Data Mining for Casting Defects Analysis

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Abstract— Production of casting involves various processes like pattern making, moulding, core making and melting etc. It is very difficult to produce defect free castings. A defect may be the result of a single cause or a combination of causes. The castings may have one or more defects. Foundries are still using trial and error methods to solve quality problems. There are benefits of using a more disciplined approach to define identify and determine the root cause of the defect.A tremendous amount of productivity is lost through defective castings, by employing a disciplined approach to understand the nature of defects and the mechanism of defect formation and controlling the key process variables we can significantly reduce the defects.

This paper presents a review of methods adopted by foundries to reduce defects and a new approach is proposed which will be helpful for foundries for controlling and reducing the defects)

Keywords— Casting Defects, Data Mining, GMDH.

I. INTRODUCTION

Casting defects are usually easy to characterize but to eradicate them can be a difficult task. Defects are caused by combined effect of different factors, whose identification is often difficult .casting process involves complex interactions among various parameters and operations related to metal composition, methods process, melting, pouring, machining. Presence of these defects exposes foundries to contribute over 70% of total quality costs. Foundries try to reduce rejections by experimenting with process parameters (like alloy composition, mould coating and pouring temperature).When these measures are ineffective, then methods design (gating and feeding) is modified. When even this is not effective, then tooling design (part orientation, parting line, cores and cavity layout) is modified. Our approach will be to systematically find the reasons responsible for rejections and analyze them. Each casting produced in a foundry is a research experiment, since no two castings have the exactly same values of their geometric, material and process parameters. When foundry engineers inspect the castings, the link to the originating (influencing) parameters is lost, since they are never systematically recorded and correlated with quality characteristics. Thus a vast amount of valuable knowledge is generated in the foundries every day, but never fully utilized for quality improvement. Thus in this paper a new approach called GMDH (Group Method of Data Handling) is proposed which is used in Data Mining and will be highly useful for foundries for understanding and correlating various parameters responsible for casting defects.

II. LITERATURE REVIEW

Singaramanan [1] analyzed the effect of various process parameters at different levels on casting quality and optimal setting of various parameters have been accomplished using Taguchi analysis. He has developed a neural network model to map the complex nonlinear relationship between process conditions and quality characteristics. Process parameters of green sand casting were optimized resulting in improved process performance; reduced process variability thus reduced casting defects. An ANN model is developed In order to capture complex relationship between percentage of casting defects and corresponding process parameters viz. moisture content, green strength and mould hardness. ANN model is successfully developed for predicting general trend with varying process parameters and it is observed that targeted outputs were in close conformity with predicted values. M. Imad Khan, Yakov Frayman and Saeid Nahavandi [2] carried out conventional die with ANN model of HPDC machines. They have carried out this work in order to improve current modelling and understanding of defect formation in HPDC machines. Obtained results were compared with current understanding of formation of porosity and it was observed that most of the findings correspond to established knowledge in the field and some of the findings were in conflict with previous studies. Mark Polczynski, Andrzej Kochanski[3] have reviewed a systematic knowledge discovery process model. They have described successful applications of KDAM (Knowledge Discovery and Analysis in Manufacturing) to creation of rules for optimising gas porosity in sand casting moulds. They have suggested that databases are so massive that we have to identify useful patterns and structures in them which is the characteristics of next generation quality and reliability technology, which is the ability to effectively utilize highly coherent, noisy, and corrupted data with missing field and record entries. They have also suggested that how KDAM can be applied in foundry production and metal cast part manufacturing. They have cited example of Warsaw University where researchers are applying KDAM for

1) Detection of causes of gas porosity in steel castings.
2) Optimization of cast iron heat treatment parameters.
3) Green moulding sand formulation and
4) Prediction and improvement of melt quality and casting properties such as strength, elongation, and hardness.

They suggested that casting being complex process KDAM technologies can be used for analysis.

