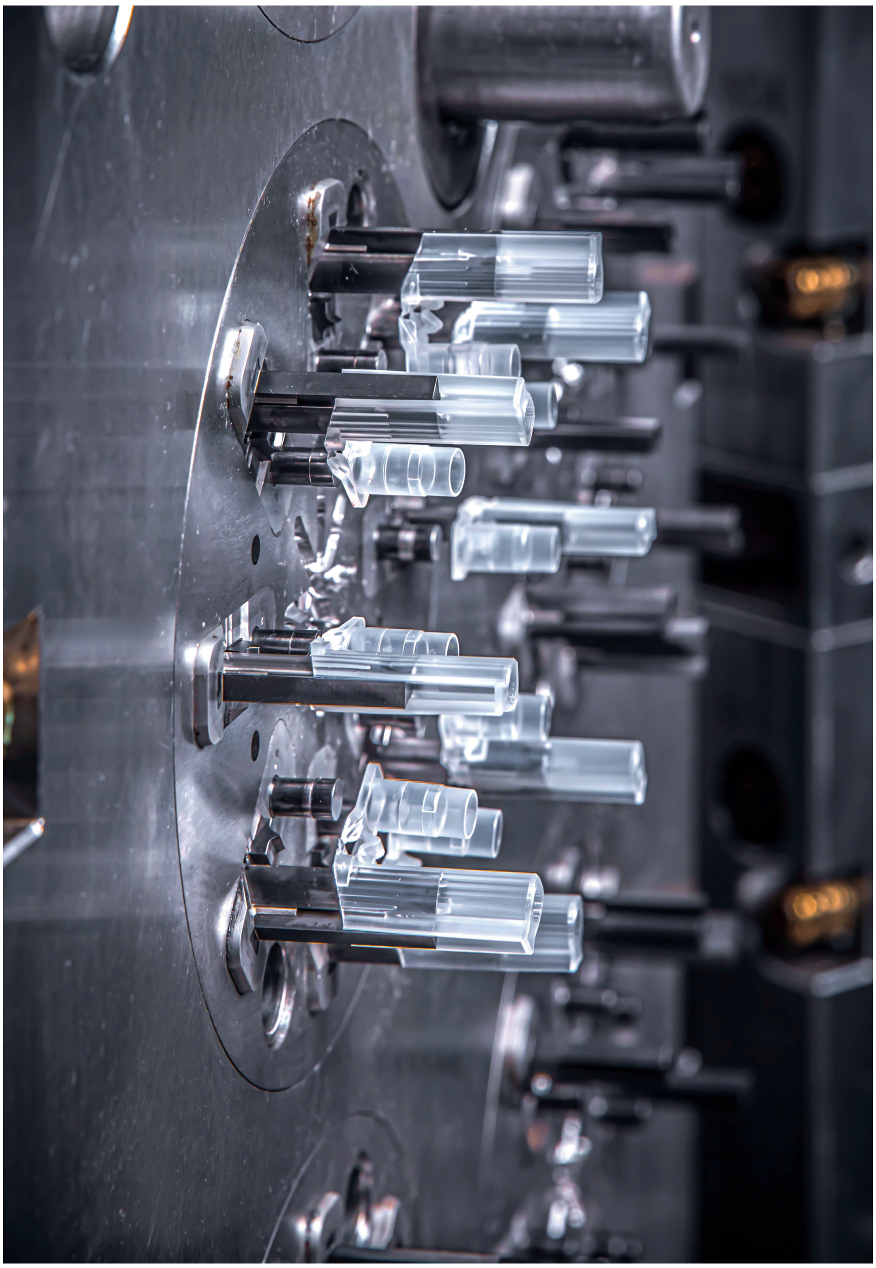
Automated Design of the Demolding Systems of Injection Molds

Anticipation of a Larger System Landscape

Cost risks and the loss of knowledge threatened by demographic change, form a scenario for the toolmaking industry for which automated tool design could be a conceivable way out. In order to address this field, the AutoEnSys research project focuses on the use of an AI-based expert system for the automatic positioning of ejectors in the demolding system. In the long term, a self-learning algorithm should also design further parts of the demolding system.



