An Industrial Application of CBR in Manufacturing to Reduce Rejections

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Abstract

This paper describes an application of a CBR System in a factory, which manufactures Fused Cast (Electro Cast) Refractory blocks used as Lining for Glass Melting Furnace Tanks. The attributes, which are associated with the manufacturing process, are captured in the shop floor. The CBR system enables the users and the experts to correlate the dependence of the success and failure of these blocks to these attributes, if any. The CBR System allows users to query about a block to be manufactured, whether a similar block was manufactured earlier or not, whether it was a success or not. If not a success earlier, what are the corrections and pre-cautions to be taken? In this manner rejections are reduced.

Introduction

Carborundum Universal Ltd. (CUMI), Palakkad, India, is in the business of manufacture of fused cast (electro cast) refractory blocks used as lining for glass melting furnace tanks. This line of 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 basic principles of design and manufacturing practices because no definite knowledge base is available as a standard package in either textbooks or journals. Each of these cases, which are production activities, is by itself an experiment and the industry will have to build on these experiments to improve continuously. This is ideally suited for an application of the case based reasoning system (Rissland, Kolodner, & Waltz, 1989).

Fig. 1 depicts flow chart of the refractory manufacturing process. The production processes have many parameters and take many days to be completed. It is not always easy to pinpoint the cause when a manufactured part is defective. Accumulated experience however enables some experts to decide upon the process modification needed. This project involves setting up a CBR system on the floor, collecting operational data, and maintaining a repository of all kinds of blocks. Each block manufactured, good or bad is added to the memory along with the corrective action taken if any. When a defective block is encountered the CBR system retrieves the best matching corrective action. With sufficient data accumulating, the system will, in the future, be in a

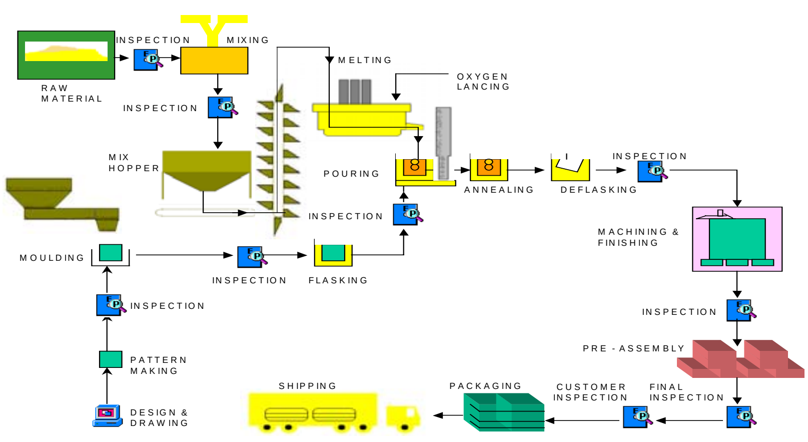

Fig.1 Manufacturing Flow Chart

position to support predictive maintenance and trigger changes in the Design Handbook. Thus it will demonstrate CBR applicability in situations where analytical knowledge is incomplete and yet experienced personnel can make decisions that succeed.

The Domain

Glass manufacturers place orders on CUMI for lining their melting tanks. The lining is made up of around 300 to 400 blocks depending on the size of the tank. These blocks are made of a mixture of Alumina, Zirconia and Silica in certain proportions depending on the location of the block in the tank. The mixture of these raw materials are melted in an arc furnace and poured into moulds, and annealed. The blocks are subsequently removed from moulds and finished. The common technical defects, which lead to rejection of the blocks, are cracks, spalls, and surface porosity. The non-technical defects will be of the nature of wrong dimensions, wrong side contours etc. This application addresses only the technical defects. The average weight of each block is around a tonne and is quite expensive. The manufacturing lead-time is almost a month considering the long annealing periods of almost a fortnight. Hence rejections are quite costly in terms of cost and time. Any reduction in rejections will save money and improve customer satisfaction. The domain knowledge not being sufficient, a CBR system was considered an ideal choice.