R. Sika , Z. Ignaszak [4] have discussed about aspect of selecting data for modelling, cleaning it and reducing it due to strong correlation between some of the recorded parameters. Their measure work is about discovering expected dependencies because manufacturing processes and parameters measured in a foundry are difficult to identify and relate. Unless expected dependencies are discovered it is difficult to get coherent results of modelling. They have also discussed about what results can be obtained using ANN and decision tree.

Z. Górny et al.[5] suggested that application of formal methods is must if nature of knowledge available is incomplete. They have used fuzzy logic and logic of plausible reasoning for finding possibility of defect identification. They have suggested that defect diagnosis must be supported by tools that can collect and use incomplete and uncertain knowledge. They have discussed about how knowledge base can be created adapted to particular casting technology, and improvement of an interface oriented at the specific user needs. Indicating cause of the defects using our knowledge acquired from standards, catalogues, and experts experience is not enough.

L.A. Dobrzański et al.[6] suggested a methodology which makes it possible to determine the types and classes of defects developed during casting the elements from aluminium alloys by using photos obtained with the flaw detection method with the X-ray radiation. They have suggested that by using image analysis, geometrical shape coefficients and neural networks it is possible to achieve better efficiency of class recognition of flaws developed in the material.

V.V.Mane, Amit Sata and M. Y. Khire[7] proposed a new hybrid approach for defect analysis. Defects have been classified in terms of their appearance, size, location, consistency, discovery stage and inspection method. This helps in correct identification of the defects. For defect analysis, the possible causes were grouped into design, material and process parameters.

Jiang Zheng et al [8] employed trained neural network as an objective function to optimize the processes in high pressure die casting. They have established an evaluation system for the surface defect of casting and ANN was used to generalise the correlation between surface defects and die-casting parameters, such as mould temperature, pouring temperature, and injection velocity. In high pressure die casting which is a complex process by using this method castings with acceptable surface quality were achieved. Krimpenis et al. [9] suggested that ANN models can replace pressure die-casting simulation software in a straightforward manner, accuracy is enhanced by the DOE, according to which a database of process parameters and effects is built and used for ANN training. The need for lengthy casting simulation runs is thus eliminated after ANN training. ANN models embodied in a GA fitness function provide the key in achieving optimal process parameter values.

R. Vinayagasundaram, V. R. Nedunchezhian [10] discussed about application of modern technology in foundries such as CAD/CAM, simulation, ERP, TQM, SPC, lean manufacturing, kaizan, 5s.They concluded how application of modern technology results in higher consistency, accuracy and production rate.Dr.M.Arasu [11] suggested a approach which is expected to motivate the foundries to use a standard classification system to describe undesirable casting artefacts for more effective failure analysis. It will also encourage foundries to develop systems to measure process parameters relating to the defects that occur in the foundries and pool the resources of domain experts. Any reduction in the scrap and rework also positively influences the environmental impact of our industry. This paper deals with the various aspects of a systematic approach to understanding and development of quality cost system in cast iron foundries. B.Chokkalingam, S.S.Mohamed Nazirudeen [12] presented a systematic procedure to identify as well as to analyze a major casting defect (mould crush) occur in an automobile transfer case casting poured in cast iron grade FG 220. This casting was produced in a medium scale foundry using green sand process in machine moulding. The root cause for this major defect was identified through defect diagnostic study approach. Finally, by taking necessary remedial actions the total rejection rate was reduced to 4% from 28%.

Rasik A. Upadhye , Dr I. P. Keswani ,Dipti Agrawal[13] intended to suggest means of diagnosing casting defects with the frequent courses of action required for their control and elimination. Besides it is intended in optimizing the critical process parameter values thereby reducing defects .B. Ravi[14] discussed about methods adopted by foundry engineers to tackle the problem such as tweaking the part design, for example increasing a fillet radius or padding a thin wall, according to him such methods result in additional and avoidable costs of machining and productivity loss. He suggests that**,** design for manufacturability (DFM) should be carried out early by product engineers; instead of late DFM currently practiced by casting suppliers .He says that castings are designed for manufacture, not for manufacturability and the reason for many defects is poor designing of part features. Because of such designing many castings are rejected.

