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## TECHNOLOGICAL KNOWLEDGE MANAGEMENT SYSTEM FOR FOUNDRY INDUSTRY

### SYSTEM ZARZĄDZANIA WIEDZĄ TECHNOLOGICZNĄ DLA ODLEWNICTWA

Technological knowledge is a collection of information from each stage of the casting production preparation process along with production data and quality control data. Knowledge and experience are the most important factors for the dynamic development of each foundry. Efficient archiving and management of technological knowledge, including computer simulations, is a critical part of building competitive advantage. Analysis of historical data allows for drawing the right conclusions, and guarantees improved quality of the final product. Effective enterprise management system, and technological knowledge management system in particular, is an indispensable tool for any innovative foundry. Simulation Process & Data Management is a new, dynamically-developing scientific field. Also in the foundry industry it is a very important step towards the management of casting simulation results.

*Keywords:* simulation process and data management system, technological knowledge base

Wiedza technologiczna jest to zbiór informacji pochodzących z każdego etapu przygotowania produkcji odlewniczej. Wiedza, doświadczenie są najważniejszymi czynnikami dynamicznego rozwoju każdej odlewni. Umiejętne archiwizowanie i zarządzanie wiedzą technologiczną, w tym symulacjami komputerowymi jest kluczowym elementem budowania przewagi konkurencyjnej. Analiza danych historycznych umożliwia wyciąganie właściwych wniosków oraz gwarantuje poprawę jakości wyrobu końcowego. Efektywny system zarządzania przedsiębiorstwem, w szczególności system zarządzania wiedzą technologiczną jest niezbędnym narzędziem każdej innowacyjnej odlewni. Simulation Process & Data Management jest nową, dynamicznie rozwijającą się dziedziną nauki. W branży odlewniczej jest to bardzo ważny krok w kierunku zarządzania wynikami symulacji dla odlewnictwa.

Complexity of metallurgical processes requires the use of modern sophisticated computational IT tools for their calculation, optimisation, storage and analysis of process data. Modern simulation programs and high-performance computing machines (workstations, clusters) allow prediction of the phenomena of physical processes occurring in solidifying castings, based on the input parameters (initial-boundary conditions).

The use of IT tools in all fields of science and industry has become a normal routine. This process is also present in the foundry industry. The foundry industry uses various IT programs divided by their specific applications as follows: CAD, CAE, CAM, CAQ.

The interdisciplinary nature of casting technology requires the use of modern tools for their design and optimisation. Modern industry adopts customer satisfaction as an indicator of the effectiveness of manufacturing processes. The basic requirement of the customers is to be provided with quality products. This trend also applies to the manufacturers of machinery and equipment, including those manufactured with casting techniques. Unfortunately, casting processes, due to their complexity, are associated with the need to comply

with dozens, or sometimes hundreds, of metallurgical process simulations within a single project.

To minimise production cost, foundries use highly specialised simulation software for mapping the actual thermo-kinetic processes which occur during the pouring and solidification of castings. Research centres and foundries using simulation software are facing the problem of how to store the data from simulation programs. Such data is stored in various ways: in the form of images, videos, animations, tables, charts, sets of parameters in different directories, depending on the type of project, version, moulding compound alloy type and dimensions of the adopted technology. The number of developed simulation projects performed in a single project is so large that it is almost impossible to easily and quickly find specific information, and it is certainly very difficult and time consuming. The overall data is estimated at tens of terabytes per year across the country.

The following conclusion can be drawn: "The data from simulation programs will never be reused in other projects." There are several reasons for this: problems with the storage of projects (according to which category should they be stored?),

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very time-consuming search for specific projects, a very large volume of data.

Software SimulationDB is an innovative knowledge base for the foundry industry, designed to shorten the technology preparation process. The uniqueness of this solution lies in a new way of developing technology using knowledge stored in the database system. The system stores a wide range of information, including specific customer requirements regarding the finished casting, developed technologies verified through virtual simulation models, and actual data from the manufacturing process.

There is a need for a modern generation of tools for technology development, and the SimulationDB system addresses this need. Not only it uses experience from developing similar systems in the past, but it also includes new essential modules that allow for quick identification of qualitative characteristics of the cast, more efficient circulation of technical documentation, advanced analysis of developed technologies, intelligent support of technologist's decision-making process, training and acquiring new practical knowledge by young inexperienced staff, reporting on the technological and production process, comparing virtual simulations with the actual process, optimizing the casting production preparation process, and finally – monitoring and managing the quality control system.

As the capabilities of computers keep increasing and computational algorithms get more and more optimized, the number of performed computer simulations grows rapidly. This generates huge amounts of data that is very rarely re-used for the purpose of developing new technologies due to the way they are stored (the structure of catalogs) and the lack of any searching capabilities. Moreover, managing such a large amount of information efficiently is impossible without specialized, dedicated IT solutions.