Design activity precedes the manufacturing activity. A design drawing is generated for all the blocks, which give all the associated attributes and manufacturing instructions. The design department of CUMI has a design handbook, which gives the design attributes for the manufacture of the blocks. The design handbook gives guidelines, which are modified whenever there is a failure, which is traced to some attribute given in the design handbook. The process of changing the design handbook is done very formally based on a corrective action record (C.A.R.)

There are close to 150 attributes, which are monitored or controlled in the manufacture of the refractory blocks. Any of these attributes or a combination of the attributes could cause the defects. But handling 150 attributes for searching cases would be an unwieldy problem. The factory does not have any shop floor automation to aid in the data collection. The cost of the computational component of the project can also be expected to increase if the number of attributes increases. In this implementation a set of 30 most important attributes were chosen in consultation with the domain experts. The methodology used in reducing the attributes for representing a case was by using the dependencies between the attributes.

The defects as mentioned earlier are of three major types, viz. cracks, spalls and surface porosity. To match cases with similar defects there must be a classification and representation of defects. Here again the domain experts were able to describe the severity of defects by the face, size, location, and depth of the defects in the block. Hence the representation of the defects needed the attributes of face, size, location and depth.

Description of Integrated System

Many Industrial applications of CBR Systems have been successful because they have been integrated with the routine manufacturing activity of the factory (Ian Watson, 1997; D. Hennessey, D.Hinkle, 1992). In this case also it was required to have an integrated system. The Schema for the Integrated Operational Database and case base reasoning system is shown in Fig. 2.

The shop floor data comes from the three departments viz. foundry, furnace and Q.C. (Quality Control). The attributes from each of the departments for each block are combined and stored in the format of a case outside the

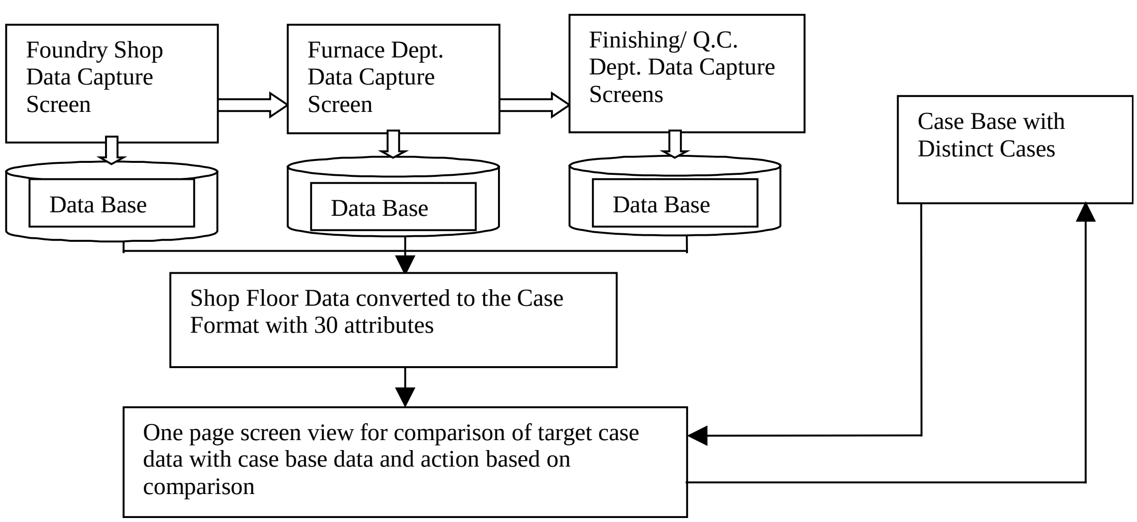

Fig. 2 Schema for the Integrated Operational Database and Case Base Reasoning System