Harshwardhan Pandit, Uday Dabade [15] proposed a web based system for casting defect analysis. The system works by finding out the optimum process parameters for the process. The input is the historical data of casting which must be generally traceable. Thus the system eliminates need for vast experimentation by design of experiments method since as the number of parameters increase the number of experiments go on increasing. The system is based on the Bayesian theory of probability which is used to find out the major reasons for the casting defect i.e. metacauses and root causes.

Bogdan Dumitru, Gabriel Marius Mumitru[16] Suggested Six Sigma Methodology to diagnose i.e. metacauses and root causes and improve the casting process for large parts. Because for the producers of large and medium casted parts defects management and defects volume reduction has proven to be a very important concern. Given the tendencies for raw materials and energy on the global market this can be seen also as a survival need of the business unit. Modern approaches like the Six Sigma tools are used to diagnose and improve the casting process for large parts. The main tool considered is DMAIC, which guide the project through the

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steps of improvement, from problem pinpointing to the implementation of result/solutions into the management system of the business unit.

S.S. Khedkar et al.[17] investigated the intelligent inspection system for fault diagnosis of metal casting. For determining the optimum design of proposed system they have used digital radiography and Artificial Neural Network and it is observed that this reduces inspection time and cost as well as maintain accuracy and consistency of inspection process.B.Borowiecki,O.Borowiecka,E.Szkodzińka [18] analyzed casting defects by using Pareto method. In this study they have have located the exact problems which solution can give largest profit.It also proves which actions do not bring significant profits. Aim of authors was to find out the factors which had an influence on the numbers of defectives or its cost.

B. Ravi, G.L. Datta[19] proposed Co-operative virtual foundry for cost-effective casting simulation .Virtual casting trials ensure that real castings are right first time and every time, in the shortest possible time. They have proposed a collaborative national initiative to create a virtual foundry that can be reached through internet and where virtual casting trials can be performed to optimize the tooling, methoding and process parameters. Advantage of virtual casting trials is they consume fraction of the resources required for real time trials, providing better insight to meet the desired quality requirements. This virtual foundry will be backed by well trained team of casting engineers to guide the users and provide necessary technical support. This will be particularly helpful for small foundries because SME foundries cannot use casting simulation technology which is highly reliable and result oriented for even complex castings, due to its higher costs.

Pavan Kumar Reddy et al. [20] suggested a framework for generating automatic suggestions for product design improvement, driven by casting domain knowledge base. They have modelled domain knowledge using XML, a self describing language suitable for use over internet which captures distilled experience in the form of rules regarding various casting features. They suggested this approach because they think process improvements alone are not enough for dimensionally accurate, high-quality, low-cost castings delivered in ever shorter time so early planning is must starting from product design.

K. Siekanski, S.Borkowski [21] discussed about some simple techniques which can be used in identification of the main course of defects in production of castings for heavy industry. Since casting is a complex process possibility of failure of finished casting is more, so they adviced to perform preventive activities and make use of research techniques for better loss prevention.

S. S. Mohamed Nazirudeen, B. Nagasivamuni[22] created neural network model for preventing defective castings production with properties such as green compression strength, green shear strength, moisture content, permeability, compatibility and mould hardness as inputs and the percentage defects produced as output. Neural network was used to predict the percent defectives.

III. DATA MINING

The most authentic definition of knowledge discovery in database or data mining is "non-trivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data" . It is very difficult for humans to understand and analyze big databases, although so many methods have been developed for data acquisition and storage technology at cheaper rates, this has tempted scientists and researchers to move forward towards the specific field of knowledge discovery in data bases [KDD] .This is a recently emerged discipline which lies at the intersection of data management, artificial intelligence, machine learning and statistics. To search for valuable information in large volumes of data is Data Mining. Data bases contain treasures of information which makes it possible to detect trends or patterns in them. But it is difficult to discover useful information which is hidden within mountains of other data by using conventional database management systems. Data mining is becoming an increasingly important research area, since knowledge, e.g. extracted knowledge trends and patterns can be used to help and improve decision making.

