IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 16, Issue 3 Ser. V (May. - June. 2019), PP 23-33
www.iosrjournals.org

Production Performance Assessment Using Lean Tools in Small and Medium Scale Industries of Central Karnataka

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Abstract: *In the era of globalization and privatization, manufacturing firms are greatly relying upon the principle of quality to fight with the challenges of current market trends. In developing nation like India, Small and Medium scale industries (SMEs) play a vital role in providing employment and boosting the economy of the country. By adopting the suitable lean tools productivity can be enhanced considerably. The concepts of lean management to increase productivity and reduce rejection in forging industries of small and medium scale in the area of central Karnataka, India, is implemented. In this paper work detail investigation on quality improvement of castings by applying lean tool such as Pareto analysis and Cause-Effect Diagram in casting SMEs is provided. Flow mark, Thread Damage, Silver steak mark, half shot, and Black spot are the major contributors for maximum percentage rejection of cylinder liners obtained from casting and forging. The materials, methods, and machine involved in the resultant effect are observed using the cause-effect diagram. By suggesting various findings and successful implementation of those, the rate of rejection for the month of May to August has reduced from 5.62% to 4.45 %.*

Keywords: *Lean; forging; casting; cylinder liner; cause-effect; Pareto analysis.*

Date of Submission: 08-06-2019 Date of acceptance: 25-06-2019

I. Introduction

It is well know that over the last decades, lean production and the search for measuring performance in organizations has been in the agenda of academics and market professionals. The search for competitiveness is forcing companies to review old industry paradigms, promoting a clear transition from traditional mass production to lean production. These methods have significant differences within specific operations management area. Based on scale economies principle the concept of mass production is developed. Whereas the aim of lean production is to provide and develop what client requests by simplification of processes and maximization of waste elimination[1], [2]. From the wide perspectives of the production methods it is well known that every single process/technique has its own particulars for performance measurement. Still the coupled role of performance indicators with lean production in the area of operations management is little understood. This alignment of lean and performance indicators required helps in developing a performance measurement tool which can boost the model for management practices in order to guide the decision makers in an optimized suitable way. The important agenda of an industry which decides to practice lean philosophy will be to develop a method which can allow to reduce cost and improve the market share[3]–[5]. On the other side if a proper strategy is not adopted by selecting relevant lean tools in the industry to reduce the cost of the production, the outcome could lead to frustration in employer and workers for improper results and erroneous emotion of increase in cost. Any performance measurement system will have to demonstrate to the organization if it is going in the right direction, continuously monitoring its movements. Therefore, a company wishing to be lean must have like any other organization a performance measurement system to show if their goals are being met[6]–[8].

Enough methods and strategies are adopted in the area of production performance measures and lean manufacturing tools. Carr and Hasan [9] have provided the recent status of performance measurement systems in New Zealand manufacturing companies and determined the approaches towards the performance measurement. The respondents revealed that the non-financial measures are being used more frequently than the financial. It was observed that the majority of the respondent's information systems are not giving good support to their performance measurement endeavors. More accurately speaking, the respondents information systems were still very much familiar to the historical dominance of the financials. World class performance measurement techniques were also used, and indications of financial as well as non-financial measures were also noted. It also showed that the performance measures should be implemented as a means of articulating strategy and monitoring business results[9].The importance of performance measurement has long been recognized by academics and practitioners from a variety of functional disciplines. Neely et al. [10]focused on the importance of performance measurement. Karim and Chowdury [11] explained lean manufacturing as a systematic approach of identifying and eliminating waste (non-value-added activities) through continuous improvement by flowing the product at the pull of the customer in pursuit of perfection. Susilawati, et al. [12] reviewed the lean manufacturing activities preparing the suitable models the lean work which can be implemented.

Breyfogle [13] emphasized on learning of lean tools which gives an opening for customer value, focusing on the value stream, making value flow, and letting customers determine the product or service they want, with a relentless pursuit of perfection in a timely manner at an appropriate price. In short the elimination of waste leads to productivity. Kukrejaet al. [14] described about the foundry problems such as raw material shortage, man power problems which are responsible for low production. As Indian small and medium scale industries play a very important role in Indian economy it was necessary to find the causes and their analysis is to be done. Focus was on the production rate at small to medium foundry industry. By the application of lean tools such as Kaizen, Kanban and 5S there was an improvement in the production efficiency. Ramachander [15] gave guidelines of Indian Standard which indicate the achievable percentage rejection in a foundry and some of the common defects in castings, their causes and remedies. Using the modern method and suitable techniques, production of quality casting to satisfy the customer requirement was easy. The guidelines and diagnosis chart were definitely helpful in improving the quality and yield of the casting. Castings are inspected with technologically advanced way, which keeps foundry men to alert condition for control of rejections and it will be within limit specified by the Indian standard. Many researchers have conducted experiments on sand process parameters and proved that they have successfully reduced the casting defects due to sand process up to 6% which varies in each case. The outcome of the work was quality of castings which depends on quality of sand, method of operation, quality of molten metal and environmental conditions etc. Rejection of the casting due to defects can be reduced for better quality. With continuous improvement and monitoring of foundry process as specified in the Indian Standard, it is possible to achieve the overall foundry rejection percentage of less than five percentages[16]–[18].

