AUSTEMPERED DUCTILE IRON KNOWLEDGE COMPONENTS MANAGEMENT VIA ONTOLOGICAL MODEL AND BUSINESS PROCESSES

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Abstract

Presented paper concerns a methodology of knowledge components management in a platform of knowledge integration using an ontological model of knowledge sources. Presented paper concerns a methodology of knowledge components management in a platform of knowledge integration using an ontological model of knowledge sources. System uses a web application that supports an integrated database from the Foundry Research Institute in Cracow and includes components of the latest publications, research projects and patents in the field of casting, forging and rolling, and the database of foundries and suppliers to the foundries. An additional advantage of this study was to develop an ontology based on the database for the application to build a knowledge base on the basis of the information gathered. To obtain Austempered Ductile Iron of specific mechanical properties, a number of parameters must be set. It is difficult to aggregate all needed information, without any decision support system, because adequate knowledge is mostly dispersed and unstructured. In the paper, we describe an architecture of the system that uses semantic technologies and business processes for management of knowledge about producing ADI. We present an architecture for a prototype environment and argue that using these technologies for management of diversified knowledge can benefit in several ways. Main advantages of using BPM tools are possibility of tracking the flow of the production process, as well as support for control of completeness of information. Semantic description of case studies and a domain ontology allow to pose semantic queries and reason over knowledge stored in the system.

Keywords: Application of Information Technology to the Foundry Industry, Austempered Ductile Iron (ADI), Business Process Management Systems (BPMS), Semantic Wikis

1. INTRODUCTION

ADI cast iron is a heat treated ductile iron which proves many positive properties, such as near-net shape technology, high strength, good wear resistance, or low cost manufacturability. In order to obtain demanded mechanical properties, one of important issues that should be solved is the choice of chemical composition and appropriate heat treatment parameters. There are different ways to obtain ADI castings with the same properties by combination of chemical composition or/and heat treatment parameters (temperature and time of austenitization and austempering). However, this knowledge is dispersed and it is difficult to find all information needed. The problem occurs mostly when a new non-typical product is under development. The aim of the project LIDER/028/593/L-4/12/NCBR/2013 is to develop a decision-support system for technologists that will aggregate information about ADI production and using appropriate Knowledge Representation mechanism be able to reason over it. In this paper, we propose a semantic wiki-based system that integrates semantic technologies and business processes for management of knowledge about ADI.

While capturing both declarative and procedural knowledge, the system remains easy to use, supports collaboration and intuitive knowledge authoring.

The paper is organized as follows: in Section 2: Problem Statement, we explain the motivation for this research based on identified challenges and commonly used technologies in the area of ADI production. Then, in

Section 3: Proposed Solution, we outline the architecture, knowledge representation possibilities and main features of the system. We summarizes the hitherto results and outline future work in Section 4: Conclusion.

2. PROBLEM STATEMENT

Information about Austempered Ductile Iron (ADI) is dispersed among various sources. In order to obtain ADI, it is necessary to start with appropriate sort of iron alloy, then conduct a 2-staged process consisting of austenisation and austempering. The parameters of the process and its stages, such as temperature and time of particular stages, influence the properties of the resulting ADI. The properties include fatigue strength, yield strength, hardness, enlongation, ductility and toughness. Depending on their values, ADI will or will not be useful for particular purposes, for instance to produce gears, wheels, engine cylinder line (automotive parts) or agricultural tools operating in soil.

When technologists want to obtain specific properties, they have to decide on several parameters and design an appropriate process. In order to gather required information, it is often necessary to search for papers describing specific experiments, browse patent databases, and various unstructured sources. Combining information from different sources is tedious and error-prone.

Patent descriptions are structured differently and they do not always contain the same bunch of information, thus so it is hard to browse and search for particular pieces of information in patent databases. Thus, various research centers develop their own databases with experiments' parameters. Such databases are often created using Excel spreadsheets or developed as dedicated relational database management systems with suitable CRUD (Create, Read, Update and Delete) interfaces.

The idea presented in this paper relies on using semantic technologies, integrated with business processes. A cornerstone of the conceptual model is an ontology describing the production process and properties of ADI. The goal of the ontology is to integrate information about consecutive stages of production, and capture dependencies between the production process and the resulting properties. It should also constitute a backbone, a vocabulary for rules and processes (all the concepts appearing in the processes and rules should be present in the ontology). On the implementation side, we use a semantic wiki Loki that integrates several knowledge representation methods and is easy to use even for non-specialists.

The main challenges related to knowledge management systems for ADI are the following ones:

- integration of information from various sources;
- diverse, semi-structured and semi-formal knowledge representation;
- semantization of the knowledge stored in the knowledge base;
- supporting execution of experiments with suggestions of parameters (based on previous experiments);
- inferencing new knowledge from data stored in the system;
- facilitating knowledge authoring, sharing and discussing.