Data mining is the cooperative effort between humans and computers. Humans design databases, describe problems and set goals; computers sift through data, looking for relationships and patterns that match these goals. The central step within overall KDD process is data mining, the application of computational techniques in the task of finding patterns and models in data. The application of computational techniques in the task of finding patterns and models in data. Manufacturing enterprises all over the world are now giving attention to utilization of KDD technology for the improvement in their current status[23].

KDD is the nontrivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data (Fayyad et al. 1996a). Data Mining (DM) is a particular step in this process, involving the application of specific algorithms for extracting patterns (models) from data. The additional steps in the KDD process, such as data preparation, data selection, data cleaning, incorporation of prior knowledge, and proper interpretation of the results of mining ensure that useful knowledge is derived from the data [24].

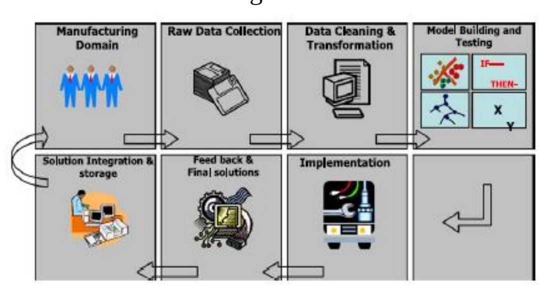

Fig. 1. Knowledge Discovery and Data mining in Manufacturing Systems Environment

IV. DATA MINING FOR CASTING DEFECT ANALYSIS.

Cast part manufacturing is a complex process and challenging due to several aspects of the casting process. First, the casting alloy can consist of over a dozen chemical components. Second, not only does the casting material experience physical changes during the melting and cooling phases of casting, the chemical composition of the material also changes. In sand casting properties of the mould also change physically and chemically during casting. And the worst problem is controlling physical environment in a foundry.

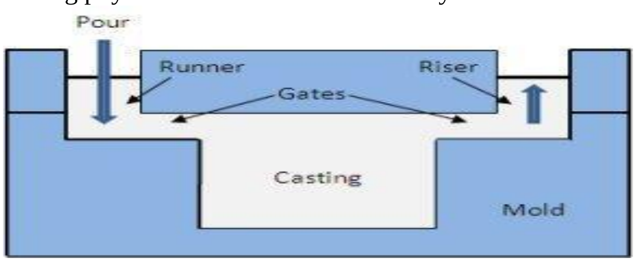

Fig.2. Elements of sand casting process

Casting is a very complex process in which number of output characteristics rely in a complex manner on a number of process inputs that interact in complex ways and experience significant variation over time. So it is very difficult to predict output characteristics based on mathematical modelling of chemical and physical process that occur during melting, pouring, and cooling very difficult, and therefore makes this process a prime candidate for analysis using KDAM technologies[3].