Bose and Kumar [19] studied the rejection rate in one of the major issues in Indian foundry. By replacing the existing trial and error method with computer simulation foundries can reduce the rejection rate from 8.5 to 3.5 %. A same case study of a cylinder clamp casting of Milacron product, which is having high rejection rate in an Indian foundry. The defects of casting are solved using the proposed simulation model with Magma 5 software and the effective solutions have come out for reducing rejection rate for the product. Rajkolhe and Khan [20] pointed out the suffering of foundries in developing countries due to poor quality and reduction in productivity. By taking at most care about the different parameters defects in casting were observed and hence the process of uncertainty which challenges explanation about the cause of casting defects. Standardization (optimization) of process parameters are taken in to consideration. Defects in casting, analysis of defect and providing their remedies with their causes were analyzed.

Ahmed et al. [21] presented the importance of minimizing the defects to ensure the quality product. The study goes with if 1% defective product for an organization is 100% defective for the customer who buys that defective product. So manufacturing the quality product is mandatory to sustain in this global competitive market. Some suggestions so that the management can apply them to minimize the frequency of those defects is suggested effectively minimize reworks, rejection rate and waste of time that will ultimately increase productivity. Matt and Rauch [22] emphasized on the introduction and implementation of lean production principles in the small enterprises as these practices were successfully running with large scale industries. It is quite possible to implement the lean tools in small scale industries as they do have hidden potential. Further the enhancement of productivity by studying the suitable factors. Juriani [23] discussed the current scenario of globalization, as foundries play a key role for manufacturing industries as they are the major source of manufacturers. As a key industry a foundry's performance should be effectively high in terms of production with minimum number of rejections. The challenges of casting defects are to be identified and minimized for effective castings. Critical casting defects and their root cause analysis is made. Productivity is to be increased by decreasing the defects. Gama and Toledo [24] showed that if an organization chooses to go with lean production, it needs to understand its principles and so that the performance can be measured, there is a need to have performance indicators reviewed so they can support the new competitive strategy. The proposed model provided a clear and objective communication model on the vision and strategic objectives of the organization, facilitated by the visual management provided by a report and also to have consensus on the objectives among all involved.

The lean implementation in the small and medium scale industries through a vast knowledge of strategies which can be adopted for minimization of wastage. By adopting the suitable lean tools productivity can be enhanced considerably. As different types of wastes are studied in small and medium scale organizations, it is necessary to find an activity that does not create value and is not necessary, must be removed by production performance measurement. Specific application of lean manufacturing tools must be addressed to improve the productivity. The goal of this research is to investigate how lean manufacturing tools can be adapted in small and medium scale manufacturing environment, and to evaluate their benefits. The overall objective of this work is to systematically demonstrate how lean manufacturing tools when used appropriately can help the small and medium scale industries to eliminate waste and minimize rate of rejection. The relationship between waste reduction and quality is developed by application of lean manufacturing tools. The current state of production performance measurement systems in manufacturing industries in Karnataka is revisited and suitable evaluation methods are suggested. In this work only defects caused and rejection during production is taken into consideration for production performance among many factors affecting productivity.

II. Methodology

In this, the research work carried out contains use of quality tools to minimize defects and rework in small and medium scale industries. It includes the theoretical ideas about various defects, various quality tools specially Pareto Analysis and Cause-Effect diagram. This segment includes the understanding about the quality control system of the selected factory and how this could be improved. The conceptual development includes the generation of ideas for minimizing defects by identifying major concerning areas and by providing respective suggestions.

A questionnaire is sent out as a sample to nearby areas of central Karnataka, India manufacturing companies, to determine the current state of performance measurement systems. More specifically, manufacturers were asked to what extent they used various performance measures, whether they had a performance measurement system in place and if so, what type and whether or not they had an enterprise planning system or any information system to support their PMS (performance measurement systems).The organizations surveyed were selected on the basis that they were manufacturing oriented. The 129 small and medium organizations meeting this criterion were selected. Copies of the questionnaire and a covering letter were used for each of the identified manufacturing companies. The survey instrument was adopted from one used to examine organizations prescription to current performance measurement by studying the literature. The instrument was divided into three sections.

