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Process knowledge for improving quality in sand casting foundries: A literature review

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Abstract

Foundry operation has many interlinked and complex processes that require skill and caution to ensure good quality of castings. The complex production processes and variables in the foundry industry also imposes quality limitation for final castings. Due to this, defect reduction still remains the main objective in sand casting foundries. In this regard, process knowledge is important in foundries to increase productivity by reducing sand casting defects. Process knowledge is defined as the identification of process variables. This includes the gathering approach, conceptualisation system and analysis to determine the varying process variables that are associated with product characterisation for final products. The paper presents a literature review on process knowledge in manufacturing focusing in sand casting method. It then explores possible application of this methodology specifically to the metal casting industry with the main aim of making it more competitive.

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Keywords: Defects; Foundry; Process-knowledge; Sand casting; Quality

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1. Introduction

Defect reduction still remains the main objective in the foundry industry. According to Roshan [1], foundries spend about 5-0% on average of their total revenue fixing internal and external deficiencies due to the sand casting process [1]. Defect reduction in sand casting foundries requires an understanding of the sand casting process variables and the process parameters as well at their effect on the final casting. According to Giannetti et al [2], defect reduction requires a detailed process knowledge - which is also foundry specific [2]. Foundrymen need to possess sufficient metal casting process knowledge to produce good quality castings [1]. Foundry processes are complex and contains many variables that could affect the performance of the foundry if not well managed. The complex production processes and variables in the foundry industry also impose quality limitation for the final casting [2]. Due to this, process knowledge is important for foundries to increase productivity and competitiveness.

2. Process knowledge in sand casting foundries

From the manufacturing point of view, process knowledge is defined as the identification of process variables, their gathering approach, conceptualization and analyzation system to determine the varying process variables that are associated with product characterization for specific castings in foundries [1]. A process is generally described as transformation of input into output [3]. Neef et al [4] describes a process as a continuous method of producing products with individuals, technologies, measures and software within an organization. This author further describes knowledge as the understanding of the effect of the input variable on the output [4]. Roshan & Ransing [5] describes process knowledge as a list of all process variables and their data collection system to meet product specification with minimal scrap and rework. Process knowledge is the understanding of how to produce products including the analysis and observation process as well as knowledge documentation [6].

For the purpose of this paper, process knowledge is defined and understood based on Roshan's definition. Figure 1 below summarises and illustrates the concept of process knowledge. Process knowledge in foundries is developed from process records and process information [5]. Process information is gained through process data analysis. Foundries need to specifically define the process variable acceptance limits based on their relationship to the final product attributes of castings. Foundries should always ensure that accurate and adequate process data is collected and analysed for any variation that may results in defect formation [7]. This could include metal and sand data analysis in sand casting foundries.

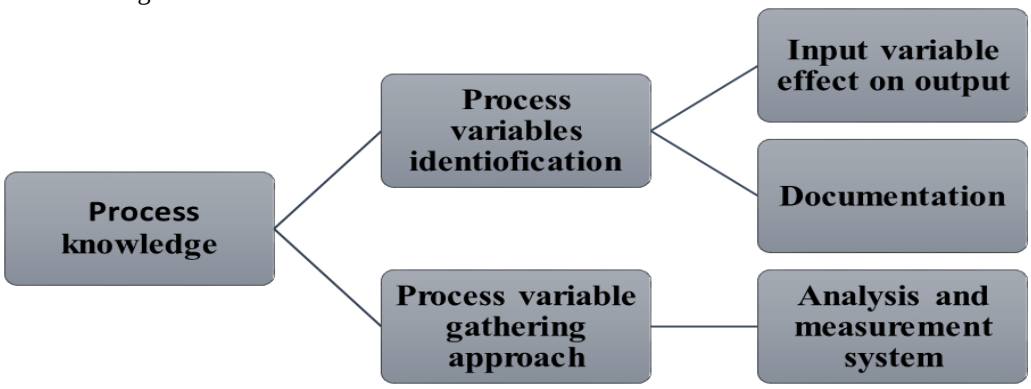

Fig.1. Process knowledge model

3. Process variation and reduction through process knowledge

The inherent nature of any process encompasses variation that cannot be avoided. Manufacturing process variation can influence product quality if they are not controlled [8]. Therefore, process variation needs to be within acceptance limits so that defects may be eliminated in the final a product [9]. Process variation is a measure of process deviations in any given process with regards to the derived process parameters specifications [9]. Variation exists in manufacturing processes because a given process involves a combination of equipment's, materials, environment and the operator 's efficiency to transform input into output [10]. Process variation in the output causes defects and affects the competitiveness of an organization [8]. Statistical techniques are used to determine and distinguish between normal and special process variation's [10]. Process knowledge enables adequate control of process variation and the understanding of the existing process as normal or special (6).