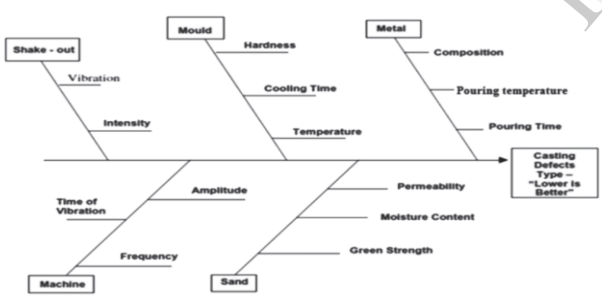

Fig.3. Cause and Effect Diagram for Casting Process Parameters

V. GMDH (Group Method of Data Handling)

Russian Scientist A.G. Ivakhnenko introduced this technique in 1966, for constructing an extremely high order regression type model termed as GMDH. The algorithm, GMDH builds a multinomial of degree in hundreds, [25].GMDH is a modelling technique that provides an effective approach to the Identification of higher order non-linear systems. Furthermore, GMDH is an inductive self-organizing algebraic model since it is not necessary to know the exact physical model in advance. Instead, GMDH automatically learns the relations that dominate the system variables during the training process. In other words, the optimal neuron's structure is selected automatically in a way that minimizes the values of the prediction error criteria and unnecessary neurons are eliminated from the network. Therefore, GMDH has good generalization ability and can fit the complexity of non-linear systems (Kondo, 1998). GMDH is used in such fields as data mining, knowledge discovery, prediction, complex systems modelling, optimization and pattern recognition.GMDH algorithms are characterized by inductive procedure that performs sorting-out of gradually complicated polynomial models and selecting the best solution by means of the so-called *external criterion*.

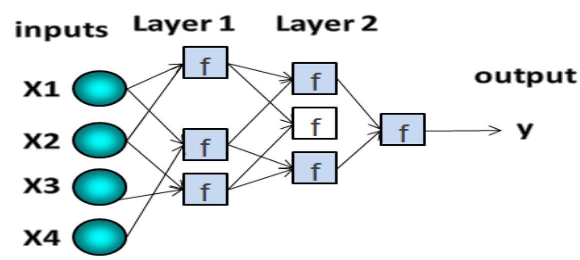

Fig.4 .GMDH Network Architecture

Many approaches were used for defect analysis of castings, but nobody used GMDH which is highly accurate and can be very useful for complex methods like casting, where there are so many parameters affecting quality of final casting and very difficult to find relationship between different variables affecting quality of castings. It is suggested if we use GMDH for defect analysis of castings it will be highly useful for the casting industry as a whole.

REFERENCES

[1] Lakshmanan Singaraman , "Improving Quality of Sand Casting Using Taguchi Method and ANN Analysis", International Journal On Design And Manufacturing Technologies, Vol.4, No.1,January 2010.

[2] M. Imad Khan, Yakov Frayman and Saeid Nahavandi, "Modelling Of Porosity Defects In High Pressure Die Casting With A Neural Network" Proceedings of the Fourth International Conference on Intelligent Technologies 2003, Chiang Mai University, Institute for Science and Technology Research and Development, Chiang Mai, Thailand, pp. 1-6.

[3] Mark Polczynski, Andrzej Kochanski, "Knowledge Discovery and Analysis in Manufacturing, ",Taylor & Francis Online, Quality Engineering,Volume 22, Issue 3 , 2010.

[4] R. Sika , Z. Ignaszak , **"**Data Acquisition In Modeling Using Neural Networks And Decision Trees", Archives Of Foundry Engineering Volume 11 **,**Issue 2/2011**,**113–122.

[5] Z. Górny, s. Kluska-nawarecka, d. Wilk-kołodziejczyk, k. Regulski, "Diagnosis of casting defects using uncertain and incomplete knowledge", A R C H I V E S O F M E T A L L U R G Y A N D M A T E R I A L S,Volume 55, Issue 3, 2010 .

[6] L.A. Dobrzański a, M. Krupiński a, J.H. Sokolowski b, P. Zarychta a, A. Włodarczyk-Fligier, "Methodology of analysis of casting Defects", Journal of Achievements in Materials and Manufacturing Engineering Volume 18, Issue 1-2 ,September–October 2006.

[7] V.V.Mane, Amit Sata, and M. Y. Khire, "New Approach to Casting Defects Classification and Analysis Supported by Simulation", a technical paper for 59th Indian foundry congress, Chandigarh, February, 2010, pp 87-104.

[8] Jiang Zheng & Qudong Wang & Peng Zhao & Congbo Wu, "Optimization Of High-Pressure Die-Casting Process Parameters Using

Artificial Neural Network", Int J Adv Manuf Technol (2009) 44:667–674.

[9] A. Krimpenis , P.G. Benardos , G.-C. Vosniakos , A. Koukouvitaki, "Simulation Based Selection Of Optimum Pressure Die-Casting Process Parameters Using Neural Nets And Genetic Algorithms", Int J Adv Manuf Technol (2006) 27: 509–517.