- Background and size of the respondent's organization.
- Existing means of performance measurement
- Any plan such as system or special software for new approach to implement performance measurement

A major limitation was the low response rate and some with incomplete information, which was probably due to lack of time for organizations. Study of correlation between enhancing the productivity and reducing the rejection by lean manufacturing techniques through production performance was focused. Development of model for productivity improvement through performance measurement and implementation of model in selected industry and validation of results.

2.1 Respondent Organization Profiles

The respondents with type of industry being small scale are 86.82% and medium scale is 13.18%. Generally small scale industries are the one who invest in plant and machineries more than 50 lakh rupees and less than 1 crore. Medium scale industries invest more than 1 crore and up to 10 crores. Also the respondents were spread over a range of industry groupings with the majority being, foundries at 57.36%,machine shops 21.79%, and fabrication shops 13.17% and general makers 7.75%. The largest manufacturer with numbers being foundry, followed by machine shops or workshops. The grouping of industry in small and medium scale in % is mentioned in Table 1. In Table 2 the classification of industries to which they belong is mentioned with their percentage.

Table 1. Classification of respondents by the Type of Industry

Type of industry	Respondents	
	Number	Percentage
Small	112	86.82%
Medium	17	13.18%
Combined	129	100%

Table 2. Classification of specific type of industry

Type of Industry	Number	Percentage
Foundries	74	57.36%
Machine Shops	28	21.79%
Fabrication shops	17	13.17%
General makers	10	7.75%
Combined	129	100%

The nature of organization visited were also noted. It was found that42.3%of the respondents said a private company. Of the remaining responses, 30% said they were a partnership and 16.7% were ‘other’. The other respondents were unspecified as “subsidiary company” and “co-operative company”. Balanced scorecard users were for the greater part publicly listed companies and the users of integrated performance measurement systems (IPMS) were predominantly private companies. The size of the companies varied greatly, from 22 to 350 employees, with annual revenue varying just as much, between Rs. 10 lakhs and Rs. 25 crores.

2.2 Performance Measures

When listing the performance measures to be rated on most, as much of 60% were with measuring of partial productivity. Most of the respondents reviews its performance measures regularly, regularly is a highly subjective work. Thus the participant’s answers to this question were based on their perception of what constituted ‘regularly’ for an organization. This gives rise to a potential inconsistency in the response to this question. The overall study of survey revealed about the need of systematic study in foundries as the major manufacturers being foundry in the said region.

Case Study

As foundry sector is a large industrial sector in Karnataka, India, quality improvement can play a vital role for improving production performance as well as economic development for the country. A case study is being conducted in Foundry, Central Karnataka, India as the survey questionnaires revealed about the majority being foundry with 57.36%.

Foundry industries in developing countries suffer from poor quality and productivity due to involvement of number of process parameter. Even in completely controlled process, defect in casting are observed and hence casting process is also known as process of uncertainty which challenges explanation about the cause of casting defects. In order to identify the casting defect and problem related to casting, the study is aimed in the present work. This will be beneficial in enhancing the yield of casting. India is the third largest casting manufacturer in the world; next only to China & USA. Installed Capacity of Indian Foundries is more than 15 Million Metric Tons/ Annum and Annual production is 9.3 Million Metric Tons and number of Foundries is 5000 (Approx.) out of which 85% are Small units; 10% are Medium Size Foundries and Only 5% are large organized units. Thus foundry sector plays an important role for the economic development of the country. Indian Foundries employ about 5.0 lakh work force directly & about 15.0 lakh people indirectly. Most foundries are labour intensive where operations and handling are manual. But to maintain this growth in positive direction it is necessary to ensure proper utilization of every resource. In today’s competitive world, the most important driver for success is time; the company that delivers goods with a shorter lead time is the market winner. Financial growth of any company also depends upon productivity improvement and waste minimization. So, to gain profit from scarce time and to increase productivity as well as to minimize waste it is necessary to identify the root causes and remedies in line for foundries. Suitable steps must be taken in this sector in order to stay alive in the new competitive market place.

Lean manufacturing concepts are widely used among various countries; Lean principle is also implemented among various apparel industries all over the world. But in India, every foundry runs in a traditional way and they rarely follow innovative method of production. So the goal of this work is to introduce lean manufacturing concept in selected foundry in the area of central Karnataka and also to identify various types of problems related to waste and to picture the existing scenario by using various types of lean tools. Waste and productivity are the two major issues in foundries and hence the case study research has been conducted. This study includes a questionnaire survey where small and medium scale manufacturing enterprises claiming to adopt Total quality management practices in their structure of governance are questioned. After data was collected it is analyzed that there is a strong relation between reduction in waste and productivity. At last various problems faced in SMEs are also highlighted. The foundry industry, small to medium sized plant, has the difficulty of implementing improvements in its internal logistics system and it has to deal with the problems arising in the industry. Lean manufacturing (LM) is seen as major breakthrough process and is widely used by major industries all over the world. The LM is demarcated as a manufacturing system that concentrates continuous flow within supply chain by removing all wastes and execution continuous development towards product excellence**.** This research is a detail investigation on quality improvement of castings by applying lean tool as Pareto analysis and Cause-Effect Diagram.

