On Developing an Expert System for Sintering Process in Iron and Steel Industry

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Abstract

An expert system for the sintering process in the Iron and Steel Company in Egypt is under development. The objective of this paper is to introduce the prototype implementation project of this system. The paper focuses on the nature of the sintering knowledge, the proposed knowledge structuring and the knowledge representation formalism. It also discusses the various prototype levels of implementation and illustrates the practical development of the structural and diagnosis levels of the expert system prototype.

I Introduction

Most of the world's iron is produced by the blast furnace process. It is therefore important that the blast furnace should operate efficiently and this will only occur if a large proportion of the feed to furnace has been properly agglomerated. Sintering is the main agglomeration process in which raw ore and flux are combined together to form the blast furnace burden. The quality of the produced agglomerated material is function of its strength, reducibility, chemical composition, etc. This quality is controlled by high number of factors and parameters such as ballet diameter of the raw material, the weight and size of coke particles, the permeability of the raw mix, the humidity of the mix, the temperature and concentration of gas, and others. It is the responsibility of the expert engineers to supervise and control the values of these factors and parameters based on the nature and characteristics of the raw materials and the quantity of returned slack as well as the previously imperfect agglomerated material. The purpose of the expert system we are developing is to capture, formalize and save the sintering knowledge distributed among expert engineers who are responsible for the different stages of the sintering process.

1. To capture, formalize and save the sintering knowledge distributed among expert engineers who are responsible for the different stages of the sintering process.
2. To help working staff and operators in producing high quality agglomerated material, by advising on the appropriate values of parameters setting. These values are not fixed, but should be determined in accordance with laboratories test characteristics of the materials.
3. To supervise the censored parameters currently collected on real time basis by more than two hundred and fifty control loops (sensing devices). In continuously supervising these parameters, the expert system is expected to detect any abnormalities and report to the operators on the corresponding diagnosis and the corresponding actions to be undertaken at the right times.

Another objective that may be considered later, is to reduce the cost of producing the sintered material by reducing the quantity of the coke component (which is imported from outside Egypt) in such a way that neither the quantity nor the quality of the produced sintered material is down scaled.

The next sections describe this methodology together with the prototyping phases and then introduce the first prototype model that we have already developed.

2 General features of sintering process

The main phases of the sintering process are:
- Ore preparation process.
- Dosing preparation process.
- Sintering process.

2.1 The Ore Preparation Process

The aim of this process is to receive the raw materials drawn from the stock yard, screen them, crush them into suitable size and add water to obtain a required humidity ratio. The following main raw materials are used:
- Iron ore.
- Limestone.
- Coke.
- Dolomite.

2.2 The dosing process

This process is responsible for the proper mix of the different raw materials. The requested amount of blast furnace burden and the raw material characteristics are the major factors determining the quantities of raw materials to
be mixed together. Sinter return is recycled to be used as an input to the mixing process.

2.3 The sintering process

It is mainly a heat process in which the mixed raw materials are transformed into sintered material with desired and mandatory chemical and physical characteristics. In this process the ore mix is loaded onto a moving grate where it is leveled to form a uniform bed. The coke particles near the surface of the bed are ignited and as the material is conveyed along the strand a heat wave progresses downwards as air is sucked into the surface of the bed and exhausted through wind boxes situated below the strand.

During the process the volatiles are driven off, the hot material fuses at approximately 1400°C and as air is drawn in behind the fusion zone, the material cools to form a friable cake of sinter which is unloaded from the strand and is broken down into small pieces from which fine material is extracted by sieving before it is passed forward for use as blast furnace burden. The block diagram corresponding to this process is shown in figure (1).

3 The Prototyping methodology and knowledge structuring

3.1 Boosting the project

We started the project by a series of meetings with the top management staff of Iron and Steel company. These preliminary meetings aimed at building mutual interests, reviewing the company major problems, establishing the project steering committee, deciding upon which sector of the company to start the project with, reviewing the existing computerized systems in this sector and setting the short and long term objectives of the expert system project.

Following these meetings, an organized course consisting of about ten lectures about the Iron and Steel Company organization, lines of productions, and the nature of sintering process had been conducted by the expert engineers of the sintering department.

In order to establish a common language among all the people involved in the project, several introductory lectures in expert system technology and its application to industry and process control had been conducted to the expert engineers of the sintering department. In parallel to these lectures, we have reviewed many edited materials (books, papers) on the sintering process.

3.2 Nature of sintering knowledge

Right after building the necessary background on this project we started the phase of knowledge acquisition[3]. There exists various knowledge acquisition methodologies such as protocol analysis, reportory grid method, visual modeling and induction[9]. The adopted knowledge acquisition methodology has been based on interviewing experts. The major drawbacks of this method are the difficulty to acquire relevant and correct information and the lack of the overall structure. To compensate for these drawbacks, we have complemented the interviewing process with visual modeling technique. This technique allowed us to communicate with experts through figures, curves and diagrams. We started by interviewing the experts about a certain subprocess, we came out with block diagrams and structures describing this subprocess. Based on this exercise, we asked the experts to prepare the diagrams and structures of the other subprocesses. This cycle has been repeated until all the knowledge details of the sintering process are acquired and structured. The type of knowledge related to the sintering process covers the following areas:

- Stages (physical/logical) of the sintering process.
- Quantities, physical properties, and chemical characteristics of materials involved in each stage.
- Machines types, working conditions and their principles of operation.
- Control loops existing all over the sintering stages, their functions, and the ranges of their values. Possible control malfunctions and their impact on the proper operation of the machines.
- Knowledge about the proper functionality of each phase of the sintering process. This knowledge covers:
  - Possible deviations (above, below) the planned quantities of materials in different stages and the possible causes of these deviations.
  - Possible deviations (above, below) the planned values of material basic attributes (e.g. humidity, porosity, permeability) and possible causes of these deviations.
  - Possible malfunctions of the machines (e.g. overheating, loud noises, stopping) and the reasons for that.
- Knowledge about production quantities, for example, how much of each raw material should be involved in order to produce a requested quantity of blast furnace burden taking into consideration that a returned quantity of bad sintered material is imposed.
- Knowledge about production quality, which means that how to measure production quality of each stage separately, and then how to measure the end product quality given that the quality of the previous production stages have been determined.