Although the currently existing solutions provide the basic search functions, they lack of a possibility to pose more advanced queries, or ask for information that is not explicitly present, but could be easily inferred. Moreover, they do not support reproducing the previously described experiments or performing a new experiment on the basis of the existing ones. There is also no possibility to track the execution of an experiment (i.e., consecutive stages of the production process) using the computer systems. Finally, they do not provide intuitive user interfaces nor support any sort of collaboration among users (domain experts).

To address the presented challenges, based on previous works [1] and [2], in the following section we propose a novel solution that uses semantic technologies and BPM system for management of knowledge about producing ADI.

3. PROPOSED SOLUTION

We propose a system that will support technologist in developing ADI of desired properties. A conceptual model of the system depicting how the system can be used is presented in **Fig. 1**.

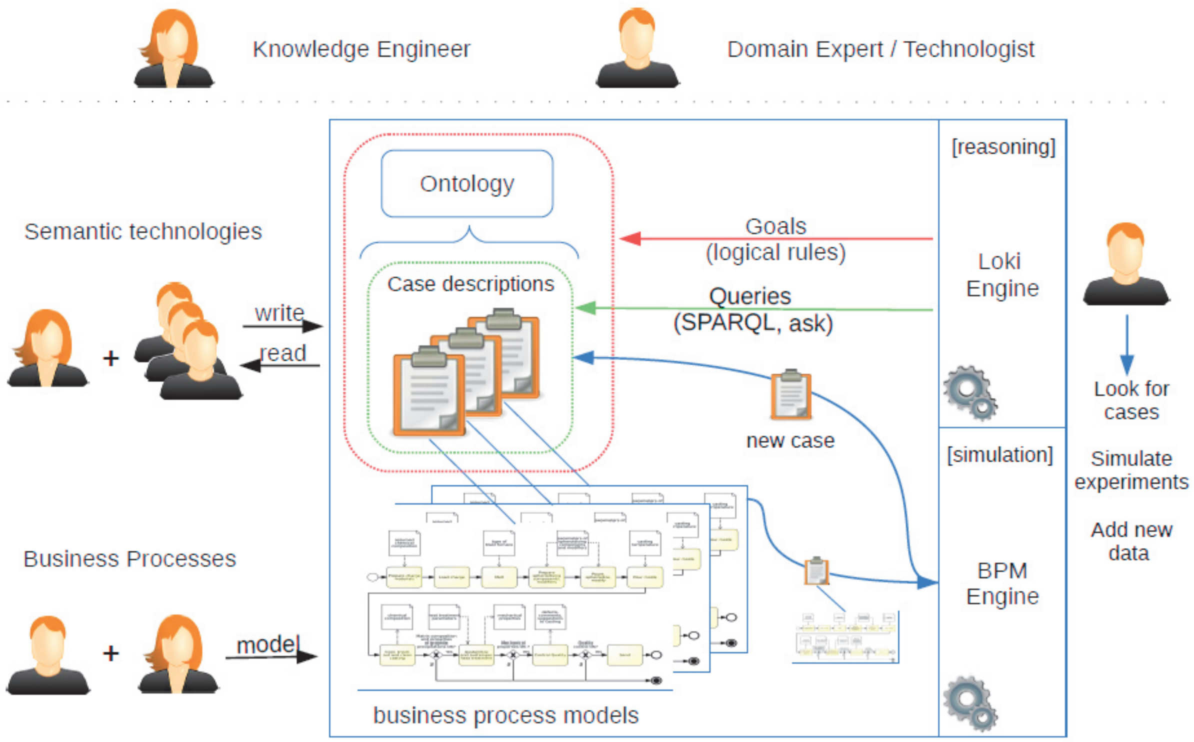

Fig. 1 Conceptual model of the system

The main idea is to build a semantic encyclopedia about ADI casting that consists of semantic descriptions of conducted experiments. A community of domain experts, after an initial training, can fill in the information based on their experiments. They can browse and query the knowledge stored in the system with semantic queries in SPARQL, as well as use logical rules (goals). They can also simulate selected processes that accompany cases' descriptions and create new processes based on existing ones.

3.1. Knowledge representation

The system integrates semantic technologies and business processes for representation of diversed knowledge.

- Declarative knowledge about experiments is stored in semantically-annotated wiki pages.
- Semantic annotation (classification, relations between objects and attributes) add structured information to the descriptions of cases and enable automatic querying and reasoning.
- Attributes of cases (represented as single pages) include: chemical composition of the initial alloy, parameters such as temperatures of austenization or austempering, and mechanical properties of the obtained iron such as hardness, elongation and micro-structure.

