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Process Improvement using DMAIC Approach: Case Study in Downtime Reduction

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***Abstract*—Process improvement is nothing but the understanding of an existing process and introducing process changes to improve quality of product, reduce costs, improve overall efficiency of process or accelerate productivity. Generally the overall efficiency of machine or process is calculated based on the machine utilization percentage and the machine productivity over the available hours for production. Most process improvement work so far has focused on defect reduction, but there is another point for process improvement work is overall efficiency improvement. Six Sigma is most common and well-known methodology used by the industries for overall process improvement and it is a systematic methodology to move towards world-class quality level. Various approaches are adopted while following Six Sigma methodology and one of them is DMAIC (Define–Measure-Analyze–Improve–Control). It is the classic Six Sigma problem solving process. However, DMAIC is not exclusive to Six Sigma and can be used as the framework for improvement applications.**

Now a day's industries are facing the downtime problems during the production hours due to some technical or nontechnical issues like hours lost in Product changeover process, Dressing Operation, Cycle time Deviation etc. hence for process improvement finding those issues and making improvements in these issues. For the Process Improvement there are some statistical analysis tools available such as ANOVA, Regression Analysis, EVOP, Process Capability Study, Pareto Analysis, etc.

This paper presents the process improvement using the DMAIC approach, as the DMAIC proved to be the most preferred technique for the defect identification and process improvement by use of various statistical tools. In this study, the major problem was downtime occurred in seven months 430 hours downtime was downtime occurred due to this the overall efficiency of the process is get down to 42%. Initially, Pareto analysis was used to detect the critical issues causing the downtime and solving them for the process improvement.

***Keywords*—DMAIC, Downtime; Process Improvement; Product Changeover Time; Dressing Time; Cycle Time Deviation**

I. Introduction

In real several manufacturing areas at present, real challenges are arising for the improvements in downtime reduction, quality improvement, efficiency improvement, machine utilization improvement, cycle time reduction etc. to do such improvement Six Sigma's DMAIC approach (Define–Measure–Analyze–Improve–Control) is very helpful.

Six Sigma is a well-structured methodology that focuses on reducing variation, measuring defects and improving the quality of products, processes and services. Six Sigma methodology was originally developed by Motorola in 1980s and it targeted a difficult goal of 3.4 parts per million defects. Six Sigma has been on an incredible run over 25 years, producing significant savings to the bottom line of many large and small organizations. Six Sigma was initially introduced in manufacturing processes; today, however, marketing, purchasing, billing, invoicing, insurance, human resource and customer call answering functions are also implementing the Six Sigma methodology with the aim of continuously reducing defects throughout the organization's processes[1]. Six Sigma techniques have two main methodologies DMAIC and DMADV. Define, Measure, Analyze, Improve, and Control (DMAIC) methodology was followed for process improvement and DMADV (Define, Measure, Analysis, Design Verify) was followed for product improvement.

Process improvement is nothing but the understanding of an existing process and introducing process changes to improve quality of product, reduce costs, overall efficiency of process or accelerate productivity. Generally the overall efficiency of machine or process is calculated based on the machine utilization percentage and the machine productivity over the available hours for production.

A. *DMAIC approach:*

DMAIC is similar in function such as Plan-Do-Check-Act and the Seven Step method of Juran and Gryna for problem solving approaches. In the theory of organizational routines, DMAIC is a meta-routine: a routine for changing established routines or for designing new routines. DMAIC is applied in practice as a generic problem solving and improvement approach [2]. DMAIC should be used when a product or process is in existence at a company but is not as per customer specifications or is not performing adequately. DMADV should be used when a product or process is not in existence and one need to be developed or when the existing product or process has been optimized and still does not meet the level of customer specification or six sigma level.

B. *Advantages of DMAIC approach:*

Can realise genuine cost savings. DMAIC is a particularly astute means of identifying waste and unnecessary rework. A successful DMAIC implementation can pay for itself several times over by greatly increasing the effectiveness of a process.

The cycle of DMAIC is reusable too businesses can continually repeat the process, identifying further enhancements and improvements over time.

Structured thinking. The DMAIC process is systematic and thorough. It enables decisions to be made based on actual data and measurement. The various tools and techniques used in the analysis phase can flush out problems and issues that might not have been exposed otherwise and the approach often brings a fresh way of thinking to established processes.