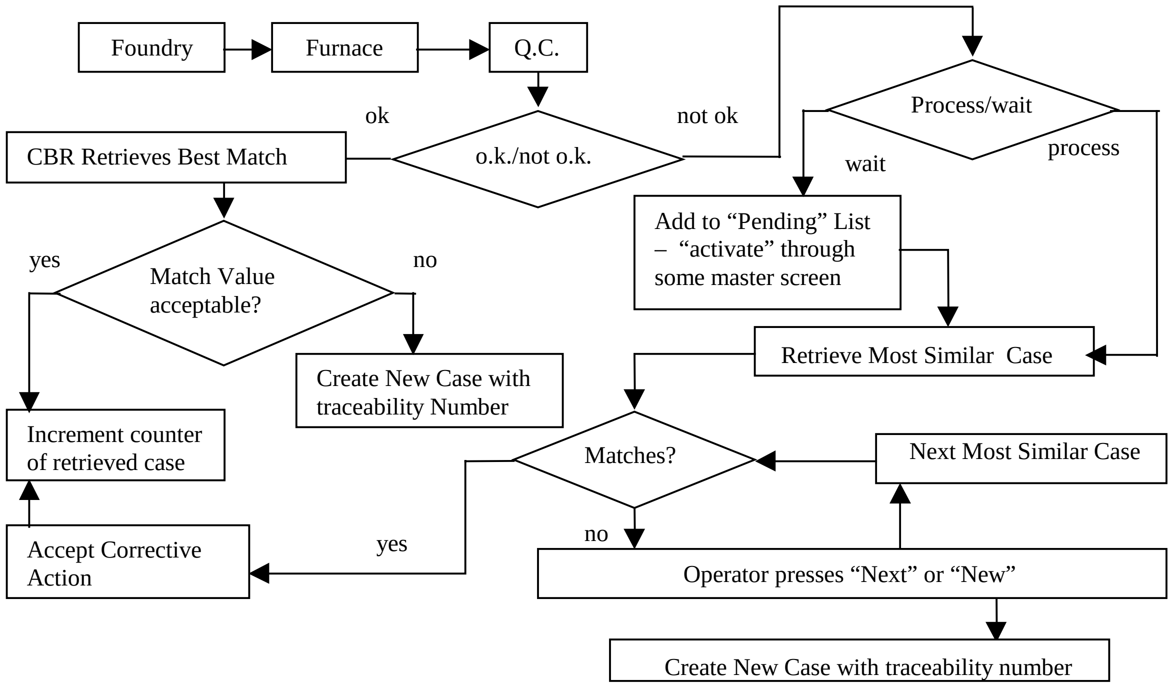

Fig. 3 Flow Diagram for the integrated System

case base. These attributes of the case are compared with the distinct cases in the case base. A one-page screen view for comparison of shop floor data with case base data and the operational user or the expert user provides action based on comparison.

The flow diagram for the integrated system is shown in Fig. 3-. The block goes through the various stages of manufacture and arrives in the Q.C. department. If the block is a success, the CBR System retrieves the best match case. If there is a match then the counter of the retrieved case is incremented. This will go in for statistical purpose to show the strength of a case. Larger the number of similar success cases show the more reliable the process for a similar block. If there is no match, then a new case is created. Up till now there has been no intervention from an expert. If the block is defective, there may be one of two activities. If the defect is a new type or very severe the expert will be called immediately, so there is a ‘wait’ state introduced. If the defect is of a regular type, the operating person can process the block in the CBR system, retrieve the top cases, match the relevant case if available and check for a solution. If there is a solution, then the corrective action is accepted as per the solution. If a good match is not found, then the expert intervenes. The next best match case is checked. In this manner the iterative process goes on until the expert decides to accept a suggested solution or flags the present case as a new case with a solution or without a solution.

CBR System

The software for the CBR System was implemented using Consult ™ (Balaraman & Vattam 1998) [Consult ™ a Registered Trade Mark of Tata Consultancy Services]

The case base consists of instances of cases with the primary 30 attributes. The attributes may be of either dynamic or static type. The static attributes will be present in all cases, whereas the dynamic attributes may or may not be available for a particular case. For instance, some of the most important attributes of a case will be the defects, but all blocks will not have the same defects. So, for the purposes of matching the cases for storage of new cases or retrieving the old cases the algorithm will go by the nearness of the cases depending on the match value of the case with other cases. For symbolic attributes the proximity is defined by treating the attributes as ordered enumerated set.