Business Process Management Systems (BPMS) [3] support management of business processes, which are modeled as a collection of related activities transforming different kinds of inputs to produce some products or services as output. In our approach we consider a process that describes a workflow of producing an ADI.

For every experiment data stored in our system, there is a related process model. Such models are similar and many experiments may even share the same model. An exemplary process model is shown in **Fig. 2**.

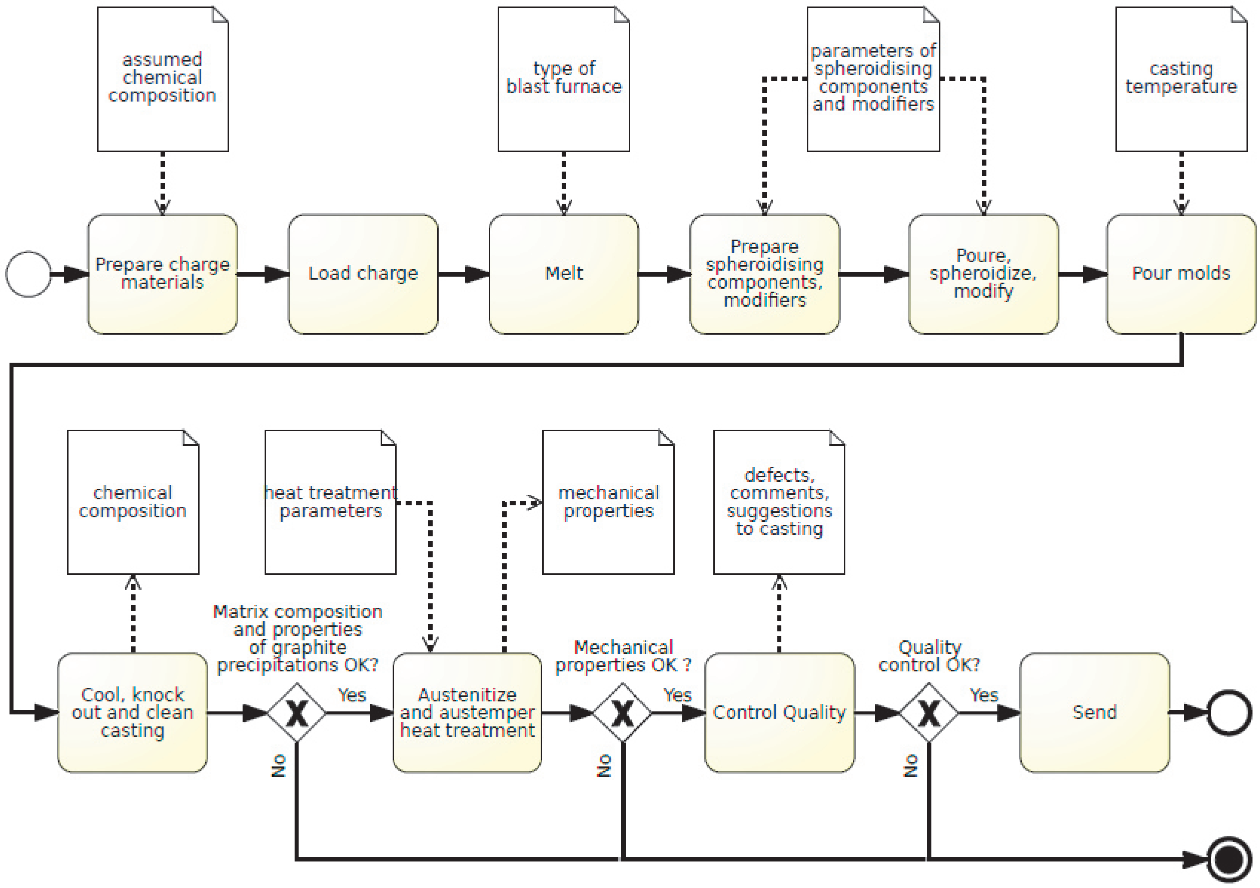

Fig. 2 ADI process model

3.2. Functionality

If users want to obtain certain properties, they pose a semantic query to the system (e.g., find me an experiment in which given hardness and enlongation was obtained and a specific sort of furnace). Then, the found case may be simulated by executing an associated process with a process engine. One may want to replicate the experiment or start it with different parameters. Upon execution, a new instance is created that may be save and in this way enhanced the knowledge base of the system.

A user of a BPM system can trace every process instances, i.e. ADI experiments, registered in the system. This allows to check in which phase a specific experiment is, as well as the supervisors of the experiment can assign workers to each phase of the experiment. Moreover, the BPM system requires from a scientist to enter certain pieces of information in each phase, so this ensures the completeness of storing results.