Looks at the longer term: DMAIC implementation is seldom about quick fixes. The approach lends itself to longer term process resolution so for established businesses or businesses with particularly complicated processes, DMAIC works very well. Many projects toy with a problem, implement a quick fix and then walk away. The control phase of the DMAIC methodology ensures that this never happens.

II. Background

The case study was conducted at a leading manufacturer of Bearings of DGBB (Deep Grove Ball Bearing), TRB (Taper Roller Bearing) types. Fig.2 Shows the types of the bearing rings. In firm the turned rings as a raw material is processed with operations like Heat treatment, Face Grinding, OD Grinding, Bore Grinding, Track Grinding and Honing and then assembly. The Critical operations in the firm is Face grinding as there is any amount of less productivity is occurs it will make big no material downtime on the channels on which the further processes are carried out. Fig.1 shows the 3D bone structure of the DDS face grinding machine present at the firm.

For face grinding operation of inner and outer rings of both Deep Grove Ball Bearings and Taper Roller Bearings, the +0 to -100 µm tolerance on the width of the rings is allowable. To achieve this tolerance there is grinding allowance is provided on the width, it is of +150 to +250 µm for each type of bearing rings. To remove this excess material, face grinding operation is done in number of passes with one finish pass. As the machine and for reliable quality from the process the machine can remove ~250 µm at once.

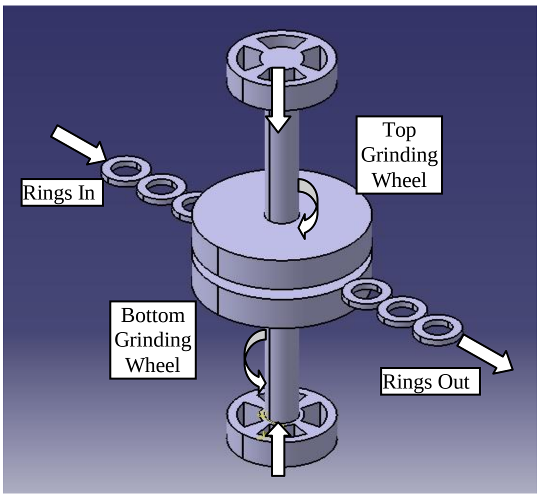
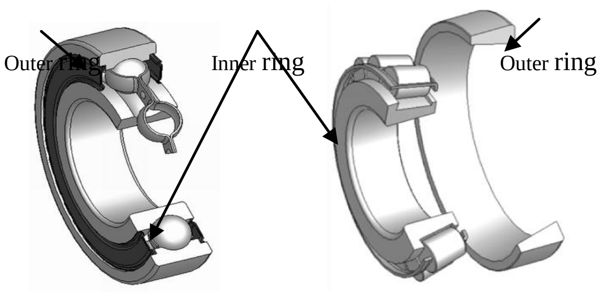


Fig.1. Bone Structure of DDS face grinding machine (Drawn in CATIA-V5)



(a) (b)

Fig.2. (a) Deep Grove Ball Bearing, (b) Taper Roller Bearing

If the target tolerance is achieved in 3 passes, in two rough passes 100µm material of width is removed and remaining 40 to 50µms material is removed in next one finish pass.

III. Case Study

The process under consideration is a special purpose process which was specially developed for performing the faces grinding operation on the bearing inner and outer rings manufactured by the firm. The operations performed in the firm on turned inner and outer are heat treatment, face grinding, OD grinding, Bore Grinding , Track grinding and honing to track of the inner and outer rings of the bearing, In first the Heat treatment of the turned ring is done and then the face and OD grinding is done by separate machines and the for further operations rings goes on to the channels. for face grinding DDS (Double Disk) and for OD the CL-46 (Center-less Grinding) machines are available. DDS grinding machine has a two co-axial vertical spindles with horizontal ring through feeding. For such specific continuous feeding of the bearing ring for face grinding there is a special feeding unit is installed. In the firm there is at least one product changeover is happened in a shift as firm has batch type production is done.

During the study of the down time of all the processes, found that the DDS face grinding machine has created the no material down time on the next processes i.e. on the channels because DDS machine itself had some downtime problem. This was a serious problem to mate the delivery date. The Pareto analysis is done regarding the Hours lost in recent seven months and it was found that the product change over time and cycle time deviation has bottleneck issues.