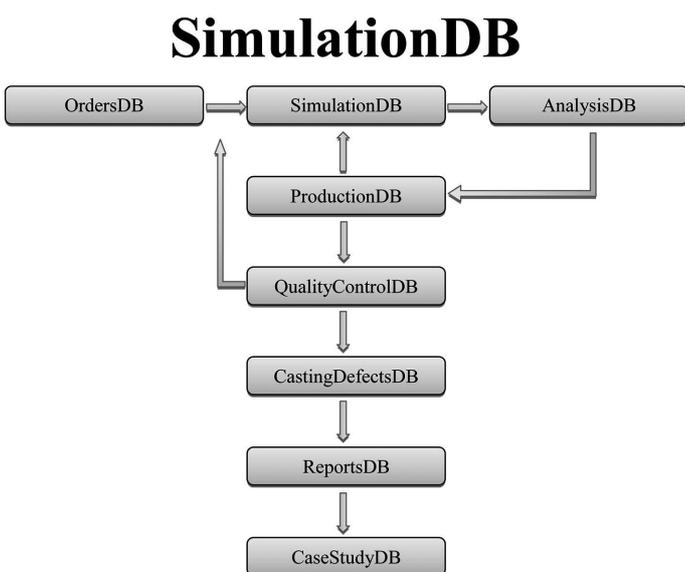


Fig. 1. Diagram of relations between SimulationDB modules

The method used so far for storing technological data – i.e. images, animations, charts, sets of parameters, simulation results and production data contained in a defined directory structure – makes processing and re-using this information basically impossible.

Designing the SimulationDB system started a new technological process which is characterised by an innovative approach to the preparation of casting technology. The process engineer does not begin from making the simulation, but only determines the particular casting features, which are also the criteria for searching the database for simulation results. As a result of this, a list of projects matching the specified criteria is obtained. After a brief analysis of selected projects of a similar nature, the engineer develops a new technology based on the knowledge stored in the database. The database system developed is characterised by the fact that it is independent from the simulation program used, and, therefore, it can be used in a foundry that has any program to simulate the casting process.

Development of the SimulationDB system requires not only adapting the existing practices and procedures, but also establishing new methods of mathematical description of the technological process, as well as proprietary procedures for merging and using technological know-how from various sources.

Nowadays, it is very difficult to provide a sufficient number of properly qualified staff for the needs of the industry. The knowledge and experience of employees is the greatest value in any business, and it can significantly contribute to the rapid development of technology. An experienced engineer can establish and predict where the defect may occur. A smart IT system, by using a special module for design analysis and technology optimisation, will easily help one gain the necessary experience and broaden the knowledge of metallurgical processes occurring during mould filling and solidification. An IT tool considerably reduces the time needed to gain relevant experience and strengthens the knowledge of the engineer. The system can also be applied as a basic tool for training of doctoral metallurgy and foundry students.

The current state of the art in terms of technological knowledge management, including simulation results, is as follows. Some of the major foundries have SAP systems implemented to help them manage the entire company. However, on the market there is no foundry-dedicated module or system designed for managing all the stages of the casting production preparation process, including technology development with the use of simulation programs. To date, the results of simulations are stored in catalogs.

Developing and implementation of a modern IT system, for cataloguing archival simulation results of monitoring and quality assurance of casting processes, is a project that should lead to improving the quality of cast machine and equipment parts, while reducing the time needed to optimise the manufacturing processes.

Another very important element is the duration of the simulation. For such a large cast, performing calculations for just a single simulation on a dedicated workstation lasted 238 hours. On a 32-processor cluster, the same calculations were shortened to 91 hours.

Using again the knowledge stored in the SimulationDB system, by analyzing the selected projects via advanced search criteria and following the procedures included in the patent applications, we can reduce the number of performed simulations by at least 14%.

By eliminating only one simulation we gain additional 9.94 days for a workstation and additional 3.83 days for a 32-processor cluster.

The interdisciplinary character of casting technology requires the use of modern IT tools for their design, optimisation and increase in productivity while maintaining the high quality of castings. Foundries use expensive simulation software more often nowadays in order to reduce production cost. The very large amount of information generated by simulation programs causes a problem of data storage, easy search for projects meeting the criteria specified by the engineer and the management of a growing number of projects.

With the technologies developed, knowledge bases and projects stored in a database, the time required to develop the proper technology may be reduced. Using SimulationDB, the engineer builds a knowledge base that will consist of the results of developed simulations, a complete description of technological procedures and recommendations for the optimisation of technologies. Easy access to the database will allow engineers to rapidly respond to disturbances in manufacturing processes and will allow for a significant improvement in the quality of castings.

Creating databases for science and industry is a step towards the computerisation of enterprises and optimisation of business procedures and processes, which greatly reduces the cost of production and accelerates the development of appropriate technologies, which, in turn, increases the competitiveness of enterprises in the country and internationally.

The main concept behind the SimulationDB system concentrates around archiving technological knowledge in the form of: descriptions of technological procedures, CAD files, simulation results or technologists' guidelines. An innovative approach is saving the script along with the CAD files, which allows for reproducing a complete simulation. This way of storing information saves approximately 40-70% of disk space compared to how much is needed to store the original simulation results. In addition to saved disk space, a lower number of performed simulations, faster and easier database searching, and a platform for training young, inexperienced technologists, the system also offers several very useful modules.