Partial automation of the demolding system represents an important step towards complete automation of injection mold design. © Werkzeugbau Ruhla

The German toolmaking industry is exposed to increasing cost and time pressure. This is primarily the result of shorter product life cycles and increasingly aggressive competition from low-wage countries. German toolmaking companies are responding to this pressure by increasing their productivity and focusing their performance. Thus, machine hour rates can be reduced, and manufacturing costs lowered by building automation solutions in direct value-added activities. Indirect value-adding activities, which nevertheless have high potential for increasing efficiency and reducing costs in the industrial value chain, experience little automation. In the tool development process, approximately 33 % of the process costs are attributable to design, try-out, project and quality management, and other indirect fields.

In the tool manufacturing process, design ties up around 22 % of the cycle time as well as 15 % of the process costs and therefore promises high potentials for strengthening competitiveness [1]. For other reasons, however, design automation also makes sense. For instance, 70 % of tool costs will be determined in the product development phase. This means, on the one hand, that there is a risk of causing higher costs in the design phase due to incorrect planning. On the other hand, the design can significantly influence the tool costs [2]. Another reason is the possibility to counteract the structural change in the German tool making industry through automation. Due to demographic change and the associated reduction in the number of qualified skilled workers, a success factor for the competitiveness of German companies will be to systematically depict know-how-intensive activities such as tool design and to reduce dependence on experienced employees.

In order to increase the above mentioned potentials, the design office Hein, the machine tool laboratory WZL of RWTH Aachen University and the WBA Aachener Werkzeugbau Akademie GmbH, both located in Germany, have jointly dedicated themselves to the research project "Automated design of the demolding system of injection molds based on self-learning algorithms" (acronym: AutoEnSys, FKZ: 01IS20081A) since January 2020. The overall objective of this publicly (BMBF) funded research project consists of fully automating the design of injection molds. Therefore, in first instance, the project team is pushing towards partial automation of the design through automated design of the demolding systems, in order to reduce the manufacturing and time as well as to improve the ease of maintenance.

Independent Design of an Expert System

First of all, a self-learning AI algorithm will be developed in the form of an expert system that will enable the automated design of the demolding system. In the first work package, project requirements for the development of the AI algorithm were defined. A distinction was made between purely technical requirements and human-machine interface requirements. In addition, low-threshold complex guiding constructions were conceptualized, which serve as representative constructions and include round, flat and case ejectors as well as simple opposing sliders. The conceptualized application processes manual inputs of design parameters as well as uploaded CAD data sets. It is also conceivable to incorporate results from injection molding simulations, such as a previously defined mold separation or a specified tempering channel and sprue layout (**Fig. 1**).

In order to ensure the independent design of the expert system, the data structure based on the algorithm was modeled in the second work package with the help of design knowledge. For this purpose, the design expertise of the designers in the project consortium was used to build a decision logic based on decision trees and UML diagrams that represent the knowledge and decisions of a designer during the design of a demolding system. This decision logic could be broken down into six decision trees that reflect, for example, the decision process for determining sliders and ejectors according to their type and positioning, as well as rules for determining tool size and mold insert size.

Furthermore, a total of 15 design rules for a geometry box were defined in workshops. These were also evaluated based on their influence on the design. The decision logic as a whole forms an important basis for the learning AI algorithm for the automated design of demolding systems.

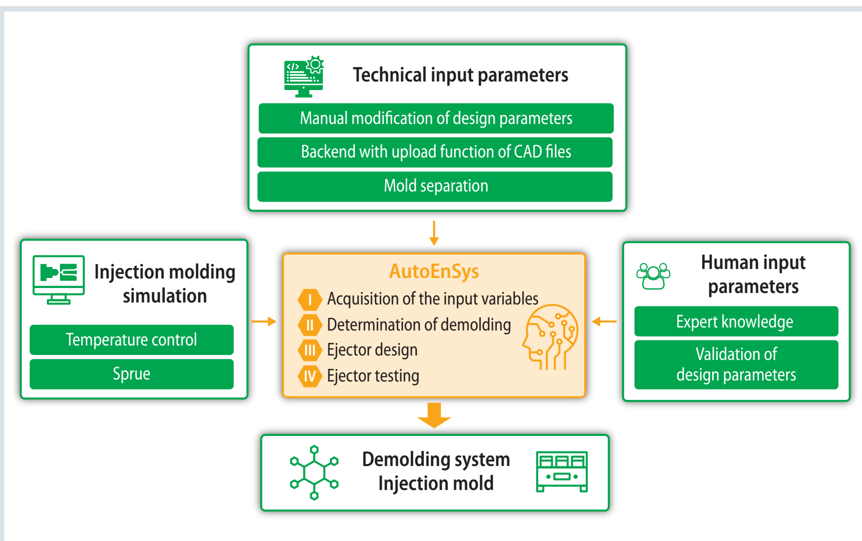


Fig. 1. AutoEnSys processes heterogeneous input factors, structures them and derives from them a demolding system. Source: WBA; graphic: © Hanser

