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The expert system for improving the technological processes of composite manufacturing

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Abstract. An expert system for improving the technological processes of composite manufacturing is presented. The domain of the expert system is the technology of pressure treatment of structurally inhomogeneous materials, including powder materials and composites. The purpose of the expert system is the interpretation of experimental data and the prediction of physical and mechanical properties of blanks and products. The function of the expert system is to issue recommendations for improving the technological processes of manufacturing blanks of non-compact metal raw materials, produced on the basis of predicting the properties and behavior of the object of the study. The problems solved by the expert system are planning natural and computational experiments, statistical processing of experimental data, regression analysis, checking the adequacy of mathematical models, multiparameter optimization of the systems and processes under study.

1. Introduction

The creation of an integrated system for the control and management of product quality is preceded by a system analysis of technological processes. At the same time, statistical quality control is the main quality management tool. The statistical direction of product quality control and management has become widespread. However, its role in the overall quality management system is often overemphasized. Often, independent and contradictory functions of quality are formulated within a uniform framework to the detriment of the studied process system as a whole. In this regard, a relatively new concept of design and implementation of quality assurance systems (the concept of overall quality management), based on reliable mathematical models using statistical data, started up. In accordance with the above concept, a number of automated systems have been developed for the current production of composites and products: the Automated System of Scientific Research, the Generative Planning System, and the Automated Technological Process Control System. The implementation and improvement of the efficiency of automated systems are ensured by their integration on the basis of coordination of informational, technical, software and organizational support. Product quality management is the development and subsequent implementation of control actions to achieve the required level of quality indicators at all stages of the life cycle of industrial products. This article



presents the first results of the creation of an automated system for product quality control and management in the processes of plastic deformation of structurally inhomogeneous materials, which include the processes of deformation of powder materials and composites. The basic principles for developing such a system are given in [1].

A schematic diagram of the product quality control and management system is shown in figure 1. The diagram shows the transfer of information on processing behaviour to the quality control windows K_p^i , as well as to the modelling center MC, where recommendations to support and improve the process system are developed using technical means and appropriate software. The automated system for product quality control and management is equipped with an expert system, which is equipped with product quality control windows and a set of programs for multicriteria optimization of technological processes and systems.

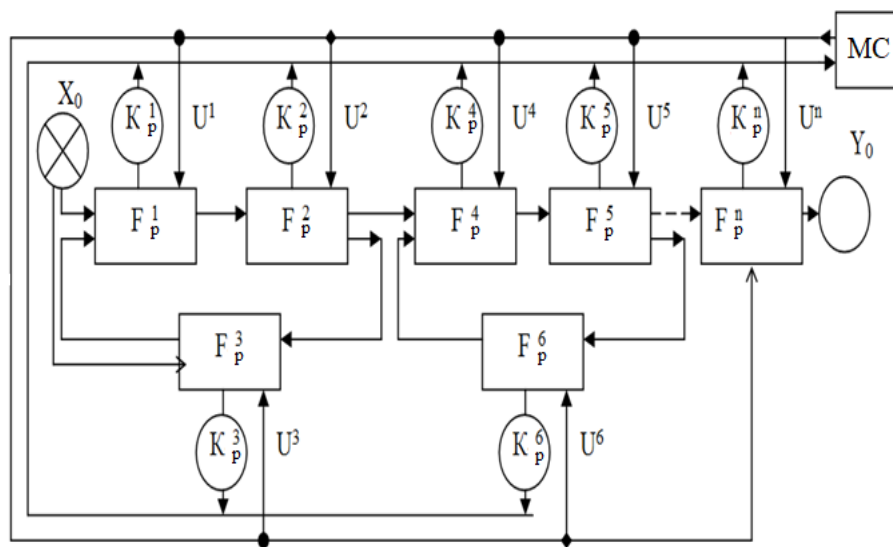


Figure 1. The scheme of product quality control and management: MC – modeling center; F_p^i – transfer functions of one-stage models (process operations); K_p^i – quality control windows, $i=1, 2, \dots, n$.

The functions of the product quality control window are shown in figure 2. The evaluation and diagnosis of the state of technological processes are performed automatically using the results of the mathematical simulation. In this case, the process engineer responsible for the state of production receives information from the MC in the "advice" mode, acting as a decision maker [2, 3].

An automated system for product quality control and management contains product quality control windows (figure 1), which include an expert system (ES). The domain of the ES is the technology of pressure treatment of structurally inhomogeneous materials, including powder materials and composites.

The purpose of the expert system is the interpretation of experimental data and the prediction of physical and mechanical properties of blanks and products. The function of the expert system is to issue recommendations for improving the technological processes of manufacturing blanks of non-compact metal raw materials, produced on the basis of predicting the properties and behavior of the object of the study. The problems solved by the expert system are planning natural and computational experiments, statistical processing of experimental data, regression analysis, checking the adequacy of mathematical models, multiparameter optimization of the systems and processes under study [6-15].

