BENEFITS OF INDUSTRY 4.0 IN FOUNDRY ENGINEERING'S GREENSAND MOULDING PROCESS.

Farai Chrispen Banganayi[1], Hannelie Nel [2], Kasongo Nyembwe[3]

Abstract

There is a need to introduce modern technologies to address inefficiencies in foundry engineering. The foundry industry is very old dating back as far as 1479. The early foundry engineers produced metal castings which were mainly cannons and bells. Foundries have been slow to adapt to disruptive technologies. However with the 4th industrial revolution foundries cannot afford to miss out. Foundry Engineering which is metal casting is under a lot of pressure from other competing manufacturing technologies. Forging, fabrications and 3D metal printing, plastic and composite materials are competitors to metal casting. The most common and cheapest way of producing castings is in greensand. This is due to the fact that it uses low cost raw materials. Though the process is cheaper than other casting processes. There is always a need for improving efficiencies in the means of production to compete with other manufacturing technologies. The 4th industrial revolution has become a pillar of improving competiveness in the metal casting process. This paper evaluates how the first cloud based green sand data analytic software Sandman plays a role in contributing towards the achievement of the sustainable development goals in African foundries. The greensand data analytic programme has been seen to be a key resource in driving for responsible consumption and production. This study will provide knowledge on the benefits of using a data analytic software in greensand moulding.

Keywords: Sustainable, Development, Foundry, Industry 4.0

1. Introduction

The metal casting manufacturing processes, involves making objects by pouring hot metal into a mould. Whilst a mould is an impression in the sand shaped to correspond to the required casting, produced by ramming sand on the pattern. The pattern is withdrawn from the sand to enable the mould to receive the molten metal (American Foundry Society, 2009). The global metal casting industry is facing several challenges and these include demand and constraints on our valuable resources, human, intellectual, financial and natural resources. It is therefore our responsibility to maximise and not waste the resources for the benefit of the future generations (Prucha, 2014).

[1]University of Johannesburg; Metal Casting Technology Station Institution; Cnr Siemert and Beit Streets Doornfontein 2028 Johannesburg;+27115596390; fcbanganayi@uj.ac.za.
[2] University of Johannesburg; Department of Postgraduate Studies in Engineering Management; Cnr Siemert and Beit Streets Doornfontein 2028 Johannesburg ;+27115591711; Hannelien@uj.ac.za
[3]University of Johannesburg; Department of Metallurgy; Cnr Siemert and Beit Streets Doornfontein 2028 Johannesburg;+27115596181; dnyembwe@uj.ac.za

The metal casting industry needs to look beyond production and invest in marketing, human capital development and management to have a strong future and enhanced sustainability (Spada, 2014).Currently, due to short product lead times, small-quantity batch production, diversified consumer needs, and inconsistent demand fluctuations, manufacturing companies are trying to achieve innovation, such as flexible and predictive production, in contrast to the mass production that is a typical manufacturing method. In terms of technologies that support manufacturing innovation, information and communication technologies (ICT) including enterprise resource (ERP) planning, manufacturing execution systems (MES), and programmable logic controller automated factories significantly improve productivity. However, they are unable to meet current production needs such as reducing manufacturing lead times and producing small and customized products (JuneHyuck, Sang Do, Hyun-Jung and Yong-Shin, 2018**).** Foundry operations need to be driven by sustainable development goals. Sustainability is the new approach to innovation and gaining competitive advantage. Sustainability drives innovation by driving new design constraints that determine how essential resources, energy, water, materials and waste are used in products and processes. Sustainability is the mother of technological and organisational innovations that gives both bottom line and top line returns. Companies need to modify their ways of doing business or introduce new ways of conducting business for them to survive. The benefits of sustainability are indisputable these include cost savings, compliance, quality improvements and enhancing reputation among others (Cooper, 2014).Casting defects are a major challenge in foundries and can be reduced by determining and controlling the relevant process parameters, through application of domain knowledge. This is however, a challenging task since the parameters vary within a wide range; and it is not easy to determine the specific range of values that should be avoided to prevent the defects (Sata, 2016).