Modeling and Training the AI Algorithm

The goal of the third work package is to model and sufficiently train the AI algorithm for the automated design of the demolding system. This is why, in the first place, the pure software architecture was modeled and software modules were implemented. Subsequent training of the algorithm is done through iterative feedback of design experts. The analysis of the 3D model of the component serves as input for the AI algorithm. Geometry-specific features will be extracted from the 3D model. Two basic feature types will be distinguished:

- point-specific properties such as material thickness and component height as well as
- geometric shape properties such as corners, edges, ribs, domes and undercuts.

The recognition of features is based on various algorithms, some of which are based on learning-based ML (machine learning) methods and some of which are based on working out the relationships between fundamental properties. Overall, this results in a feature recognition system that extracts all relevant features with which the experts work according to the design rules. The data required for training the algorithm were generated on the basis of expert knowledge. The training initially performed, forms the basis for the usability as well as the testing of the algorithm in the next work packages.

Assessment of Practicality

After successful training, the ready-to-use AI-based expert system will be tested and optimized in the fourth work package (**Fig. 2**). To this end, possibilities of recirculation feedback, for example through evaluation sheets, were first worked out. The algorithm will be tested under laboratory conditions and with the involvement of design engineers from the consortium. The designers evaluate the automatically designed » demolding systems based on several criteria – including size, overall part and surface quality, cycle time, possibility of tempering, and geometric position – and communicate the feedback back to the programming team.

Finally, the tested and optimized algorithm will be piloted and validated under practical conditions in the fifth work package. Practical suitability is a key requirement of the research project, which is why this work package is of particular importance. The practical suitability will be evaluated by means of feedback forms from the users. The user companies in the research consortium will use the developed software solution in current design projects. Subsequently, it is planned that other partners from the WBA partner network will use the software in order to ensure continuous optimization of the application in the feedback process.

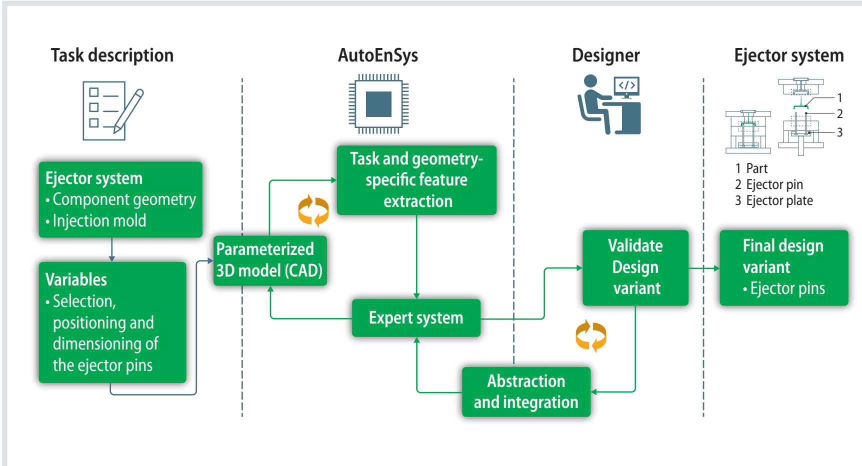


Fig. 2. The AI system AutoEnSys extracts features from a 3D model and generates a design proposal that will be validated by a design engineer. Source: WBA; graphic: © Hanser

Outlook

The efforts to date within the AutoEnSys research project focus on a single solution which, as a central building block, is intended to enable the mechanics of further projects to fully automate the design of injection molds. The expert system developed in the project is to become part of a larger system landscape. Therefore, it is further necessary to develop interfaces to CAD, injection molding simulation and FEM systems. The AutoEnSys expert system is intended to represent a generally valid and open system that bundles a large number of systems via individually adapted interfaces.

In order to push the development of the described application, the project consortium is already striving for follow-up projects. It was therefore established in the course of the project that it improves the functionality if FEM simulations are taken into account. The positioning and the selected ejector type are to be optimized by means of interfaces to FEM systems, taking into account the demolding forces. In addition, it is planned to take into account injection pressures, shrinkage as well as gating systems in the design by integrating injection molding simulation results. Another development focus will be on the iterative selection of design variants from the developed AI algorithm in the context of human-machine interaction. ■

Info

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