According to Sinha & Field [6], The eradication of the different causes of variation makes the process mean predictable and reduce process variation which then reduces the possibility of defect formation [6].
Statistical and data driven methodologies are normally applied to eliminate defect in processes by reducing process variations. There are several statistical methods for controlling and monitoring process variables, correlating the effects of the variable, and problem analysis for improving quality in the foundry industry [7] these techniques includes statistical process control(SPC). Process knowledge for quality improvement in manufacturing is also tightly embedded into the Six Sigma DMAIC (Define, Measure, Analyse, Improve and Control) process. Six Sigma technique is reliant also on data, information gathering and statistical analysis techniques which requires process knowledge [2]. According to Veza & Grubic (2004), Six Sigma technique from a business viewpoint focuses on removing defect in processes through key process knowledge [11]. Six Sigma technique utilizes statistical techniques to eliminate defect in processes and thus improve the process.

4. Sand Casting process and sustainability

Sand casting also known as sand moulding is a metal manufacturing process categorized by utilizing sand as an aggregate material for making the mould [18]. The sand casting process encompasses, moulding, metal melting, solidification, shake out and fettling [19]. The mould is a cavity where the molten metal is poured into and allowed to solidify. During the sand casting process, the sand is rammed around the pattern to produce the mould cavity [18]. A pattern is a reproduction of the final casting [18,19]. The mould must have adequate strength to carry the metal during casting and it must be permeable enough to allow gases to pass through during solidification [20]. After solidification, the casting is removed from the mould and the sand is reused again in the process [20]. Sustainability in manufacturing is driven by cleaner and more efficient productions [21]. Sustainable manufacturing involves a variety of concepts that encompasses profit, environmental impact, product life cycle, operator knowledge and recyclability [21]. In addition, the sand casting process is a sustainable method in that, the refractory sand is recycled during the process after its separation from the final casting. The recycling of the sand is made to reduce the cost of the process and as well as to prevent environmental pollution caused by dumping of the sand. As such, sand casting is one of the most popular and efficient casting methods for small and medium parts since it gives good properties of parts.

5. Quality improvement of the sand casting process

It is also important to note that the quality of the casting depends on the pattern and the quality of the sand [20].
Quality is defined as conformance to specification or customer requirements [3]. It is also defined as fitness for use [12]. However, in manufacturing the widely used definition of quality is conformance to specification. In this context quality is achieved through process improvement. Process improvement is defined as the classification and control of the input process parameters to attain the desired output in any given process [12]. Six Sigma methodology has been regarded as a well-structured method for improving the quality of processes and products [7]. In a nutshell six sigma convert knowledge into opportunities for business development and it is cantered on defect

elimination through practices that highlights process understanding, measuring and process enhancements [11]. The Six Sigma methodology for process improvement is DMAIC. Six Sigma DMAIC is utilized in an existing process that is not performing satisfactorily [12]. This framework can be applied in any processes. It measures process variation that leads to defect formation. The table below gives detailed information about the Six Sigma DMAIC Technique [11, 15].

Table 1. Six Sigma DMAIC frameworks [11, 14, 15].

Six Sigma step	Activity	Tools
Define	•The key Customer requirement	SIPOC
	•The key process that is affecting the customer requirement	Pareto charts
	• The process parameters to be measured	Scatter Plots
	•The goal of Six Sigma Implementation	XY Matrix
Measure	•Identify the fundamental process measures	Process flow,
	•Measure the process variation	Check sheets
	•Identify the required data to solve the defect	Pareto Chart
	•Design the data collection plan.	Histograms
	•Collect data	
Analyse	•Analyse the collected data.	ANOVA
	•Analyse the process variation	FMEA
	•Find the root causes of the defect	Cause and effect Diagram
Improve	•Make a list of all possible solution to the defect problem	Affinity diagram
	•Examine the possible solutions	Multi-voting
	•Validate the solutions	FMEA
Control	•Control and monitor the process	Control chart
	•Collect process data	TPM
	•Come up with new process control limits of the improved process.	

Processes operating under Six Sigma technique produce 3.4 defect per million of on non-conforming products in a process [13]. According to Montgomery &Woodall, 2008, Six Sigma technique is cantered in reducing variation in product characteristics in specified target so that defects are not likely to occur and if they do, they are at 3.4 defect per million opportunities [13]. Six sigma technique gathers and analyses data using the basic tools of quality. The Six Sigma DMAIC technique may be understood with the use of different quality tools and techniques including the seven basic tools of quality (7QC) [14]. Not only does Six Sigma methodology eliminate defects in a process, it also influences process knowledge creation and application. Work teams implements process knowledge to reduce variation [6]. Process knowledge is created through process data collection and interpretation [8]. According to Giannetti et al (2014), knowledge creation in Six Sigma methodology is the fundamental contributing aspect to achieving process improvement [2].