Pareto Analysis is a simple technique for prioritizing possible changes by identifying the problems that will be resolved by making these changes. By using this approach, it is possible to prioritize the individual changes that will most improve the situation. Pareto Analysis uses the Pareto Principle – also known as the "80/20 Rule" – which is the idea that 20% of causes generate 80% of results. With this tool, trying to find the 20% of work that will generate 80% of the results that doing all of the work would deliver. The Cause & Effect diagram is used to explore all the potential or real causes (or inputs) that result in a single effect (or output).

Causes are arranged according to their level of importance or detail, resulting in a depiction of relationships and hierarchy of events. This can help to search for root causes, identify areas where there may be problems, and compare the relative importance of different causes. The cause and effect diagram for all the reasons were drawn. Thus the aim of this study is to minimize defects that will reduce rework and rejection rate. In this organization, worked in a particular section (i.e. studying the rate of rejection) for particular product. Eight months defect data has been collected from the shop floor and Management.

III. Results before and after lean Implementation

From the data collected for eight months related to cylinder liner, it is observed that as many as five types of defects are responsible for rejection of component. The prime defects reported by the respondents for the cylinder liner were Flow mark, half shot, Black Spot, Thread Damage, Silver steak mark, and thread damage. Out of these the thread damage is left out as the numbers very less significant. The remaining defects were focused and the % of parts with their numbers are tabulated in Table 3. The Fig. 1 shows such variation for each month having different % of rejection rates per month with specific causes. In Table 4 the average rejection for cylinder liner having different defects are mentioned. The same reasons for rejection of cylinder liner by parts is demonstrated in Fig. 2. The flow mark is found to be maximum among all the defects which leads to rejection.

Table 3. Rejections for cylinder liner

Month	No. of parts produced	No. of parts rejected	Reasons for rejection	No. of parts rejected under particular reason (%)				
				Flow mark	Half shot	Black spot	Thread damage	Silver steak mark
May	10980	549	Flow mark, Half shot, Black Spot	(247) 45%	(148) 26.95%	(154) 28.05%	0%	0%
June	9960	458	Flow mark, Thread Damage, Black Spot	(247) 53.94%	0%	(146) 31.87%	(65) 14.19%	0%
July	8800	396	Flow mark, Thread Damage, Black Spot	(113) 28.54%	0%	(256) 64.65%	(27) 6.81%	0%
Aug	63460	3518	Silver steak mark, Half shot	(218) 6.21%	(1116) 31.72%	(200) 5.68%	0%	(1984) 56.39%
Sep	16855	1045	Flow mark, Thread Damage, Black Spot	(564) 53.97%	0%	(324) 31%	(157) 15.03%	0%
Oct	14380	906	Flow mark, Thread Damage, Black Spot	(499) 55.09%	0%	(289) 31.89%	(118) 13.02%	0%
Nov	23215	1509	Flow mark, Thread Damage, Insert damage	(818) 54.2%	0%	(269) 17.82%	(422) 27.98%	0%
Dec	69090	3800	Flow mark, Thread Damage, Silver steak mark	(1855) 48.81%	0%	(300) 7.89%	(455) 11.97%	(1190) 31.33%