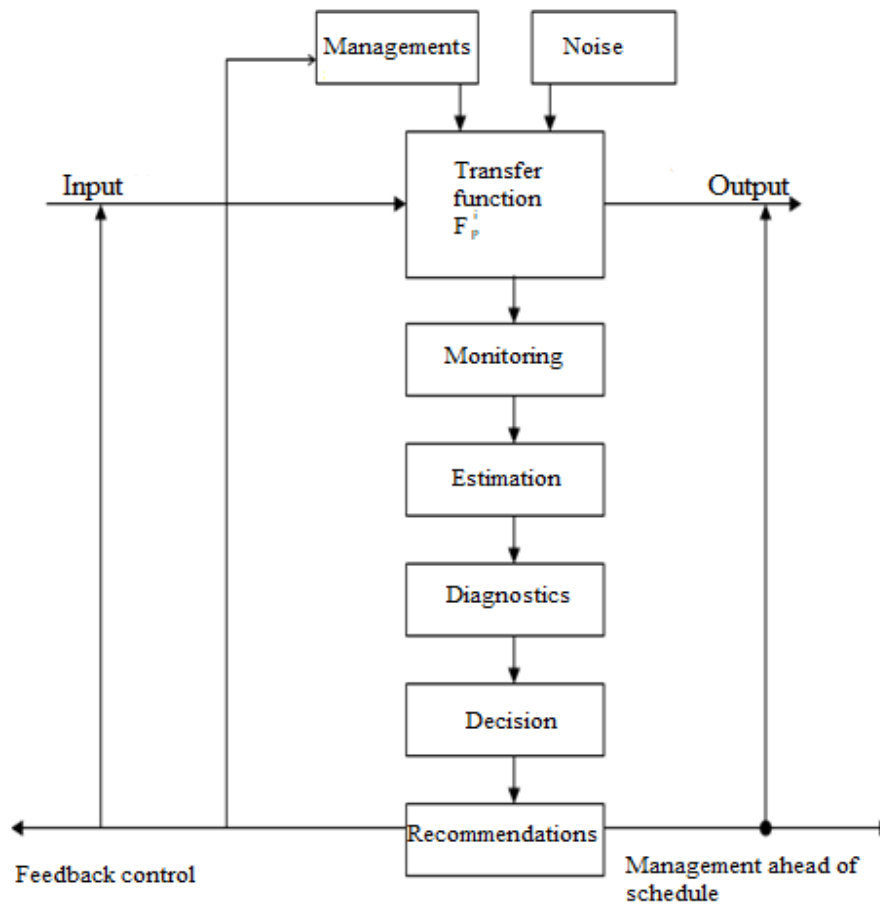


Figure 2. Functions of the product quality control window.

2. Expert system description

A functional scheme of the ES is shown in figure 3.

A Knowledge Base (KB) is designed to store long-term data describing the considered domain, and rules describing expedient data conversion in this area. The specialist application area is selected as the domain. To create the ES in the selected area, facts and rules are collected, which are placed in the KB along with the inference and simplification mechanisms.

Unlike all other components of the ES, the knowledge base is a variable part of the system that can be supplemented and modified by knowledge engineers on the basis of the experience of using the ES, between consultations and in the consultation process.

There are several methods for representing knowledge in the ES; however, the common thing for all of them is that knowledge is represented in a symbolic form (elementary components of the knowledge representation are texts, lists, and other symbolic structures).

Thus, the ES implements the symbolic nature of reasoning; the process of reasoning is represented as a sequence of symbolic transformations. There are dynamic and static KBs.

The proposed ES provides a dynamic KB, which changes in the mode of dialogue with the user. New facts added to the knowledge base are the result of inference, which is applying rules to existing facts. In the ES, even the data that has already caused triggering of some rules after the inference can be changed. In other words, it is possible to modify the attribute values as part of facts in the intermediate memory. Changing the facts leads to the need to remove from the knowledge base the conclusions obtained with the help of the mentioned rules. Thus, the inference is repeatedly performed in order to reconsider those decisions that were obtained on the basis of the changed facts.

