KNOWLEDGE MANAGEMENT IN MANUFACTURING TECHNOLOGY

An A.I. application in the industry

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Abstract: Traditional manufacturing plants rely on an engineering department, which acts as an interface between the R&D experts, and the shop floor managers to ensure that the best engineering solutions are available for problems encountered in the shop floor. This paper focuses on enhancing the effectiveness of the engineering department by the use of knowledge management and information technology. This paper discusses the processes introduced to facilitate knowledge management. This paper also discusses the use of one discipline of artificial intelligence, case based reasoning, in providing an information technology solution where domain knowledge is weak and tends to be lost when experts leave the plant.

1 INTRODUCTION

Glass manufacturing plants use refractory blocks as lining walls for the glass-melting furnace tanks. Glass is melted in these tanks at very high temperatures of 1500 to 1600 ^{o} C. Glass manufacturing is a continuous process and these tanks have a life of 4 to 8 years mainly because these blocks have a life of 4 to 8 years. If the blocks fail then the tank can leak out the molten glass, which is a safety hazard. Any shut down for cold repairs when these blocks fail will last 6 to 12 weeks because the molten glass has to be drained, furnace has to be cooled and solid glass sticking to the lining blocks has to be broken before any repair can be undertaken. After the repair, there is a graded heating process, which takes about a fortnight so that thermal stresses do not crack the blocks. So it is important that the blocks are manufactured to a very high standard of quality.

The quality of the block is determined by both physical and chemical properties. Cracks are indicative of physical defects. Cracks are of many types. The severity of the defects depends on the type of crack. Some of the chemical qualities required are resistance to corrosion, reduction in exudation and seeding. Exudation and seeding lead to defects in the glass. Cracks lead to faster corrosion and lesser life of the glass tanks. Moreover, a defective block cannot be reused, it has to be crushed and recycled. These blocks take 4 to 6 weeks to be manufactured. If there is a rejection then making the block again and making a customer to wait for his block will lead to holding up the commissioning of the entire plant.

1.1 Role of Engineering Department

The engineering department has the difficult task of making sure that the rejections in the plant are low and the customer complaints due to quality problems are minimal.

2 PROBLEM

2.1 Quality and Safety

Glass manufacturing is very old, but improvements in materials and technology have kept it young, modern and scientific. It is sophisticated enough to require professional glass tank designers who give the design of the glass melting tank and the associated requirements viz., fuel, structures, end machines, etc. A balance is to be maintained among all the components of the glass-manufacturing unit. The refractory lining blocks is a key component because it is in contact with the molten glass. The influence on the quality of glass and the safety of the personnel are directly dependant on the quality of the refractory blocks.

2.2 Quality, Business and Knowledge

This paper reports the work done on this topic in one of the refractory blocks' manufacturing plant Presently, the plant has secured ISO 9002 certification and also installed an E.R.P. software. While ISO 9002 has addressed some quality related processes, and E.R.P. has addressed business related processes the knowledge processes (Steffen Staab, 2001) have not been addressed. Briefly, "the knowledge processes essentially revolve around the following steps *knowledge creation or import, knowledge capture, knowledge retrieval and access, and knowledge use which will not only recall knowledge items but will process them for further use"*.

2.3 Hidden Knowledge

The knowledge of the refractory blocks manufacturing process is contained in a document called design handbook. But this knowledge is not complete. Knowledge also resides with the experts who have been working in the plant for many years and also to those to whom they handed down the knowledge through notes and informal interactions. The fact that the knowledge contained in the design handbook is not complete is evident by the nature of changes effected in it. ISO 9002 has played a significant role in highlighting the nature of these changes by introducing a process for recording the changes done to the design handbook. However this is not effective because it is not easily accessible because of lack of proper organization. This paper brings out the need for knowledge processes and the solution to the problem of lack of knowledge process.

3 DOCUMENTS AND KNOWLEDGE IN THE PLANT

A description of the manufacturing process along with brief details of the documents generated in each stage of manufacture is given below. Figure 1 shows the manufacturing flow chart.

3.1 Design

The glass manufacturer gives his requirement of the refractory blocks to the plant. This is accompanied by a drawing. This is often a design drawing from a CAD package. The engineering department evaluates the requirement based on the design handbook and puts out a CAD drawing with a drawing control number. The drawing contains all the manufacturing instructions as well. This

