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An Application of PARETO Chart for Investigation of Defects in FNB Casting Process

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Abstract

Casting is one of the widely used manufacturing processes consisting of melting and pouring the metal into the mould to get the desired shape. Furan no-bake system is a binder system consisting of furan resin and acid catalyst. It is a fast growing system due to its excellent surface finish and dimensional accuracy. Although having high dimensional accuracy, many defects arise in FNB casting such as sand inclusion, gas porosity, blowholes, cold run, slag, hard metal etc. The defects such as sand inclusions, gas porosity and hard metal contribute more than 50% of total defects. The major defect arising in FNB casting is sand inclusion defect. Pareto chart enables ordering and easy to understand analysis of gathered digital dates. This paper describes the identification of major defect sand inclusion in furan no-bake casting by application of modern and selected quality management tool, Pareto chart. The Pareto chart assists to check and determine defect priority related to furan no-bake castings.

***Keywords**: Defect, FNB, Pareto, sand inclusion*

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INTRODUCTION

Resin type binder which is catalyst (acid) cured, was introduced in 1950's in no-bake binder family, known as Furan binder. It has become the largest selling and consumed binder after 30 years of invention. Furan no-bake is simple two part binder system having one part of furfuryl alcohol and other part of sulphonic acid. It is having wide utility in terms of size and material. The amount of furfuryl alcohol usually taken is 0.9 to 1.2% based on sand and levels of sulphonic acid from 20 to 40% based on binder weight.

It finds tremendous response in terms of applicability and wide acceptance due to reduced defects at mould metal interface, excellent dimensional stability and internal integrity, and excellent shakeout with thermal or mechanical reclamation. The sand reclamation can be possible with furan binder sand and up to 95% reclamation and 5% new sand. Industries are striving for quality and quality development due to development of modern technologies [1–4].

Quality control of FNB castings is a complex process which requires the accurate and précised choice of identification and diagnostic methods of quality parameters [5]. The user demands the best fit quality product and the producers and manufacturers are obliged to produce the same i.e., which meets the maximum expectations defined by the user. Quality checks are done to check the products.

Quality checks/tests are defined as tool to check whether product meets up specific standards and requirements. The collection and analysis of data related to quality parameters which are assisting in quality inspection are done with the help of quality management tools. These tools include Shewhart control charts, histograms, ishikawa fishbone diagrams, control sheets, variable correlation diagrams and Pareto charts.

There are standardized instruments which are applied for diagnosing and monitoring the processes of control assembly, manufacturing, design and similar other activities of product life cycle. This paper indicates application of control sheets for drawing Pareto charts, for identifying defects occurring in furan no-bake castings. Primary objective was the prioritization of these defects, for description of defect by quality management tool and to specify the quality properties of FNB castings.

Pareto charts are majorly used for quantifying defects of FNB casting. It enables ordering and easy to understand analysis of gathered digital dates. The system of gathering the dates and its reliability decide about the system usefulness. The charts show the percentage of defects occurring every month.