Industry 4.0 is a strategic initiative introduced by the German government with the aim of transforming industrial manufacturing processes through digitisation. Industry 4.0 is key to handling big amounts of data. This data needs a lot of analytics to convert it to useful information. The data then supports solid actions, which is the backbone of an adaptive, continuously self-optimising process (Rojko, 2017). The fourth industrial revolution is growing and evolves around Internet of things (IoT), big data, and artificial intelligence (AI) (JuneHyuck, *etal*, 2018). In this modern society most industries have accepted the power of data analytics and adopted it in one way or another. Industries are striving to enable IOT integration in their production and anticipating to get profits out of the data analytics (Chowdary and Krishnan, 2018)

2. Building blocks of Industry 4.0 in the greensand moulding process.

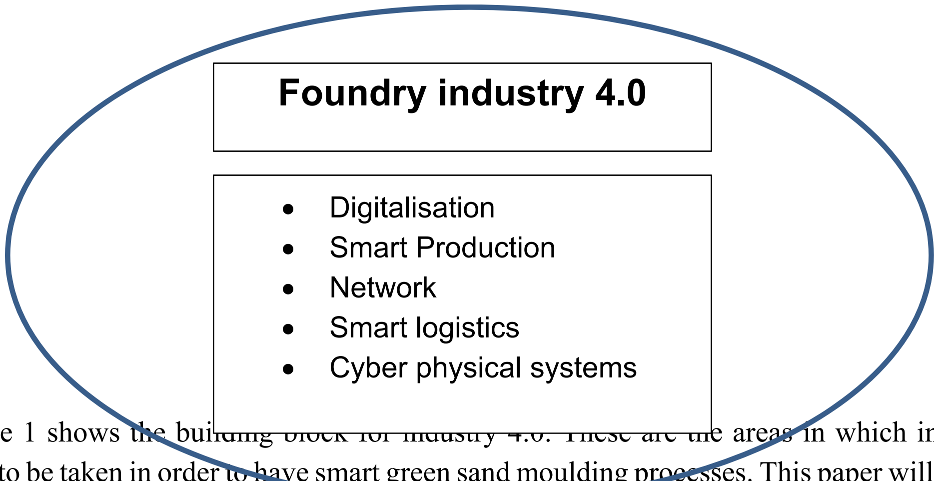

Figure 1 shows the building block for industry 4.0. These are the areas in which interventions need to be taken in order to have smart green sand moulding processes. This paper will breakdown different areas within the greensand moulding process were information has been taken to supply

Figure 1: Building blocks of Industry 4.0 in greensand foundries

to the various industry 4.0 building blocks in figure 1. This information will then be used in the integration which is what makes industry 4.0

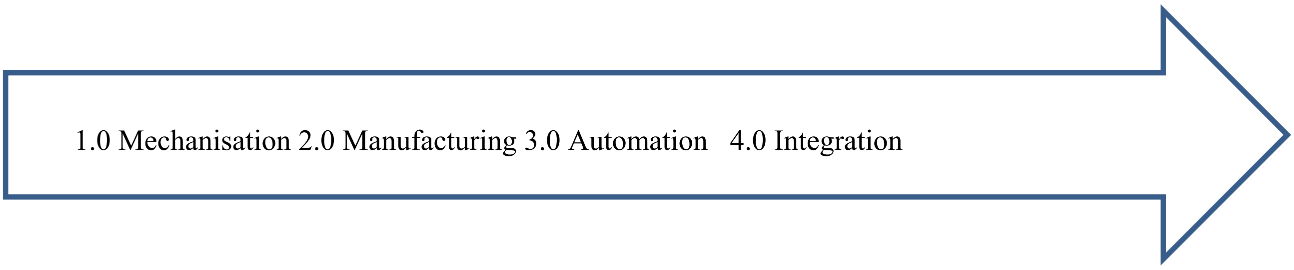

Figure 2: Evolution of industry 4.0

The greensand moulding processes has evolved from compaction moulding to pneumatic moulding machines then to high pressure moulding machines (Kothari, 2018). This could be sequence in which greensand moulding has been evolving towards industry 4.0 based on the industrial evolution process in figure 2.

3. Integration of greensand moulding industry 4.0 building blocks and automation

3.1 Digitalisation

The process in the foundry starts from digitisation which is converting manual information into the digital format. Digitisation is then followed by digitalisation whereby the results from the digitisation process are used to enhance business processes. Digitisation is very much possible to achieve in most areas of the foundry were data is collected. However based on the definitions there could be a number of foundries that are digitised but however have not attained digitalisation. This is because the information will be collected in a digital format but is not put to use in the business processes.

In most cases sand casting foundries collect moulding related data from the following sources

1. Production planning data
2. Sand preparation data
3. Sand testing data
4. Quality Control/Inspection

3.2 Smart Production

Cyber Physical Production systems (CPPS) is a promising technology of Industry 4.0 and an essential component of a smart factories. Specifically, CPPS are composed of collaborating computational entities that connect the cyber world with the surrounding physical environments or processes through data access in an internet environment. Smart factories allow the collection of massive amounts of in-plant data through real-time synchronization of the factory components and information systems, and they also improve quality and productivity through smart and flexible responses to abnormal situations that occur in a plan. Currently foundries have different components that can collect data but however this data faces a challenge of being synchronised because the other component with the data that needs to be synchronised is not capable or does not have sensors to collect the required data.