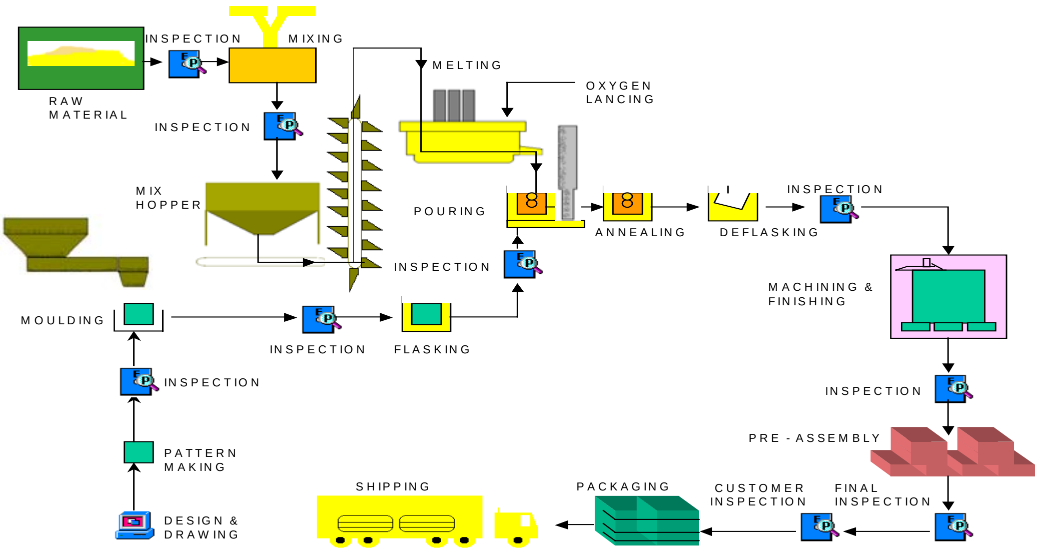

Figure 1: Manufacturing flow chart

document is a reference document. This document is given to different departments in the shop floor so that each department will be ready to carry out its activity in the manufacturing cycle.

3.2 Manufacture

After the design drawing, the manufacturing activity branches off to two different departments. One branch is the Mixing Department, where the raw materials are crushed and mixed in the right proportions. The mixture is ready for feeding to the Arc Furnace. The document generated at this stage is called the mix ticket. This has details of the composition in a codified form and a mix ticket control number. The other branch is the Mould shop. Here the patterns are made and moulds are made from the patterns. Each drawing can have one or more moulds prepared. Hence the relationship of the drawing control number to mould control number is one-to-one or one-to-many. The document generated here is a mould shop data form with a mould control number. It was at this stage of manufacture that some key attributes, which determine the quality of the blocks, were not being captured. The moulds are placed in bins, which are packed with heat retaining materials. This stage is called Flasking. The document generated here is Flasking ticket. This has details of the bins and the moulds relationship and has a flasking ticket number. Each bin has a bin control number. The relationship between the mould control numbers to bin control number is one-to-one or many-to-one. Here again at the stage of manufacture also some key attributes, which determine the quality of the blocks, were not being captured. The next stage in manufacturing converges both the branches in the Furnace department. The raw materials coming from the mix department is fed to the arc furnace, melted and poured into the moulds. The document generated here is the Furnace log, which captures all the parameters of the furnace and the control numbers of all the previous stages of manufacture. At this time the Q.C. department takes samples and sample blocks are made and tested for all the chemical properties, viz. composition, corrosion, exudation and seeding. The document generated here is the test report. The control number is the mix ticket number. The next stage is annealing and deflasking. The document generated here is deflasking ticket. This has a deflasking ticket but did not capture a vital data for establishing traceability between the block and the mould. The next stage is the pre-finishing inspection stage. The document generated here is the Q.C.(Quality Control) report. If the block is defective, it is rejected at this stage otherwise it is passed on to the next stages of finishing. The control number generated here is the traceability number of the block. The block can get rejected in any stage of finishing operations. This will be captured in the Q.C.report. After the block comes through the finishing stages, the final Q.C. inspection takes place. The data captured at this stage on the quality of the blocks were not informative enough on the type of defects or its severity. The knowledge process introduced here resulted in domain ontology definitions and procedures to capture data defined by the ontology (Allen Preece, 2001).

At this stage, the blocks are assembled in a fashion similar to the assembly in the glass-melting furnace tanks. The documentation in this stage is called a “red mark drawing”. The significance of the red mark drawing is that the position of the blocks in the glass-melting tank is marked and linked to the traceability number. This is significant data because it allows the tracing of the performance of the block right into the glass tank.

3.3 Engineering

The experts in the plant find solutions for the problems of rejections in the plant. It is done quite formally. They meet over a defective block, examine it and suggest changes to the process based on their knowledge and experience. This is recorded in a document called (CAR) Corrective Action Record. When further blocks are made according to the suggestions of the CAR and found successful, then the design handbook is modified, otherwise more suggestions are tried out to solve the problem. All these are recorded in the CAR.

Trials are conducted in the plant quite regularly to improve the quality or improve the process to reduce costs. Some customers may have a special requirement. Trials may be done before accepting the order. The process followed is the same as above until the final inspection. However, there will be no assembly red mark diagram stage.