The CastingDefectsDB module is an electronic catalog of casting defects. It includes simulation results, specific causes of each defect, and technologist's recommendations as to how they can be eliminated.

The ProductionDB module is a module designed for storing and analyzing all the production parameters. QualityControlDB is a quality control module. Quality control is one of the most crucial stages of the production process in a foundry. It determines whether a cast will be classified for sale or whether it will be classified as being useless.

AnalysisDB is a module designed for an advanced analysis carried out through automated, computerized examination of images of compared results for different versions of the simulation, which is performed on the client side.

Another module is CaseStudiesDB which integrates all the previous modules into one unit. It is also a training platform based on technologies developed in a particular foundry. In the times of a significant deficit of qualified staff, it is a very useful tool for carrying out trainings covering each stage of the production process.

The last module is ReportsDB which is used to print some or all of the information from any stage of the process.

Efficient circulation of documentation within a company provides higher productivity, reduces workload, and improves communication between different departments.

The uniqueness of this solution lies in a new way of developing technology with the use of knowledge stored in the database system. The technological knowledge base SimulationDB is an innovative, interdisciplinary information system, whose aim is to shorten the technology preparation process, control the production process in an optimal way, as well as monitor and ensure the quality of casting production processes. The system stores a wide range of information, including specific customer requirements regarding the finished casting, developed technologies verified through virtual simulation models, and actual data from the manufacturing process. The complexity of metallurgical processes requires the use of modern, computationally-advanced IT tools that can handle calculating, optimizing, storing and analyzing technological data. Specialized simulation software and high-performance computing machines (workstations, clusters) allow for predicting and forecasting physical phenomena and processes that take place in solidifying castings based on the input parameters (initial/boundary conditions).

Interdisciplinarity of casting technologies requires the use of modern tools for designing and optimizing them. In the modern industry, customer satisfaction is treated as an indicator of the efficiency of production processes. The basic requirement of the customers is providing the quality of products. This trend is visible also among producers of parts of machinery and equipment, including those manufactured with casting techniques. Unfortunately, casting processes – due to their complexity – require performing dozens or sometimes even hundreds of simulations of metallurgical processes as part of a single project.

Nowadays it is very difficult to provide a number of qualified specialists that would be high enough to meet the industry's needs. The knowledge and experience of employees is the biggest value at every company, and it can make a significant contribution to the rapid development of a technology. An experienced technologist can identify and predict at which point of the process a defect can occur. The intelligent IT system, thanks to its special module for analyzing projects and optimizing technologies, can help employees gain the necessary experience and expand their knowledge in the field of metallurgical processes taking place during pouring and solidification of castings. The technological knowledge base SimulationDB significantly reduces the amount of time needed by a technologist to acquire relevant experience and consolidate his/her knowledge. The system can also be used as a basic tool for educating students and doctoral students of metallurgical courses, including the ones studying Foundry Engineering.

These are some of the advantages of the SimulationDB system: access to simulation results at any time, without the help of qualified workers; archiving complete technologies while maintaining identical structures of the projects; easy searching for specific projects through the use of special search criteria; comparing various versions of the simulations, and comparing simulations with actual processes that take place

in a foundry; it allows young technologists, who have just graduated and do not have practical skills yet, to acquire the necessary knowledge and experience very quickly; effective management of an unlimited number of projects; generating reports in electronic and paper form; viewing statistics allowing for analyzing the entire process of the casting production preparation; monitoring and ensuring the quality of castings; optimal control of the production process; building a technological knowledge base.

The project of the innovative technological knowledge base SimulationDB has a very significant application potential, as confirmed by the market's strong interest in the system.

The new approach toward technology development generates the following benefits: shorter technology preparation process, lower use of human resources, and lower use of expensive hardware with specialized software for simulating casting processes.

The feedback obtained from technologists indicates that 32% of the time spent on the technology preparation process can be saved this way, which directly translates into lower costs of the foundry and its improved competitiveness on the international market.

There are currently no similar solutions on the market offering such an impressive complexity – therefore, the concept behind the technological knowledge base SimulationDB is a niche technology with a significant commercial potential.

The simulation consisted in preparing the required range of materials for the analysis by an independent, experienced employee who was not involved in the project. This process allowed the lead technologist to focus solely on the analysis of documents, without having to search for them. Under the current rules, the lead technologist was able to develop 31 technologies in a 250-day working year ( $250:8 = 31.25$ , as-

suming that only reproducible technologies were developed, and that the process was always simulated three times).

When using the modified SimulationDB solution, and under the same boundary conditions, the technologist is able to develop 41 technologies ( $250:6 = 41.66$ ). This way we obtain a 32% ( $41:31 = 1.32$ ) increase in the productivity of a group of technologists. As a result, production of many additional products can be launched. Another benefit is the better utilization of the installed fixed assets, which results in lowering the unit cost of power technology development.

This only affects time and cost aspects of the production preparation area, however, one should also take into account the lower risk of passing over some critical data. Such a risk is difficult to evaluate, and the element of human error should always be taken into consideration.

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