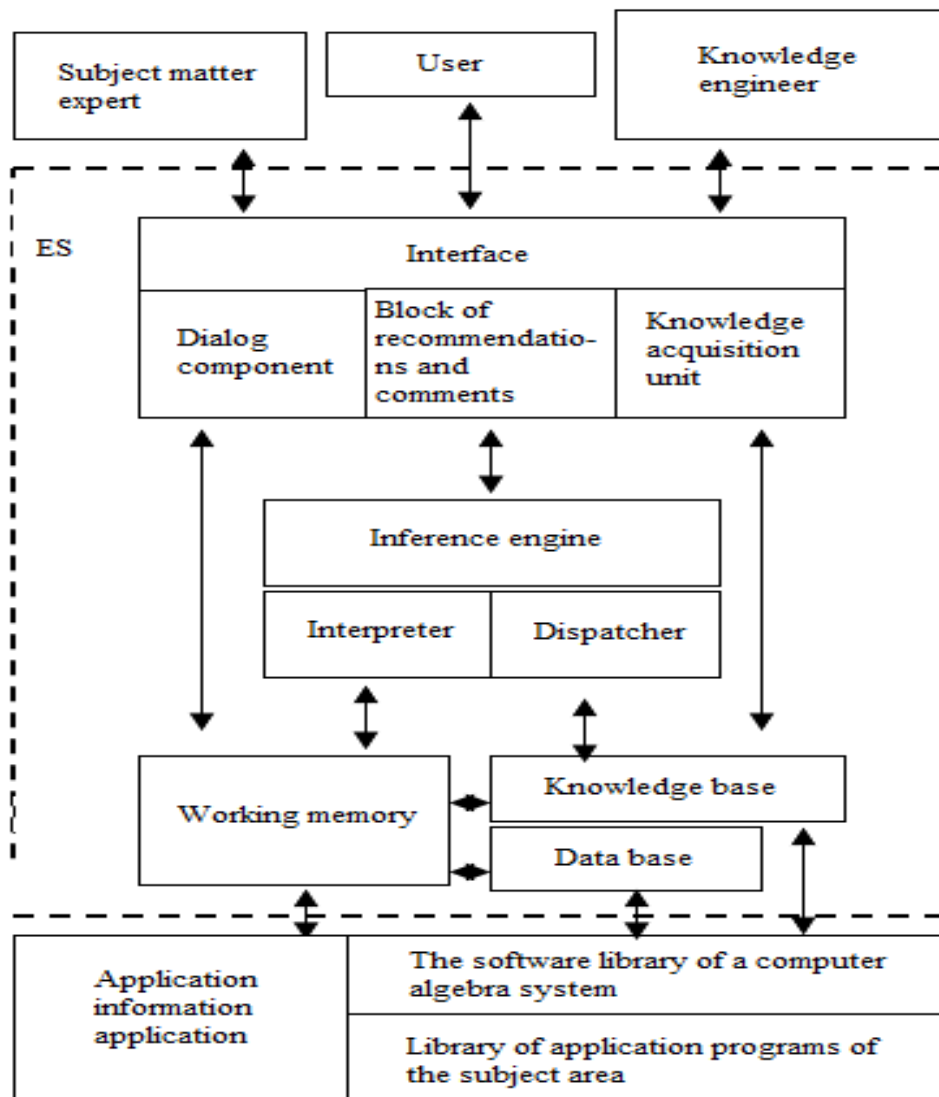


Figure 3. Functional scheme of the ES.

The database is designed to store the source and intermediate data of the currently solved problem.

The inference mechanism uses information from the KB and generates recommendations for solving the desired problem. The KB consists of facts and rules (if <parcel> then <conclusion>). If the ES determines that the parcel is correct, then the rule is recognized suitable for this situation and it is started. Starting the rule means accepting the conclusion of this rule as part of the process. The purpose of the ES is to derive some given fact – a targeted statement (that is, as a result of applying the rules, to ensure that this fact is included in the working set), or to disprove this fact (that is, to ensure that it is impossible to derive it, therefore, with a given level of knowledge of the system, it is false). The target statement is extracted by the system from the user dialogue. The system operation is a sequence of steps, at each of which some rule is selected from the base, which is applied to the current content of the working set. The cycle ends when the target statement is derived or refuted. The work cycle of the expert system is a logical conclusion. The proposed ES uses direct inference (inference by controlled data) and reverse inference.

The inference mechanism uses a production model that is based on rules and allows representing knowledge in the form of sentences: if (condition), then (action). The assumption of the presence of a particular property, taking the value true or false, for example, can be used as a condition and action in the rules. In this case, the term action is interpreted broadly: it can be a directive to perform any operation, recommendation, or modification of the knowledge base – the assumption of the presence of any derived property. Direct inference (from the data to the target) and reverse inference (from the target for its confirmation to the data) are used. Here, the data refers to the facts on the basis of which the inference engine is launched – a program that enumerates the rules from the database.

The explanatory component of the ES provides information on how the system obtained the solution to the problem (or why it did not obtain the solution) and what knowledge was used, which facilitates testing by an expert and increases user confidence in the result.

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