. | Testing of knowledge and advanced training of workers. Training in finding solutions to problematic situations. |

The information base includes permanent and variable information. Permanent information consists of an indicator of the state of the furnace heating element, data on the temperature of melt heating in the crucible, an indicator of the state of the mold lubrication process, verification of melt pressing in half-molds, crystallization and cooling control [5]. Variable information includes data on the number of defects, data on technical diagnostics, laws describing any change in technical condition, and more. The expert system consists of a large number of algorithms that are combined into computational and logical models. These models help to find a solution to the problem and form the content of the model base. In the process of operation, ES databases can be corrected and updated with new information, previously unknown problem situations and models for their solution [6].

The decision-making function is aimed at choosing the optimal solution to problematic situations in case of malfunction in the normal operation of the control object. The implementation of the recommended measures is carried out by the regulatory function. The function of the planning unit is to calculate the resources necessary for the smooth operation of the system as a whole [7]. The control function compares the control object’s planned and accounting indicators and analyzes the impact of decisions on the system. This block forms a control loop. In case of data disagreement, the transition to the control loop begins, then additional recommendations to the control object are made.

The implementation of ES is based on the constant interaction of three main parts: a person (a decision maker), a hardware-software complex, and a control object, which is main part in decision making process [8].

The interaction of the decision maker and the system occurs in a dialogue mode, in which, when describing the problem, the ES proceeds to the automatic search for a solution. ES decision making is concluded in a series of logically interconnected steps corresponding to the tasks that the system solves:

- evaluation of the process system;
- definition of goals and performance criteria;
- solution development;
- decision making;
- decision implementation;
- evaluation of results.
The expert system should apply a policy of direct withdrawal and splitting into subtasks. The essence of crushing into subtasks is to refine the fragments. Fragments are considered as the achievement of intermediate goals on the way to the final goal. An example would be the situation of deflection of the rod. The main factors, that can affect this defect, are formulated (uneven heating by thickness or width, mismatch of the axial load level, initial twist) [9], [10], this allows us to reduce the volume of technological methods of searching for regulatory parameters.

3. Conclusions

Thus, injection molding is a complex manufacturing process for producing castings, and there are many factors that affect the quality of their production. The correctness of the decisions taken to eliminate defects in each specific situation is directly related to the experience of the staff, which negatively affects the efficiency of the IMP process. Taking into consideration the good background of the IMP process for automation, the most promising is the use of computer systems utilizing artificial intelligence based on expert systems. This makes it possible to increase the efficiency of the injection molding process by improving the quality of the obtained castings, as well as saving various resources.

References

[1] 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 Conf. Series: Materials Science and Engineering 240 012019 DOI: 10.1088/1757-899x/240/1/012019
[2] Yan Q S, Yu H, Lu G, Xiong B W, Lu B P and Zou X 2014 Effect of crystallization pressure on secondary dendrite arm spacing of vacuum counter-pressure casting aluminum alloy School of Aeronautic Manufacturing Engineering Nanchang Hangkong University (Nanchang) 330063 Vol 24 No 5 pp 1194-1199
[3] Gavariev R V, Savin I A and Leushin I O 2017 Improvement of zinc castings surface quality by laminated protective coating Tsvetnye Metally No5 pp 84-88 DOI 10.17580 / tsm.2017.05.13
[4] Hu X P, Zhao G Q and Wang W M 2010 Solidifying pressure and microstructure of alsi10cu3 in die sleeve in high pressure die casting International Journal of Cast Metals Research vol 23 № 5 pp 289-295
[5] Gavariev R V and Savin I A 2017 Improvement of surface quality of casting produced by casting under pressure Solid State Phenomena 265 pp 988-993 DOI: 10.4028/www.scientific.net/SSP.265.988
[6] Gavariev R V and Savin I A 2018 Research of the mechanism of destruction of compression molds for casting under pressure of color alloys Solid State Phenomena Vol 284 pp 326-331 https://doi.org/10.4028/www.scientific.net/SSP.284.326
[7] Pankratov D L and Gavariev R V 2019 Improving the quality of castings made of non-ferrous metal alloys when casting in metal molds IOP Conf. Series: Materials Science and Engineering 570 012072 doi:10.1088/1757-899x/570/1/012072
[8] Deev V B, Prusov E S and Kutsenko A I 2018 Theoretical and Experimental Evaluation of the Effectiveness of Aluminum Melt Treatment by Physical Methods La Metallurgia Italiana №2 pp 16-24
[9] Gavarieva K N, Simonova L A, Pankratov D L, Shibakov V G and Gavariev R V 2018 Application of multi-agent system for control of parameters of precision stamping process of bevel gears IOP Conf. Series: Materials Science and Engineering 412 012020 DOI: 10.1088/1757-899X/412/1/012020
[10] Gavariev R V, Savin I A and Leushin I O 2019 To the question of casting alloys of non-ferrous metals in the metal mold Materials Science Forum 946 pp 631–635. https://doi.org/10.4028/www.scientific.net/msf.946.631