LITERATURE REVIEW

Woldert stated that the desired quality of moulding sand can be obtained by maintaining desired and optimum values of parameters of sand such as residual dust content, sand temperature and loss on ignition etc. [6]. He also related the quality of binder consumption quality of casting surface with quality of sand. He also suggested that furan resin sand should be used in order to get high sand strength to large size casting moulds that will ultimately reduce or eradicate sand inclusion defect. Ravi described a collaborative system for obtaining quality castings in which integration of methodology, part design, process planning optimization, tool design and its feedback to part design is provided [1]. He specified control parameters for each phase like feeding and gating system for methods, wall thickness for part design, pouring temperature for process etc. He has defined quality as conformance of ‘as cast’ parts with the categorized and design conformance into three, prosperity, integrity and geometry. As per his research, sand inclusion is caused due to integrity nonconformance by pouring process and metal melting process. His survey of 200 foundries indicates 7.4% rejection due to integrity defects itself. Dobrzanski studied defect analysis using microscopic images and concluded that defects can be minimized by proper controlling of the process [2]. He analyzed that reduction of defects using computer technology will ultimately reduce cost and environmental pollution. Borowiecki studied casting defects using Pareto charts and concluded that gating system should be given more importance in order to produce quality castings [3]. Defects occur in casting due to improper construction of gating system. He also advised directional solidification of casting. Falecki *et al.* explained that shrinkage occurs only where liquid metal is fed improperly [4]. Also the reasons can be hot moulding sand or wrong projection of gating system. Jadhav *et al.* studied quality control tools for reducing defects and concluded that correct identification of defect is necessary for defect minimization on its primary stage [7]. They presented the systematic approach to find cold shut defect. They also found the main reasons for the defect were pouring temperature and alloy composition. Their analysis showed the reduction of defect from 12 to 6.6%. Gawdzinska studied ishikawa charts and Pareto charts for identifying major defects occurring in metal composite castings [8]. He concluded that each weighted ishikawa diagrams should be studied properly to find quantitative information on cause of each defect and higher the weighted value of cause, higher is the percentage of defects occurring due to that cause. Mays *et al.* explained that prevention of defect can improve both productivity and quality [9]. If the number of defects injected is reduced, then the quality improves as the number of residual defects decreases. Fewer injected defects reduce efforts and integrally reduce costs, increasing productivity and quality. Shivappa *et al.* analyzed casting defects and identified remedial measures for eradicating them [10]. Their diagnostic study shows the causes of sand drop, blowholes, mismatch of castings and casting oversize and remedies for the defects such as cleaning of the mould, modification of gating systems, proper setting of cores and clamping of moulds properly to withstand the pressure of pouring. Sandhya *et al.* suggested foundry parameters to reduce defects of castings and concluded that foundry process involves many stages [5]. At each stage no. of defects rises and appropriate measures are to be taken up. Their study showed the improvement of performance and efficiency level of casting by a six sigma approach. They improved the quality by six sigma approach of parameters at lowest possible cost. Main focus was on blowholes and shrinkage which have higher account in total rejection of foundry. Sharma *et al.* explained classification of defects of castings in aluminium die castings which are grouped according to their sources from which they can

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be detected [11]. This study helps the caster to take proper corrective actions to identify and eradicate the raised defects. Mane *et al*. carried out casting defect analysis using if then rules, ANN, DOE etc. which mainly focused on identifying the casting defects individually and classify them in terms of shape, size, consistency, inspection method and location [12]. They also proposed new hybrid approach for defect analysis. Ravi *et al.* proposed timely inspection of techniques based on control of quality to avoid occurrence of defects in the products [13]. They suggested collection of information of components leading to rejection and further analysis of rejection using Pareto charts and control rejection using proper remedies. Chokkalingam *et al.* has presented cause and effect diagram for sand drop, sand inclusion and stressed the need of proper root cause identification to help in defect elimination [14]. According to them, the improper procedure and parameter control during sand, gating and mould preparation, wrong core, mould, gating system design etc. result in sand drop and in sand inclusion. The different major causes are categorized and are represented by cause and effect diagram in the paper. Jolly stated that the liquid front should not move too fast to avoid formation of inclusions [15]. Alagarsami has explained a systematic approach to defect identification, defect mapping and use of analytical techniques like Design of Experiments (DOE) to find root causes of the defect [16]. According to him, sand and slag inclusions are ambiguous defects. He stressed the importance of process data and defects documentation like time of making castings, location of defect in casting etc. For analysis of defect formation, Siekanski *et al*. have prepared ishikawa diagram for non-conformities during pouring operation of CI and considered sand inclusion as one of the reasons for mechanical failure of material [17]. The data of foundry defects like sand hole, drop and sand buckle etc. are collected. It is concluded from the diagram that the poor casting quality is mainly because of negligence of employees, process parameters and procedures non-compliance etc. Acharya *et al.* by experiments gave the solution to have best compressive strength of mould by suitable percentage of resin and temperature [18]. The good quality FNB mould system minimized defect by improving quality of casting.

ANALYSIS OF CASTING DEFECTS USING PARETO CHARTS

The index of percent of faulty castings (for test period of 12 months) was oscillated in the range from 5.2 to 8%. There, some defects of most cases of produced castings frequently have been displayed, for example, the per cent participate of assortment concerned: Sand inclusion 30%, gas porosity 30% and hard metal 10%.