4 REQUIREMENTS

4.1 Domain Ontology

At present, the design drawing document as mentioned earlier is a CAD drawing with instructions for manufacture. Corrective action records refer to their design-drawing document while mentioning the problem and solution. But the details of the drawing are lying elsewhere so that it will be an effort to refer to it. It has been observed that the experts do not refer to the earlier instances of similar problems or even earlier trials conducted. Similarly, the corrective action records could also refer to the documents generated in each stage of manufacture. These documents are lying in different places, and deter the people from reaching for them and getting the benefit of the knowledge.

As mentioned earlier some of the critical data required for tracking quality-related problems are not being captured. Also, the problems reported and solved in the corrective action records are not written in a clear and unambiguous manner. Both these gaps are present because there is no ontology defined for the domain.

These two requirements can be met by defining ontology for the domain and defining data pertaining to the knowledge of problems and solutions, and by capturing this data in a database.

4.2 Knowledge Management

However, our requirement goes beyond defining the ontology and data capture. The data have to be converted to knowledge and that knowledge has to be managed. We have described how problems of rejection are handled and the corrective action records are maintained. This is where the knowledge of the problems and solutions are captured. We also mentioned the trial orders being undertaken and manufactured and their results being captured. This is yet another place where the knowledge is captured. At present, this knowledge does not give the intended benefit because of two reasons. The first is that the knowledge captured does not follow any defined ontology of the domain and the second is that it is not integrated with the day to day data capture. The lack of ontology definitions can be solved without the use of information technology, but the integration with day-to-day data capture needs a knowledge management solution supported by information technology.

4.3 Case Based Reasoning

Domain experts maintain that refractory blocks manufacture is such that the technology is unique, not freely available in the world, specific to the application and the equipment, and is not fully mastered yet (R.Srinivasan, 1998). A number of cases have been outlined where the observations made by the operating personnel have changed the principles of design and manufacturing practices because no definite knowledge base is available as a standard package in either textbooks or journals (Ravi Kannan & A.Sivakumar, 1998). Each of these cases, which are production activities, is by themselves an experiment and the industry will have to build on these experiments to improve continuously. The domain experts also observed that a solution could be the same for many problems. That is, these attributes need not exactly match two cases to have the same solution. In other words this would require inexact matching. There would be a relationship to the nearness of the attributes to determine the solution. These observations gave a clue that a case based reasoning system would be more suitable than a rule based expert system to capture the knowledge of manufacturing blocks. Hence the requirement is for a case based reasoning system integrated with the day-to-day data capture software (Ian Watson 1997).

5 SOLUTIONS

5.1 Data Capture

If shop floor automation is installed in a plant, then capturing shop floor data is by default. But if the shop floor managers have had a hard time getting used to an E.R.P. system then capturing of shop floor data meets resistance. People do not want to share information for which they do not get anything in return (Nancy M. Dixon , 2000). “People are not enthusiastic about keying in data into a database. Little personal benefit comes from contributing to a database that is accessed by others with whom one has no connection and moreover from whom one is unlikely to hear. A database, from the perspective of a shop floor supervisor asked to key in data, is like a black hole. It gives nothing back-no thank you, no smile, no sigh of relief, and no enthusiasm at the other end of the line.”

In order to counter the resistance on the part of the shop floor personnel for data capture in the shop floor, provisions were made so that the user would be able to see the data he has entered in the same screen in a separate table. It gave a personal touch to the user, that he was not keying into a black hole, but that which was visible to him and gave him information, which helped him to know his daily production from any computer. He did not have to go searching for a document when needed.

5.2 Knowledge Processes

Knowledge engineers interviewed the domain experts, to elicit information about ontology that define the domain. Once the ontology was defined, the shop floor user had no difficulty in relating to the data he was capturing and the potential benefits to him and the plant. Based on the details, the data capture screens were designed to include the attributes and their range.

5.3 Integration

An integrated system is being developed to convert the data captured in the shop floor into cases which are to be stored in the case base. Though every block that is manufactured can be a success or a failure case, it will be a wrong notion to call each block a case, because there will be many blocks which are similar with similar attribute values. Blocks, which have similar attributes with similar results, will form only one case, though in the ERP software each block would be an item sold and invoiced to a customer and hence is stored as an item in the E.R.P. database. So we need a provision in the integration software to allow a decision to be taken as to whether the block manufactured will be classified as a new case or an instance of an item manufactured of an old case. This means that the software must have an interface to the case based reasoning software to compare the attributes of the block manufactured to cases in the case base and retrieve the closest matching case. If it is within a threshold percentage confidence level it must increment a counter as an instance of an item manufactured belonging to an old case. The larger the counter values the greater the statistical strength of the case. If it falls outside the threshold level, then it must prompt a user to decide whether it is a new case or an old one. Since there are a large number of attributes for a case it will be very difficult for a user to compare the values of each attribute. So it is planned to give a visual aid of color differences through which it will be easy to locate differences between two blocks being compared. The correlation between the cases and corrective action records are very straightforward because a block, which has failed and has a solution, will definitely be a case in the case base. But it was realized that classifying successful blocks as success cases and storing them as success cases would enhance the usage of the system. When a customer places an order for a block it will help in accepting the order if the block had been made earlier, and it was a success. If the block earlier had some failure cases, then it would alert to the potential problems and the precautions to be taken to avoid facing those problems again. This is how the day-to-day data capture can be converted to knowledge and accessed and retrieved when necessary. Because of the information technology support, the knowledge can be viewed by anyone with the access rights from anywhere. A flowchart diagram for the integrated system is shown in figure 2.