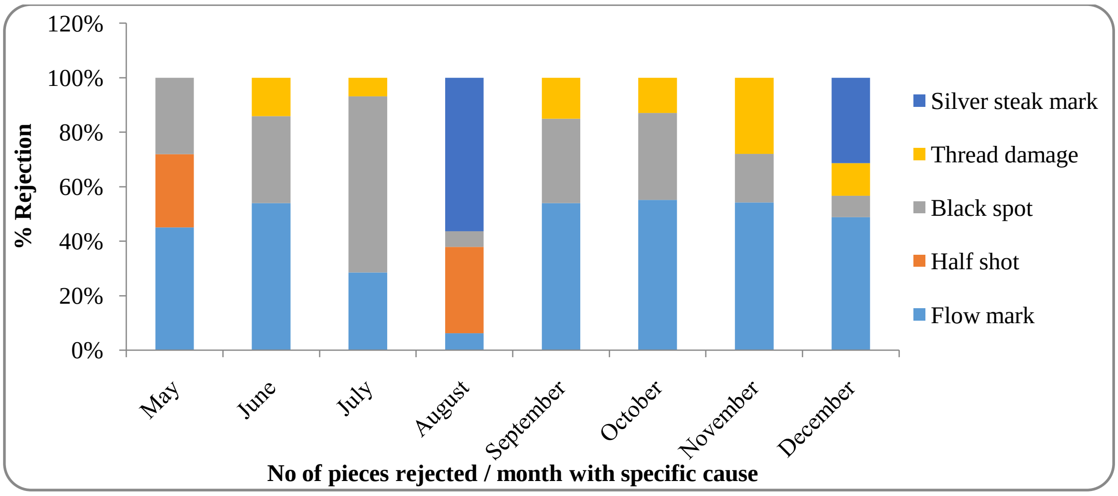

Fig. 1. No of parts rejected under particular reason

Table 4. Average rejection for cylinder liner

Sl.No.	Type of defect	No of Parts rejected	Cumulative defect	Cumulative percentage (%)
1	Flow mark	4561	4561	37.44%
2	Silver steak mark	3174	7735	63.50%
3	Black spot	1938	9673	79.41%
4	Half shot	1264	10937	89.78%
5	Thread damage	1244	12181	100.00%

Priority analysis is performed based on eight months combined with defect data of rejection for cylinder liner. From this analysis the "Vital few" areas where maximum defects occur are identified. The priority analysis performed is shown in Fig. 3. Here horizontal axis represents defect cause positions, vertical axis at right side represents defect number and vertical axis at left side represents defect percentage. The defect positions with their respective defect amounts have been represented by the blue colored bars. The cumulative percentage line is represented by gray color. From the Fig. 3 it is observed that Flow mark is the most frequent defect with as much as 37.44% of the total. Silver steak mark is the second most frequent defect with 26.06% of the total. Black spot contributes 15.91% of the total. These three top defect positions are the "vital few" where 79.41% of total defects occur. So these three defect types are responsible for 79.41% of total defects. Total number of rejects being 12181, total number of rejects in major concerning areas are 9673. This contributes to percentage of rejects in major concerning areas = 9673/12181 * 100 = 79.41%. The total number of concerning areas are 5, number of major concerning areas is 3, and Percentage of concentrating area = 3/5*100 = 60%.