In a greensand foundry the equipment below are capable of collecting data;

1. Sand laboratory equipment.
2. Sand mixers
3. Moulding line
4. Humidity and temperature loggers

3.3 Smart Data

Smart data is data that can be collected and acted upon from collection before analytics can be done. Therefore smart data can be used in the decision making purpose for a specification action in real time.

Currently in the greensand moulding the most highly sources of smart data is

1. Humidity and temperature loggers

This source of data will be able to directly control the compactibility set points on the moulding line.

3.4 Industrial Networking

This is the collection of technologies at the internet protocol layer and below that enables transformation of industries. This forms the foundation of industrial internet of things (IIOT) were the industrial assets which are machines, environments and sites are connected to business professionals and processes. The network is an important infrastructure that supports various application needs and different deployment situations in the wide range of industry sectors. (Zhe Lou, 2018).

In greensand moulding connections are needed between the following professionals and processes.

1. Melting
2. Coremaking
3. Sand mixing/preparation
4. Moulding process
5. Sand reclamation/regeneration process
6. Fettling Process
7. Quality control Process
8. Technicians
9. Operators
10. Technical Professionals
11. Process Professionals

12. Production Professionals
13. Maintenance Professionals

Through the network we can get self-optimising processes.

3.5 Smart Logistics

Smart Logistics is related to planning and control by tools, means and intelligent methods, the degree of intelligence depends on the applications and methods used since the traceability of products and the identification of the elements of its environment until the detection of the problem, the choice and the automatic execution of the solution. Douaioui (, 2018).

The logistics in greensand moulding have to do with information from the following processes;

1. Melting
2. Coremaking
3. Sand preparation
4. Moulding
5. Sand reclamation/regeneration
6. Fettling
7. Quality control

4. Sandman benefits of industry 4.0 in greensand moulding from implementation in African foundries.

4.1 Benefits realised during data collection

The implementation of sandman has immediate benefits before you can even start running the software programme. As you progress with collecting data and putting it in the format required by the programme you continue to accrue benefits. Collecting and arranging the data required by sandman is systematic. The final benefits are realised during use of the programme specifically that require networking and analytics.

4.1.1 Centralisation of data

Initially most of the data in the foundry was in different locations with different people. This system enabled all the production data required to produce a casting to be put in one central place. This makes it convenience especially when information pertaining a particular casting is required. There is a central place were information can be obtained in the foundry. In this case information from all the different foundry sub processes can be found in one place.

4.1.2 Disintegration of data

Part of the data was summarised data. Digitisation enabled the foundry to disintegrate their data. The data was summarised as monthly consumption, for new sand, bentonite and water. The digitisation enabled the consumption data to be broken down to component, shift, and day wise.

Disintegration of data becomes key to smart logistics. This allows you to be better able to plan and not waste resources and financial resources on unnecessary inventory especially when it comes to materials used for production.

4.1.3 Collection of previously neglected data

Additional data was collected which was previously ignored. Amount of core sand used per part was compiled as part of the component master enabling core sand to be measured more accurately to the lowest level of production. There are a number of areas in the foundry where production takes place and a lot is missed out because the data is not recorded. Industry 4.0 big data concept plays a key role where data is collected whether smart or raw. The ultimate goal is it will eventually be taken through some analytics engine so that it helps the foundry engineers to make informed decisions.

4.2 Benefits realised when using the programme

The use of the programme mainly has to do with benefits derived from data analytics. The benefits are mainly to do with, cyber physical systems, smart production, smart logistics and network. This is the rea in which most of the value is significantly derived from algorithms.

4.2.1 Variable dose by need

There is now some degree of flexibility in the way different casting components are produced. The addition of water, bentonite, coal dust and new sand changed from being on a flat addition depending on sand test results and moved away from irregular based on sand laboratory tests and specification limits to a component wise or shift wise based on analysed data. Depending upon the planned production additions can be shift wise or component wise. This is the initial benefit that you get when you start using the software programme after uploading and cleaning the data.

4.2.2 Informed decision making

The foundry is now equipped with all its production data related to greensand moulding in one place. This allows the foundry to pull out the data it would like to use at a click of a button and make informed decisions. The data collected is mainly big data. The data is then refined by the use of algorithms and regressions in data analytics this point in time the data becomes smart. The programme is now able to tell something meaningful to the foundry engineer. Based upon the analysed data the foundry engineer was capable of making informed decisions.