Each block, which is manufactured, is reckoned to be a case with many attributes. The block may be accepted in which case it becomes a success case. Or it may be rejected in which case it becomes a failure case. Similar blocks would have been manufactured with similar attributes, and with similar outcome. In which case they would not be added as new cases to the case base. The solution to the rejected block may not be available immediately. So the case must be kept pending until the solution is found out and entered into the CBR System

The retrieval of the case is based on the matching done by the ‘k’ nearest neighbor algorithm (Balaraman et.al

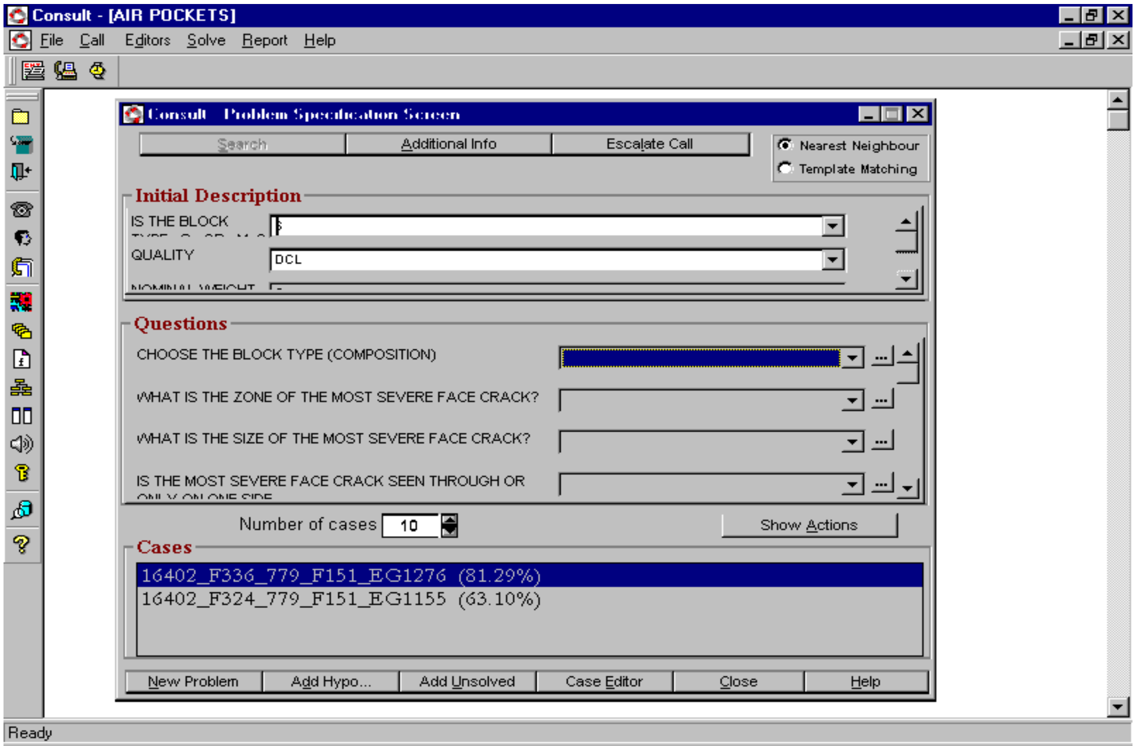

Fig. 4, Screen Shot of Case Retrieval

2000). The percentage of the closeness is also calculated. So the level of confidence with which the case is retrieved will guide the expert in storing the case as a new case or not. The operational personnel will use the CBR to retrieve proactively similar cases manufactured earlier and the problems and solutions assigned to them. This will reduce the rejections.

Case Structure

The following case illustrates the case structure in our system. This case "16402_F324_779_F151_EG1276" was returned as the best match for an input test case with Quality as "DCL". The match value was 81%. Figure 4 shows the screen shot of case retrieval.