On the basis of received results, authors have drawn different Pareto charts for different months. Cumulated values have been located on vertical axis, while on horizontal axis, casting defects in per cent scale. On the basis of received graph it has been affirmed that in more than 50% of general number of casting defects, it composed of three types of defects: sand inclusion, gas porosity and hard metal. The three defects indicate that it is necessary to modify quantity of resin, types of sand and their GFN, resin to sand ratio, binder to catalyst ratio, pouring temperature, pouring height and molten metal flow rate. The remaining four types of defects have affected less than 40% of faulty casting. Analysis of received results permits to determine the direction of correct actions in order to limit or to eliminate the three most effective defects.

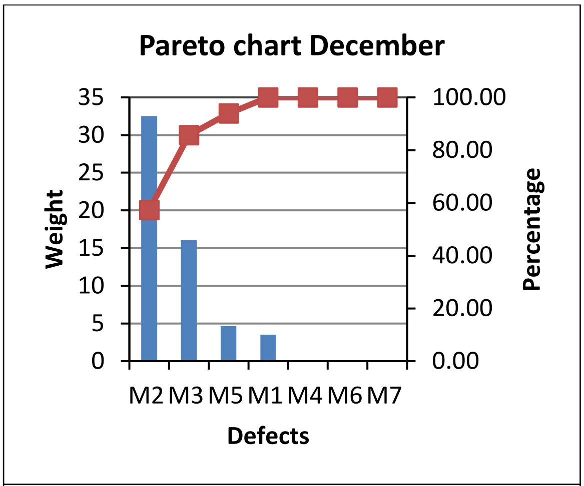
Quality control on a stage of selection of the manufacturing process is concerned with product design. The selection of manufacturing process consists of engineering process selection, quality control and auxiliary’s process, starting from material properties through inter-operation control to inspection and testing of final products. The selection of engineering process, apparatus and tools, essential machines, installation and special instrumentation consist of the selection of manufacturing process. During selection of manufacturing process, an enterprise should plan and work out the process necessary for realization of the product.

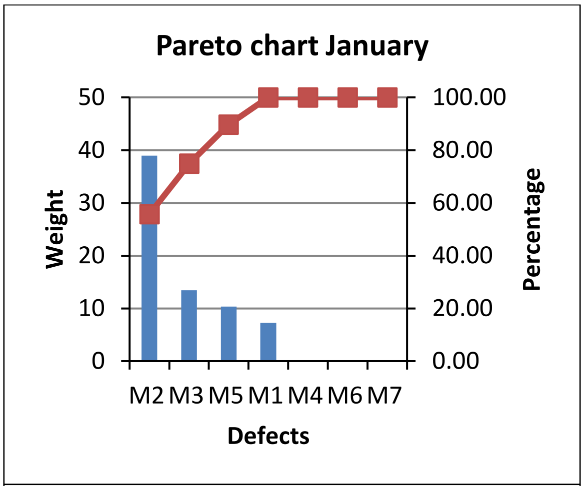
The product realization and planning should be coherent with the requirements concerning other process of quality management system.

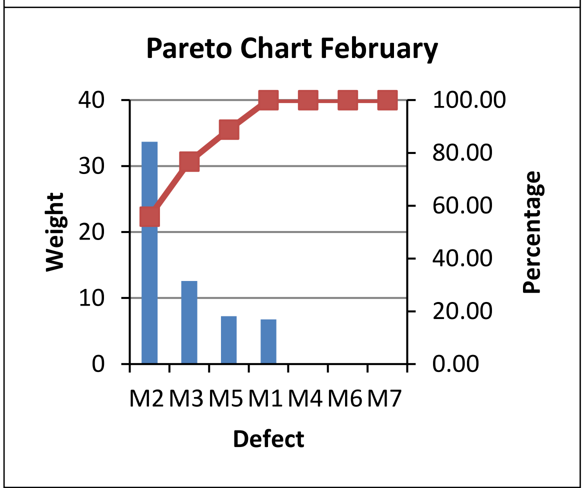
For planning the product realization, the enterprise should define:

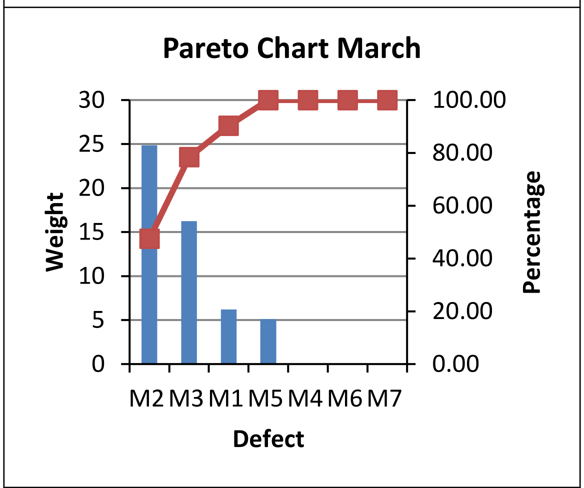
- Requirements and aims concerning the product and quality respectively.
- Keeping records and documentation, providing specific resources for the product as well as production [19].
- Actions required concerning validation, tests and monitoring control and verification.
- Necessary recording of evidences to prove that process and product meet the quality requirements.

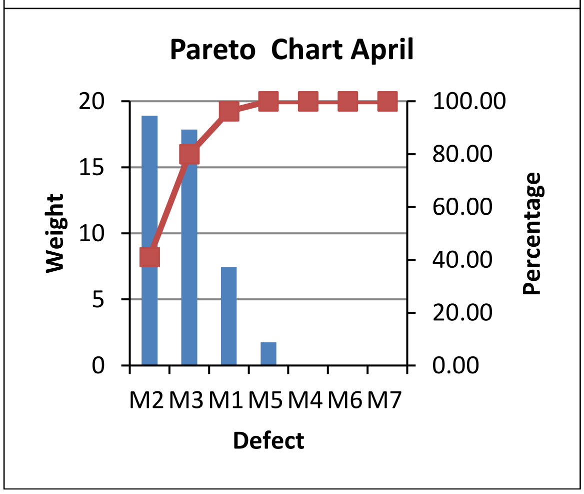
The connections among different groups which are participating in planning and development should be managed by enterprise in order to have a clear determination of responsibility and proper and effective communication [20].