3.3 Sintering knowledge structuring

The sintering knowledge, as we have identified, varies in its nature as [4]:

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4 Prototype levels of implementation

Regarding the main objectives outlined earlier in the introduction, we decided to implement the prototype in successive phases[5]. Next, we summarize these phases and give the main features of each one:

- Structural and definitional level.
- Symptoms, diagnosis and action level.
- Quality and costing level.
- Real time operations level.

The first two levels have been implemented and are now under revision by the iron and steel expert engineers.

4.1 Structural and definitional level

In the structural and definitional prototype level, the expert system is capable of providing to its users (junior engineers at the sintering department) the full details of the sintering process from the following points of view:

- The definition of the sintering process.
- The phases of sintering and the definition of each phase including the physical and logical description of the process.
- The materials used in each process, their quantities (nominal values and estimation methodology), and their physical and chemical characteristics.
- A comprehensive dictionary (glossary) of each term, attribute, process, machine, and component that appear anywhere in the total sintering process.

4.2 Symptoms, diagnosis and action level

This level aims at providing the users with the type of problems that they may encounter during daily operations. These problems are classified according to the process in which they may appear. The types of problems and the symptoms indicating them range over physical problems as well as quality problems. The relationship between types of possible problems and corresponding observations are expressed in froms of “If-Then” rules[6].

This level also provides users an accurate procedural steps taken to overcome potential problems. These actions may be immediate, for example, increase the opening of a water valve, or may be in the form of recommendations to be considered in the successive operations shift. The relationship between diagnosis and corresponding actions are represented in the form of “If-Then” rules[6].

4.3 Quality and costing level

This level will provide an estimated value of the product quality as sintering process progresses from one phase to another. These estimated values will be accompanied with justification reasons. These reasons are to be considered in next operation shifts. In this level also users will be provided by possible material mix ratios that may pserve the product quality and at the same time keep the coke percentage as low as possible in order to lower the cost of the produced sintered material.

4.4 Real time operations level

In this last level, the integration of the expert system with the running sintering process will be done[7]. A preliminary investigations of building an appropriate interface between the real process and the expert system are underway. This level, once completed, will be the first of it’s kind to be implemented in our region.

5 Conclusions

The development of an expert system for sintering process in iron and steel industry provides a suitable tool to capture, formalize and save the sintering knowledge. It also helps the staff to achieve a higher rate of working performance. The sintering knowledge is complex in nature and varies between descriptive, procedural and declarative ones. A knowledge acquisition structure has been proposed to implement the expert system in four levels. The two levels expressing the structure and diagnosis of the sintering process have been already developed. Other levels for quality assessment and real time operations are under development.
### Process Frame

<table>
<thead>
<tr>
<th>Process code:</th>
<th>Global parameters:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant code which relates a process to its parent process, e.g. process 3.1 indicates that it is the first process in the main process number 3.</td>
<td>They are similar to local parameters, but they are also seen by other surrounding processes. This classification is important when symptoms are analysed in order to determine the source of malfunctions.</td>
</tr>
<tr>
<td>Process name:</td>
<td>logical process description:</td>
</tr>
<tr>
<td>Significant name given to the described process.</td>
<td>This is a process description in a more formal way. It is given in form of successive related steps. This description will help us in providing the correct action to be taken when some problems occur.</td>
</tr>
<tr>
<td>Process objective:</td>
<td>Symptoms (observations):</td>
</tr>
<tr>
<td>The objective of the current process.</td>
<td>These are the possible signs of unusual operations taken from expert engineers' viewpoint. They also cover the cases of improper parameters and attribute values.</td>
</tr>
<tr>
<td>Input to the process:</td>
<td>Diagnosis Rules:</td>
</tr>
<tr>
<td>A List of input materials fed to the process together with the name of processes producing them.</td>
<td>These rules relate the observations to the type of problems that we may encounter during daily operations.</td>
</tr>
<tr>
<td>Output from the process:</td>
<td>Action Rules:</td>
</tr>
<tr>
<td>The name of output materials from this process. A single process may produce more than one output. An output may have different characteristics, e.g. materials with different physical sizes.</td>
<td>These rules relate the problems to the corresponding actions to be reported or to be taken by the supervising operators.</td>
</tr>
<tr>
<td>Physical process description:</td>
<td>Process Quality Rules:</td>
</tr>
<tr>
<td>This is a description of the current process as dictated by the expert engineer. It includes a block diagram and a physical diagram of the process.</td>
<td>These are quality estimation rules that are related to the values of the measured and observed parameters of the current process.</td>
</tr>
<tr>
<td>Local parameters:</td>
<td></td>
</tr>
<tr>
<td>These are the parameters uniquely seen by the process itself. These parameters cover materials, quantities, and attributes together with their minimum and maximum allowable values.</td>
<td></td>
</tr>
</tbody>
</table>

**Figure (2). Process Frame**

**Figure (3). Frame Description**

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Acknowledgement

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References