It is also possible to change the process. As under certain conditions, loading and melting of the charge can be carried out in parallel, this can be easily introduced in the BPM system, as it requires only to remodel the process using a parallel workflow pattern. Similar operation can be done for “Prepare spheroidising components and modifiers” with “Prepare charge materials”. In some cases one can skip some steps of checking the quality, especially if the smelting process is stable, repeatable or an operator has the appropriate experience.

3.3. Prototype implementation

A prototype implementation of the system uses Loki [4] semantic wiki that supports semantic annotations and logical reasoning [5, 6]. Thanks to plugin mechanism, it is under continuous development, and new plugins appear. It is also extended by a plugin for modeling Business Processes [http://loki.ia.agh.edu.pl/].

Wiki mechanism supplies an engine providing possibility of semantic knowledge integration [7]. We assume that knowledge that forms the basis of knowledge base would be largely algorithmically derived from resources using data mining methods and artificial intelligence algorithms, what is possible and has already been described in the publications [8-13].

An ontology that captures the dependencies between parameters and properties of the obtained iron is under development (see **Fig. 3**). It will serve as a common vocabulary for semantic descriptions and business process models, as well as improve the reasoning possibilities. Currently, ontological reasoning is simulated by the Loki engine.

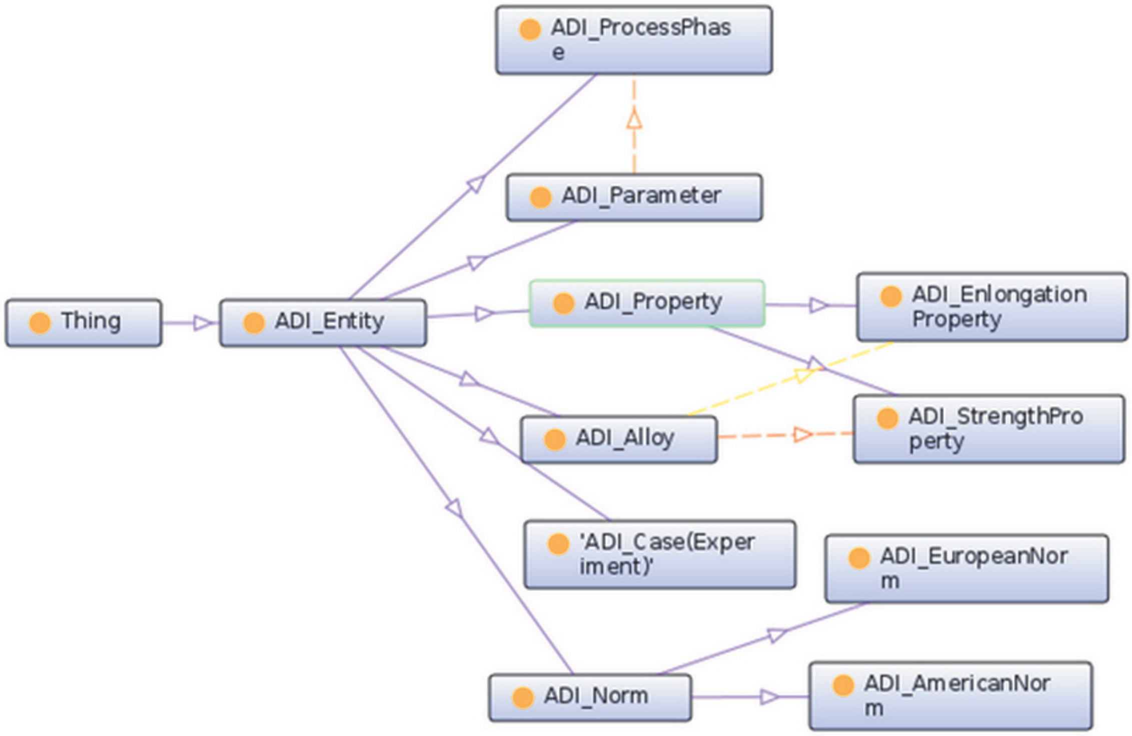

Fig. 3. ADI ontology fragment

4. CONCLUSION

The goal of this paper is to present an innovative approach to knowledge management in iron casting. After reviewing existing challenges in this area and explaining why current techniques are not sufficient, we present a novel idea of a semantic wiki-based system for ADI knowledge management. The technologically demanding process of the ADI had been described, but we refer interested readers to [14-15]. Our solution takes advantage of semantic and business process technologies. While capturing both declarative knowledge (about chemical composition, required temperatures, etc.) and procedural knowledge (iron casting process), the system remains easy to use and supports collaboration and intuitive knowledge authoring. It also supports tracking the flow of the production process and execution of a new experiment based on parameters from the existing data of a previous experiment. An ontology capturing dependencies between parameters and iron properties is under development.

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