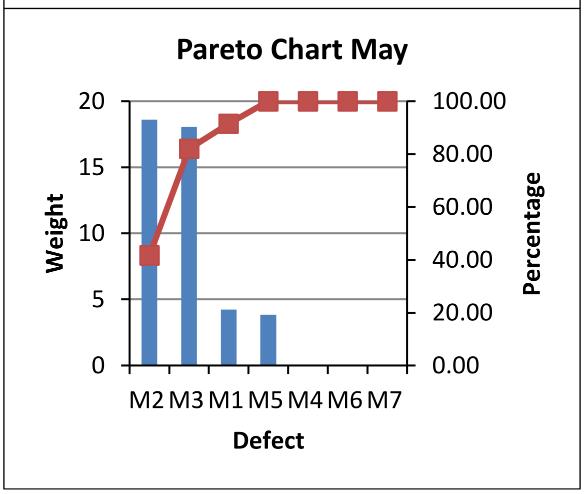












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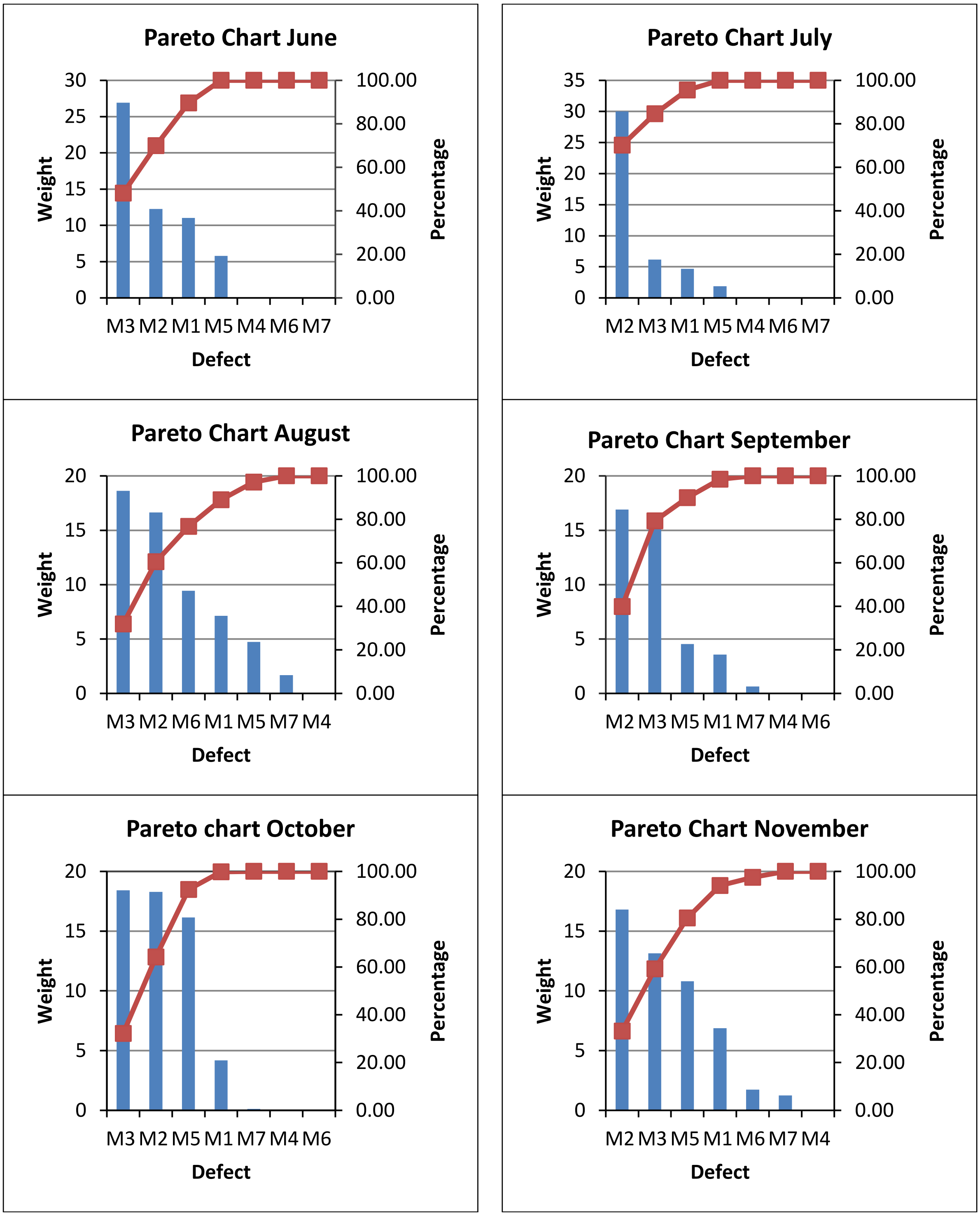

Fig. 1: *Pareto Charts of Defects from December to November (All Seasons). Nomenclature: M1: cold run/cold shut, M2: sand inclusion, M3: gas porosity/blow holes, M4: high temperature shrinkage, M5: hard metal, M6: short pouring and M7: slag*

RESULTS AND DISCUSSION

From the Pareto charts for 12 months we can see the contribution of different seven defects and majorly three defects namely sand inclusion, gas porosity and hard metal (Figure 1). The following Table 1 shows the percentage contribution of three defects per month. Here we can see that these three defects namely sand inclusion, gas porosity and hard metal contribute more than 50% almost every month [21].

Table 1: *% Defects Occurring Per Month.*

Month	M2 (%)	M3 (%)	M5 (%)
December	32.53	16.06	4.65
January	38.96	13.41	10.34
February	33.7	12.6	7.27
March	24.87	16.24	5.12
April	18.9	17.85	1.77
May	18.62	18.06	3.84
June	12.26	26.94	5.78
July	30	6.17	1.87
August	16.64	18.62	4.73
September	16.9	16.63	4.54
October	64.19	18.42	16.15
November	16.81	13.15	10.8

CONCLUSION

Different parameters are affecting on the cause of defects such as incorrect quantity of resin, incorrect sand to binder ratio, binder to catalyst ratio, incorrect pouring height, contaminated molten metal, incorrect gating design etc. In FNB system, casting defects mainly arise due to incorrect gating design, improper resin to sand ratio and improper binder to catalyst ratio. Major defects arising in FNB casting are sand inclusion, gas porosity and hard metal, out of which sand inclusion contributes maximum to casting rejection, which is more than 30% of actual casting defects. Generally, gating design plays a very vital role for green sand casting defects such as sand inclusion, but for furan no-bake mould system, over and above gating design, sand to resin ratio, pouring height, and pouring temperature are very vital parameters for sand inclusion. Furan resin gives compressive strength to sand mould system. So, in order to have a quality casting we should have proper quantity of resin to sand ratio and catalyst to binder ratio.

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