6. Conclusion

In today's global completion, it is important for foundries to focus on process improvement to increase competitive advantage. Competitive advantage for sand casting foundries means improved production process, improved plant maintenance processes, improved product quality and proper utilization of resources, especially scarce resources. Process knowledge could be very critical for sand casting foundries to alleviate its limitations compared to other metal manufacturing techniques. This paper aimed at defining process knowledge and outlining its importance for

defect reduction in sand casting foundries mainly through six sigma methodology. Understanding and implementing process knowledge are key for process improvement. The paper reviewed the literature on process knowledge applied to manufacturing. Emphasis was made on Six Sigma technique as a suitable process knowledge with better benefit compared to the traditional process statistical control. Finally, the paper attempted to relate process knowledge to Six Sigma technique to sand casting method in order to reduce process variation and improve quality of castings. Future work will include case studies of Six Sigma implementation in South African foundries.

Reference

[1] H. Roshan. Start gaining process knowledge. Modern casting (2013), 24-29
[2] C. Giannetti. R.S. Ransing., M.R. Ransing., D.C. Bould. D.T.Gethin., J.Sienz. Knowledge management and knowledge discovery for process improvement and sustainable manufacturing: a foundry case study. Sustainable Design and Manufacturing. (2014).554-565.
[3] S. Foster. L.B. Managing quality: Integrating the supply chain. International edition ed. United States of America: Pearson Education. (2013)
[4] D. Neef., A. Siefeld, & J. Cefola, 1998. The economic impact of Knowledge. United States of America: (1998). Butter Worth Heinemann
[5] H. Roshan., R. Ransing. Process knowledge and Product characteristics gained using casting process optimization. Foundry management &Technology. (2010)
[6] J.M. Field., K.K. Sinha. Applying Process knowledge for yield variation reduction: A longitudinal Field Study.
[7] B.J. Singh & K. Dinesh. Wrap the scrap with DMAIC: Strategic Deployment of Six Sigma in Indian foundry SMEs. Anchor academic Publishing, Humburg. 2015.
[8] L. Landryova &C, Irgens. Process knowledge generation and knowledge management to support product quality in the process industry by supervisory control and data acquisition (SCADA) open systems. Production planning and control.17:2, pp.94-98. (2006)
[9] N. Gopalakrishnan. Simplified six sigma: Methodology, Tools and Implementation. New Delhi: PHI learning Private limited. (2013)
[10] D. H., Bester field. Quality improvement. 9th ed. united states of America: Pearson. (2013)
[11] I. Veza & T. Grubic. Improvement of a production process with the use of Six Sigma Methodology. International scientific Conference: University of Mostar 23rd -24th September.2004.
[12] H. Roshan. Process optimization as a tool in the analysis of steel casting defects, Maynard steel casting company. (2005) [13] W. H. Woodall & D. C., Montgomery. An overview of six sigma. Journal of international statistical institute, 3(76), 2008.pp. 329-346.
[14] M. Sokovic, J. Jovanovic, Z. Krivokapic, & A. Vujovic. Basic Tools in continuous Improvement process. Journal of Mechanical Engineering, 55(5), pp. 333-341. (2009).
[15] G. Brue, Six Sigma for managers. United States of America: Mc graw-hill. (2002)
[16] C. E., Jones., M. Mallet& G. S., Adams. A frame work for effective Six Sigma implementation. Total quality management, 21(4), (2010). pp. 415-424.
[17] T. R., Vijayaram, S., Sulaiman, A. M. S., Hamouda, & M. H. M., Ahmad. Foundry quality control aspects and prospects to reduce scrap rework and rejection in metal casting manufacturing industries. Journal of Material processing technology, 178, (2006). pp. 39-43.
[18] Z. Mpanza, D. Nyembwe, & H. Nel. Investigating the impact of poor utilization of quality management system in a South African foundry, SAIIE25Proceedings,9th-11th of July 2013, Stellenbosch, South Africa pp. 5661-5
[19] P.R., Beeley. Foundry Technology.2nded. Butterworth: Heinemann. (2000)
[20] J. R., Brown. Foseco Ferrous Froundryman's Handbook. New Delhi: Butterworth- Heinemann. (2000)
[21] J., Berglund. J., Michaloski., S. Leong., G. Shao., Frank Riddick., J. Arinez, & S. Biller. Energy efficiency analysis for a casting production system; Proceedings of the Winter Simulation Conference. National Institute of Standards and Technology Gaithersburg, MD 20899, USA. (2011). [Online] Available at https://ws680.nist.gov/publication/get_pdf.cfm?pub_id=909011
[Accessed on 14November 2018]