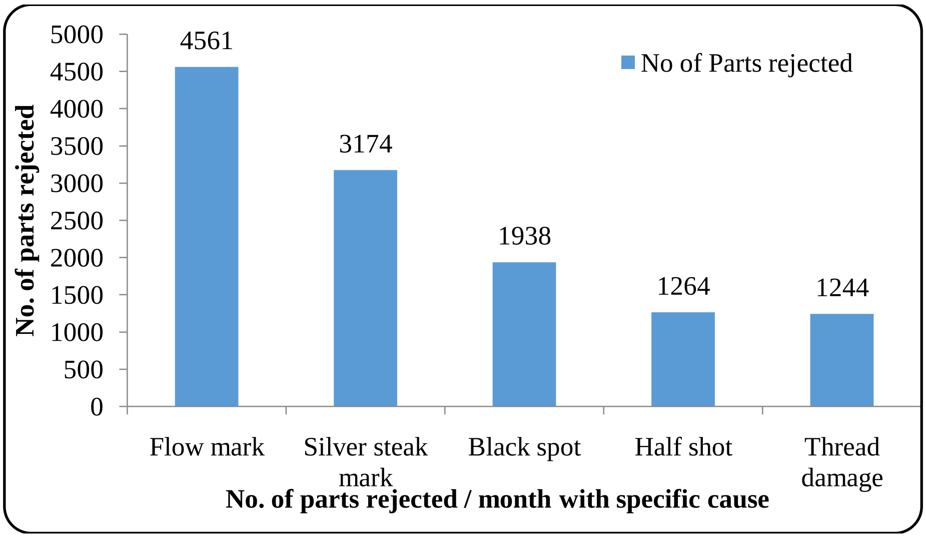

Fig. 2. Reasons for average rejection of cylinder liner

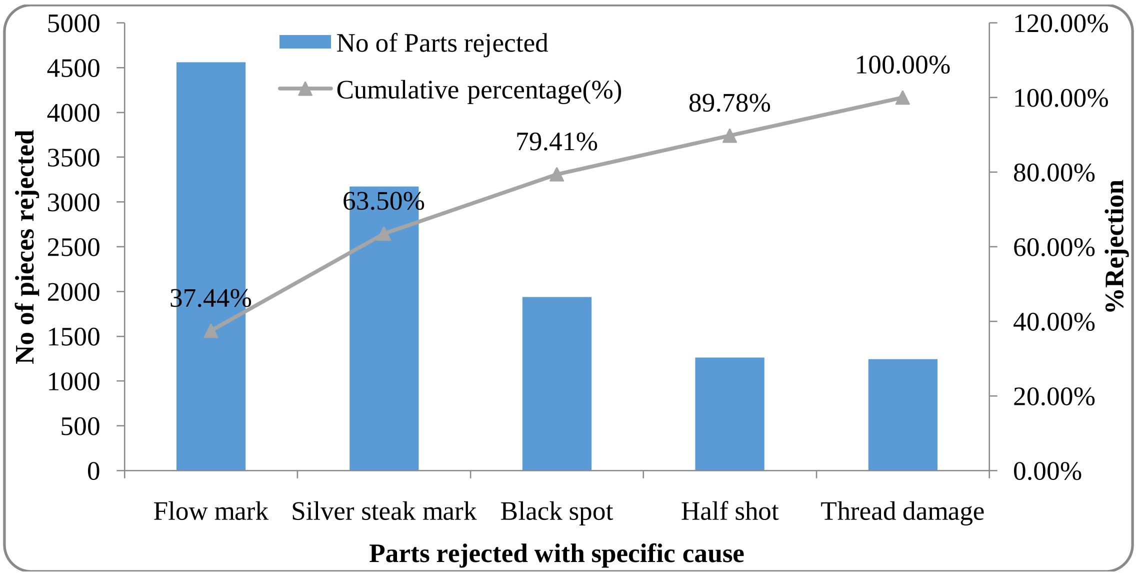

Fig. 3. Priority analysis for cylinder liner

From Priority Analysis it is identified about top defect positions, those defects being flow mark, silver steak mark and black spot. These types of defect occur due to some specific causes. By self-observation and data provided by supervisors from questionnaires, the causes for each specific defect types identified. Cause-Effect Diagram for each of the defect types using 3M (Machines, Materials and Methods) bones. These Cause-Effect Diagrams is shown in Fig. 4.