[10] R. Vinayagasundaram, V. R. Nedunchezhian, "Application of Modern Technology in Foundries and its Impact on Productivity and Profitability", European Journal of Social Sciences, Vol.29 No.2 (2012), pp. 320-330

[11] .Dr.M.Arasu, " Development of quality cost system in cast iron foundries".Metal Casting Technologies , 2010, Foundryinfo-India.org.

[12] B. Chokkalingam, S.S. Mohamed Nazirudeen , " Analysis Of Casting Defect Through Defect Diagnostic Study Approach" , Annals Of The Faculty Of Engineering Hunedoara – Journal Of Engineering. TOME VII (2009), Fascicule 2 (ISSN 1584 – 2665).

[13] Rasik A Upadhye, Dr I. P Keswani , Dipti Agrawal , "Casting Defect Analysis In Iron Foundry For Continuous Quality Improvement",National Conference on Operations and Manufacturing Excellence 2012,Shri. Ramdeobaba College of Engineering and Management, Nagpur .

[14] B. Ravi, "A Holistic Approach to Zero Defect Castings", Technical Paper for 59TH INDIAN FOUNDRY CONGRESS, Chandigarh, February 2011.

[15] Harshwardhan Pandit, Uday Dabade, Harshwardhan Pandit, Uday Dabade,"A New Web-based Expert System for Casting Defect Analysis", fisita2012.com.

[16] Bogdan Dumitru, Gabriel Marius Dumitru, "Sigma Tools For Management Of Defects by Steel Casted Parts", Proceedings of the 10th WSEAS International Conference on MATHEMATICAL and COMPUTATIONAL METHODS in SCIENCE and ENGINEERING (MACMESE'08).
Prediction using Machine Learning Algorithms" Software Engineering, An International Journal (SEIJ), Vol. 2, No. 2, SEPTEMBER 2012.

[17] SS Khedkar, GK Awari, SP Untawale ,S.S .Chaudhari, "Investigation on Intelligent Fault Diagnosis System for Valve Casting Using ANN", VSRD-TNTJ, Vol. 2 (2), 2011, 58-63.

[18] B. Borowiecki, O. Borowiecka, E. Szkodzińka, "Casting defects analysis by the Pareto Method", ARCHIVE S o f FOUNDRY ENGINEERING, Volume 11, 3/2011, 33 – 36 .

[19] B. Ravi, "Co-operative Virtual Foundry for Cost-Effective Casting Simulation", Technical paper for the 54th Indian Foundry Congress, Pune, 2006.

[20] Pavan Kumar Reddy, "Domain Knowledge Modelling for DFM of Castings".International TEAMTech Conference, Bangalore, 4-6 October 2007.

[21] K.Siekański, S. Borkowski , "Analysis of Foundry Defects And Preventive Activities for Quality Improvement Of Castings", METABK, 42 (1)57 (2003), UDC - UDK 621.746:669.13:008.6:346.54=20.

[22] Mohamed Nazirudeen1 and B. Nagasivamuni, "Improving the Quality of Green Sand Castings to Minimise the Defects Using Artificial Neural Network", Indian Foundry Journal, Vol 58, No. 2, February 2012.

[23] Muhammad Shahbaz,, Syed Athar Masood, Muhammad Shaheen, Ayaz Khan, "Data Mining Methodology in Perspective of Manufacturing Databases", Journal of American Science, 2010; 6(11).

[24] A. K. Choudhary, J. A. Harding, M. K. Tiwari "Data Mining in Manufacturing: A Review Based on the Kind of Knowledge", J Intell Manuf (2009) 20:501–521 .

[25] Ruchika Malhotra, Anuradha Chug, "Software Maintainability Prediction using Machine Learning Algorithms" Software Engineering: An International Journal (SEIJ), Vol. 2, No. 2, SEPTEMBER 2012.