4.2.3 Prescriptive analytics

The sandman software is capable of prescribing to the foundry what recipe to use in each shift. The tool is so specific to the extent that it gives you a dosage component wise and defect wise to reduce any particular defect with the ability of telling you your next sand test results after changes with a high confidence interval. The programme was capable of determining the condition of greensand in advance and prescribing the dosage of bentonite, coal dust and water in order to have optimal quality on that particular shift, day, or casting component.

4.2.4 Reduction in defects /improved Quality

The reduction in defects is the key to the software with cumulative benefits in other areas. Reduction in defects refers to the production of good quality castings. This provides customer satisfaction, reduces the lead times, fettling shop consumables savings, energy savings. The most important feature to this benefit is we now involve the product which is to be sold to the customer. On top of all the other process related raw material savings we now have metal. The biggest cost in the foundry is energy which has to do with melting metal. If there are defects chances are high that the components might need to be produced again depending on severity.

4.2.5 Increased raw material savings

The prescriptive analytics, dose by need and improved quality contribute to the savings in raw material and energy usage. Therefore the greensand moulding process becomes self-optimising production system within industry 4.0‘s cyber physical production systems. There is a significant amount of savings that you get from input materials at the initial stages of implementation. Ounce the system is stable it then maintains and continuously makes it better but in this case the savings are not as significant as at the start. The saving of energy is good for climate change since it reduces the emissions of greenhouse gases especially for African countries that rely mainly on fossil fuels for energy.

4.2.6 Internet of things

The internet of things that comes with this programme assists in monitoring of humidity and temperature which have a great influence on the preparation of greensand. The humidity and temperature controller allows for adequate moisture additions to the greensand and automatic adjustment of compactibility set points which are coherent to the environmental conditions at the given time. This is smart data at source. This innovation is a contributor towards industry innovation and infrastructure development.

4.2.7 Real time semi-automated tools.

The programme provides real time automated tools like histograms, run charts, trends, Pareto, analysis of variance (ANOVA). This significantly reduces the amount of time required by process engineers to come up with these tools and therefore being able to divert that time to other value adding activities.

4.2.8 Communication and institutional knowledge

The programme can improve communication within the foundry by communicating to relevant personnel on actions taken and process parameters in the greensand moulding plant via email and automated text messages. The programme has a feature for annotations which build up institutional knowledge with respect to any changes in the plant and how they affected the greensand moulding process.

4.2.9 Upskilling of Operators.

The operators can now load their information on tablets instead of writing manually on paper. The operators have now been upskilled by being provided and trained to use computers and tablets in their respective work areas.

5. Conclusion

Industry 4.0 brings phenomenal benefits in the operation of green sand moulding lines. The different elements of Industry 4.0 when combined have the potential of making very useful tools that eliminate waste and significantly increase efficiency whilst allowing for flexibility on products manufactured on greensand moulding lines. The benefits attained from industry 4.0 in green sand moulding contribute significantly to sustainable development goals under industry innovation and infrastructure SDG 9, responsible consumption and production SDG 12, and climate action SDG13. Based on these implementations it was observed that greensand foundries have a lot of potential to become smart factories. However the foundries need to first digitise their data.

6. References

1. American Foundry Society. (2009). *Pattermaking handbook* (3rd ed.). Illionis: AFS.

2. Chowdary , D., & Krishnan, M. (2019). Reducing Rejections and Optimizing Additive Consumption by Data Analytics, Machine Learning and IoT – The Next Dimension for Industry 4.0 in Foundry Sand Molding Process Technology. *68th Indian Foundry Congress.* Chennai : Institute of Indian Foundrymen .

3. Cooper , D. (2014). Sustainability is the key driver of innovation. Bilbao: World Foundry Congress.

4. JuneHyuck, L., Sangdo, N., Hyun-Jung, K., & Yong-Shin, K. (2018). Implementation of Cyber-Physical Production Systems for Quality Prediction and Operational Control in Metal Casting . *Sensors* , 1-17.

5. Prucha , T. (2014). Applying the Principles of 7-Is to improve Technology Transfer. Bilbao : World Foundry Congress.

6. Rojko, A. (2017). Industry 4.0 concept Background and Overview. *IJIM*, 77-90.

7. Sata, A. (2017). Bayesian inference-based investment-casting defect analysis system for industrial application. *The International Journal of Advanced Manufacturing Technology*, 3301-3315.

8. Spada, A. (2014). Global Metal Casting Asssessing our Strengths and Weaknesses and Developing Inputs for aSustainable Future. Bilbao: World Foundry Congress.

9. ZheLou , D; Holler, J; Whitehead , C; Germanos , S; Hilgner , M; Wei, Q. (2018). *Industrial Networking Enabling IIoT Communication.* Industrial Internet Consortium.