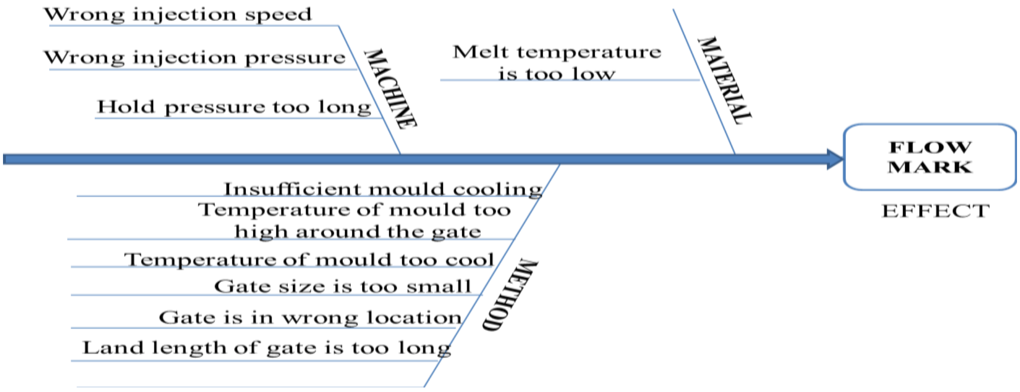

Fig. 4. Cause and effect diagram for flow mark

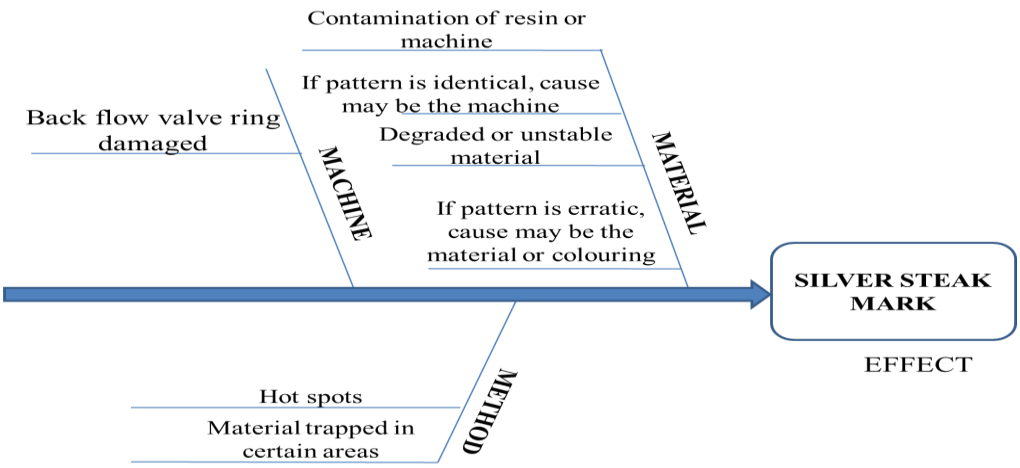

Fig. 5. Cause and effect diagram for silver steak mark

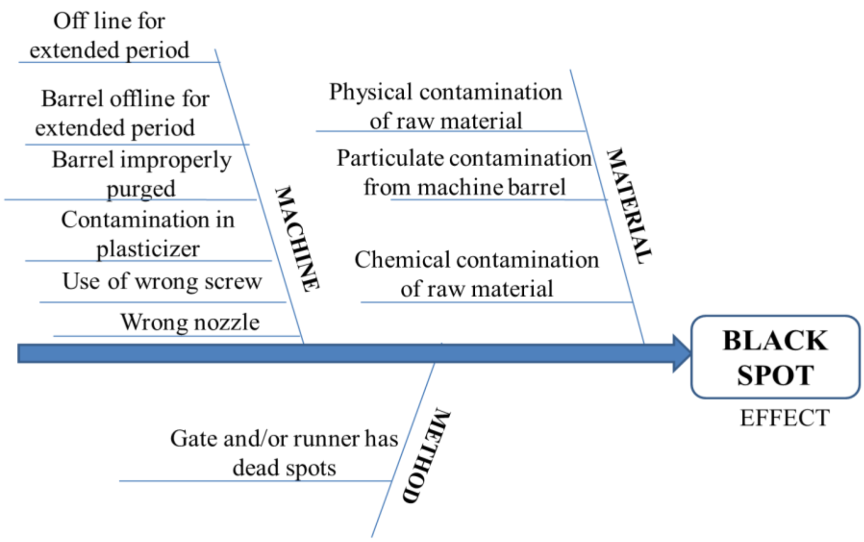

Fig. 6. Cause and effect diagram for black spot

3.1 Suggestions to reduce top defect

From own observation, literature review and consultation with management some suggestions with their corresponding causes are provided below to reduce defect percentage in Table 5, Table 6 and Table 7.

Table 5. Suggested solutions for flow mark

Cause Types	Probable causes	Suggested solutions
Moulding machine	• Poor injection speed • Poor injection pressure • Hold pressure too long	• Adjust injection speed, holding pressure • Increase injection pressure
Mould	• Insufficient mold cooling • Temperature of mold too high around the gate • Temperature of mold too cool • Gate size is too small • Gate is in wrong location • Land length of gate is too long • Incorrect hot runner system	• Identify and eliminate dead pockets /sections • Add a large cold slug area • Add cold wells at the end of the runner system • Use hot sprue bushing • Check gate dimensions, quantities and locations
Material	• Melt temperature is too low	• Increase the melt temperature

Table 6. Suggested solutions for silver steak mark

Cause types	Probable causes	Suggested solutions
Moulding machine	• Back flow valve ring damaged	• Check barrel purging • Inspect back flow ring for wear or cracks • Inspect feed screw for wear and tear • Inspect screw/barrel for tolerance
Mould	• Hot spots • Material trapped in certain areas	• Verify heater operation • Verify thermocouple operation
Material	• Contamination of resin or machine • If pattern is identical, cause may be the machine • If pattern is erratic, cause may be the material or coloring • Degraded or unstable material	• Check for contamination

Table 7. Suggested solutions for black spot

Cause types	Probable causes	Suggested solutions
Moulding machine	• Off line for extended period • Barrel offline for extended period • Barrel improperly purged • Contamination in plasticizer • Wrong nozzle • Use of wrong screw	• Purge system with appropriate material • Trace source of contamination and repair, remove or discard • Adjust melt temperature if necessary • Inspect feed screw for degradation
Mould	• Gate and/or runner has dead spots	• Inspect for dead spots: gates; runners; nozzle; back flow valve
Material	• Physical contamination of raw material • Chemical contamination of raw material • Particulate contamination from machine barrel • If pattern is identical, cause may be the machine • If pattern is erratic, cause may be the material or colouring • Degraded or unstable material	• Trace source of contamination and repair, remove or discard

3.2 Implementation of suggestions

In the last phase of the quality improvement model implementation and possibility of deficiencies appearance is assessed as well as methods for their prevention and removal. Identified changes and improvements are implemented in the process and their continued use is ensured. Activities carried out during this phase of the application of the model provide a systematic approach to defects reduction and the application of adopted improvement. Quality improvement activities of the process within the framework of the implementation of this operating model end by the formal closing of the improvement work. Comparison is made by before implementation and after implementation. In Table 8 the rejections obtained before the implementation of lean practice suggestions and in Table 9 the result obtained after the implementation of suggestions are described. Implementation of suggested solutions are carried out for the top three rated rejects namely, flow mark, silver steak mark and black spot from May to August production.

From the presented tables and graphs it is observed that the average rejection rate from May to December is 5.62%. By suggesting various findings and after implementation, the rate of rejection for the month of May to August has reduced to 4.45 %. The reasons for reduced rejections being, adjusting injection speed and holding pressure, increasing the injection pressure, tracing the source of contamination and repair, adjusting melting point temperature, inspecting feed screw and other simple suggested techniques.