An off the shelf CBR package, Consult ™ (Consult is a trademark of Tata consultancy Services) has been deployed on a prototype basis to store this domain knowledge of problems and solutions (Balaraman and Vattam 1998).

6. CONCLUSION AND FUTURE WORK

A thorough knowledge engineering exercise has resulted in a good understanding of the ontology-based definitions of the domain. This has increased the confidence of the domain experts in capturing knowledge and using it to solve problems by retrieving previously captured knowledge and having a decision support system to take informed decisions. This has also shown that the design handbook review, which is equivalent of revising the

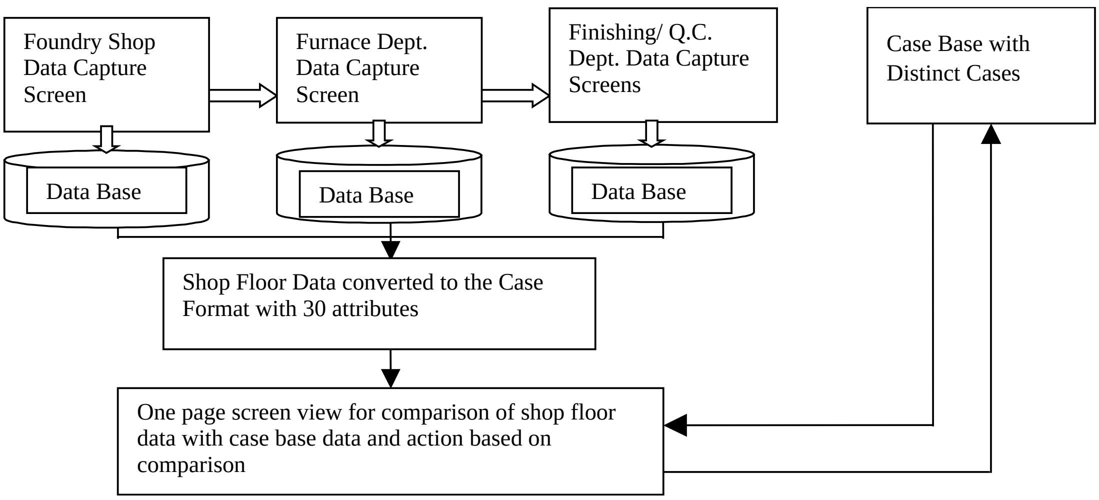

Figure 3: Flow chart for the integrated system

design rules, can be integrated with the day-to-day shop floor data capture.

The exercise carried out leads to a model for knowledge management of manufacturing technology supported by information technology. The need for a knowledge engineering process to establish the ontology for the domain has been brought out. The need for capturing data to be converted to knowledge has also been established. The need for winning over the users for capturing

data using innovative methods has also been emphasized. The information technology used for knowledge capture and retrieval has incidentally been a case based reasoning system. However, the use of a design handbook by the domain experts suggests that it is possible to have a rule based system for capturing the knowledge of the domain and modifying that knowledge by case based reasoning when the domain knowledge grows. Studying this model more in detail and extending to other domains will be a future work.

Future work would also be to carry forward the idea to provide packaged support to the glass manufacturing industry. Based on the knowledge of the placement of the blocks in the glass-manufacturing tank, it will be possible to monitor the performance of the block in terms of corrosion suffered. But the corrosion of the block will not be dependent only on the attributes of the block. It will have a lot to do with the running of the glass plant. An exercise has been done to collect details of the running of the plant and the attributes, which affect the performance of the blocks. Some glass manufacturers want the refractory block manufacturers to give lifetime guarantee for the blocks. The refractory blocks manufacturers are willing to provide such guarantees provided the glass manufacturers will run the glass manufacturing plants to a set of agreed attribute values being maintained. When the glass manufacturer and the refractory blocks manufacturer enter into non-disclosure agreement of confidential information, then the mutual sharing of the data will lead to

benefits to both the parties. An integrated system to collect data from the glass manufacturing plant and a CBR system will lead to finding solutions to problems of refractory blocks in the glass manufacturing tanks.

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