Sample Case

Case "16402_F324_779_F151_EG1276"
Case Status : STORED
"IS THE BLOCK ACCEPTED?" : 0
"QUALITY" : "EPIC"
"NOMINAL WEIGHT" : 486
"POUR WEIGHT" : 856
"ACTUAL WEIGHT" : 876
"IS THE BLOCK SHAPED OR RECTANGULAR?" : "RECTANGLE"
"BY HOW MUCH IS THE MOULD OFF THE CENTER OF THE BI" : "CENTER"
"ANNEALING PERIOD IN DAYS" : 12
"CORE MEDIUM" : "NIL"
"CHILLING PRACTISE" : "MAJOR SIDE"
"CHILL AREA IN SQUARE METRES" : 0.080000
"OXYGEN TURBULENCE" : "MEDIUM"
"IS THE BLOCK TYPE ~S~ OR ~M~?" : "S"
"TYPE OF ~S~" : "S5" Category : DEFAULT
"SOLUTION IF ANY" : "accepted block , so no solution , but there are four defects "
"FACE CRACK 1 ZONE" : "Z4" Category : DEFAULT
"FACE CRACK 1 SIZE" : "B" Category : DEFAULT
"FACE CRACK 1 SIDE" : "ONE SIDE ONLY" Category : DEFAULT
"FACE CRACK 2 ZONE" : "Z6" Category : DEFAULT
"FACE CRACK 2 SIZE" : "A" Category : DEFAULT
"FACE CRACK 2 SIDE" : "SEEN THROUGH" Category : DEFAULT
"HOT TEAR 1 ZONE" : "Z1" Category : DEFAULT
"HOT TEAR 1 SIZE" : "40" Category : DEFAULT
"HOT TEAR 1 WIDTH" : "2" Category : DEFAULT
"HOT TEAR 2 ZONE" : "Z2" Category : DEFAULT
"HOT TEAR 2 SIZE" : "40" Category : DEFAULT
"HOT TEAR 2 WIDTH" : "2" Category : DEFAULT
End Case

Practical Difficulties and Innovations

There were certain hiccups in implementing E.R.P. System, which created a prejudice against the introduction of another Information Technology system. Our approach was to win over the operating people by the use of technology rather than force them to use a system. We identified the factors, which would instill confidence in the user and get a buy-in for using the system.

Shop Floor Data Capture

The ideal situation would be that all data generated in a place is captured only once. Because of the E.R.P. implementation there is already a data entry-taking place. But most of the elements required for the Case are different from the E.R.P. Data. Hence it became unavoidable for some data to be captured in two different applications. ERP being a huge application required many linkages which made the data entry not very user friendly, and the data once entered was invisible to the user. In this project the system for data capture was custom built and hence it was user friendly and fast. The front-end screens given for the capture of the data pertaining to each block has a table in the lower portion of the screen displaying the data entered so that operational person can see the data immediately and not wait for a query output.

The capturing of defects as described earlier is a new effort within the company, viz. face, location, size and depth. So, as an aid, a template was given on a sheet of paper where these details can be ticked off, and entered in the front-end screen. An effort is under way to use a palm top to capture the defects details because the inspection region is not conducive for data recording.

As the data get captured in three different work places, the block is tracked by its trace ability attributes. Invisible to the user the data from all the three work places are combined using the trace ability numbers and made into the case format with the 30 attributes mentioned earlier.

Use by Domain Expert

The domain expert is given a screen, which shows a one-page view of a screen with all the attributes of a case as combined using the trace ability numbers, and made into the case format with the 30 attributes mentioned earlier. He is also given a few buttons on the screen to aid in retrieving the closest case. This is an aid to navigate among the best matching cases, which have been retrieved. This aid also gives a graphic support for easy comparison and relieves him of comparing the 30 attributes according to their values. Depending on his judgment of the match value he can add it as a new case. If there is a match, then only the counter for similar cases will be incremented. This information can be used for statistical purposes.

Use by Operational Personnel

With the increased number of cases in the case base, the operational personnel can use the CBR system to query potential problems. The query will be based on the attributes, which are given in the purchase order given by the customer requesting for supply of lining blocks and their specifications. At present the number of cases in the case base is low. Hence this usage is not exploited. There is another effort underway to start using this facility of capturing trial orders. Customers give trial orders before they release bulk orders. These are for non-standard products, which are not commonly used. These trial orders' details, if they are captured in the CBR system, will help in giving accurate information about previous trials. These trial orders directly widen the case base. Trials need not be repeated. Thus the benefit of Experts' Memory would be seen immediately.

Conclusion

The use of a CBR system in a manufacturing environment has been demonstrated. The practical difficulties encountered and the solutions have also been described. The need for integrating the operational data with the CBR System has been explained. The integration has also been achieved. The operating personnel have recognized the benefits of the system in reducing the rejections.

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