Table 8. Rejections of cylinder liner before implementation

Month	No. of parts produced	No. of parts rejected	Reasons for rejection	Number of parts rejected under particular reason (%)				
				Flow mark	Silver steak mark	Black spot	Half shot	Thread damage
May to Dec	216740	12181	Flow mark, Half shot, Black Spot, Thread damage	(4561) 37.44%	(3174) 26.05%	(1938) 15.91%	(1264) 10.38%	(1244) 10.22%

Table 9. Rejections of cylinder linerafter implementation

Month	No. of parts produced	No. of parts rejected	Reasons for rejection	No. of parts rejected under particular reason (%)				
				Flow mark	Silver steak mark	Black spot	Half shot	Thread damage
May	10000	480	Flow mark, Half shot, Black Spot, Thread damage	(208) 43.35%	0%	(121) 25.2%	(140) 29.16%	(11) 2.29%
June	10000	447	Flow mark, Thread Damage , Black Spot	(242) 54.13%	0%	(142) 31.76%	0%	(63) 14.09%
July	9000	360	Flow mark, Thread Damage , Black Spot, Silver steak mark	(88) 24.44%	(10) 2.77 %	(203) 56.38%	0%	(59) 16.38%
August	62000	2566	Silver steak mark, Black shot, Half shot	(186) 7.24%	(1339) 52.18%	(124) 4.84%	(917) 35.74%	0%

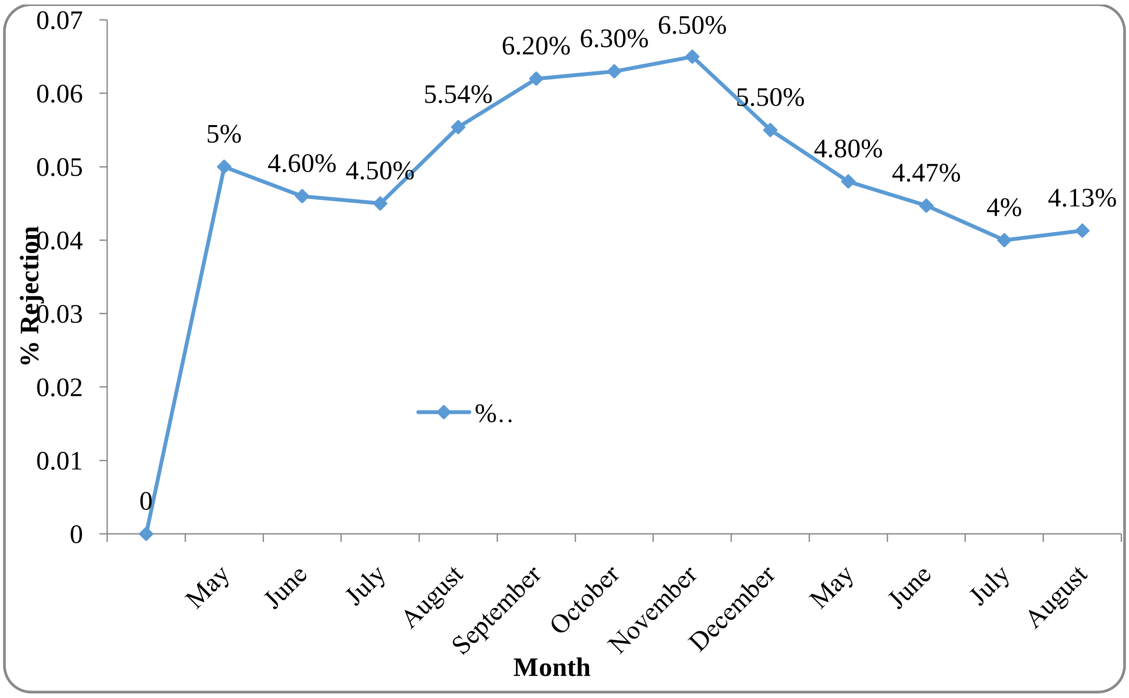

Fig. 7. Rejection after implementing suggestions May to August

IV. Conclusion

There exists a strong relationship between production performance measurement and productivity in industry. Productivity is influenced by man, machine, materials and methods. Several critical factors that determine the success of implementing the concept of lean manufacturing within SMEs are identified in this work. Leadership, management, finance organizational culture and skills and expertise, amongst other factors; are classified as the most pertinent issues critical for the successful adoption of lean manufacturing within SMEs environment. As a case study, the casting industry where the cylinder liner is produced and the wastage observed due to different defects are identified. The cause behind the effect is identified and suitable suggestions are made. It is observed that the average rejection rate from May to December is 5.62%. By suggesting various findings and after implementation, the rate of rejection for the month of May to August has reduced to 4.45 %. The reasons for reduced rejections being, adjusting injection speed and holding pressure, increasing the injection pressure, tracing the source of contamination and repair, adjusting melting point temperature, inspecting feed screw and other simple suggested techniques.

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