Therefore the objective of the study was to minimize the product changeover time and reduce the cycle time deviation without affecting the quality of the product To solve these issues the Six Sigma technique was selected.

IV. Process Improvement

As the study aimed at improving the existing process, DMAIC methodology was considered [3], It consists of phases, namely, Define, Measure, Analyze, Improve and Control. The whole Six Sigma project starts with Define phase and is defined based on the customer requirement and company strategy and mission [4]. Measure phase helps the project team to refine the problem and begin the search for various causes of the failure. In Analyze phase, the causes found are analyzed using various data analysis tools and the data is validated for Improvement phase. Improvement phase helps in finding solutions and implementing them so that the problems can be eliminated. In Control phase, the performance of the process after improvement is measured routinely and accordingly adjustments are made in operations. If the Control phase is not implemented, it may revert the project to its previous state [5]. Fig. 3 shows the flow diagram of the DMAIC approach with its five main phases.

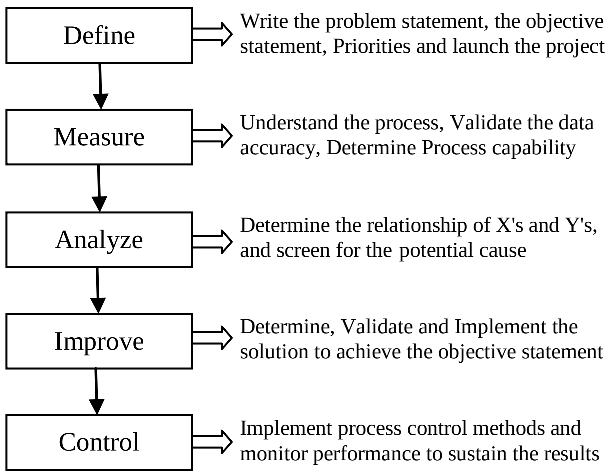


Fig.3. Flow Diagram of the DMAIC Approach

In the case study presented, the DMAIC methodology was applied to identify the probable sources of process downtime in machine performance and successfully reduced one of the issue. In proposed study only the second issue of cycle time deviation is explained in detailed. The following sections explain the methodology applied for the purpose [6].

A. *Step 1- Define*

The main objective in this stage is nothing but writing down what you currently know about the problem. Seek to clarify facts, set objectives and form the project team and Define the problem statement, the customer(s) as well as customer needs, Critical to Quality (CTQs) - what are the critical process outputs?, the target process and other related business processes, project targets or goals, project boundaries, a project charter is often created and agreed during the Define step [7].

Problem Statement. Selected firm is the leading bearing manufacturer in the country and is known for its quality bearings. But currently due to some internal production efficiency loss company facing the downtime problem. Face and OD Grinding department is one of the low efficient department in the firm. As the firm works for 24 by 7 hours with tree shifts first and second each of 8 hours and third shift of 7.3 hours, so the total working hours for seven months are ~5000 Hrs. For the recent seven months Jan 2013 to July 2013 due to low efficiency at Face and OD grinding department creates the downtime of 430 Hrs out of 4939 Hrs at the channels on which further operations are carried out. Downtime was nearly ~9%.

Efficiency loss largely depends upon the performance of the process. Hence, process improvement have to be done. By doing this we can reduce the downtime of the other channels.

B. *Step 2- Measure*

The main objective is to collect data pertinent to the scope of the project. Leaders collect reliable baseline data to compare against future results. Teams create a detailed map of all interrelated business processes to elucidate areas of possible performance enhancement [8,9].

In the proposed study, first find the bottleneck machine of the Face-OD grinding department for that studied the recent seven months efficiencies. See the Table. I which gives the month wise efficiencies of all the Face grinding machines of the department.

TABLE I. Month wise efficiencies of the face grinding machines

Machine No.	**Month Efficiency (in %)**						
	Jan	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***
DDS Cell	41.4%	42.5%	46%	44.1%	42.7%	44.2%	41.2%
DDS 544	66.2%	61.7%	64.2%	60.3%	62%	59.6%	69.9%
Gardner 1016	58.4%	55.8%	60.1%	63.5%	60.8%	65.2%	63.5%
Gardner 1601	66.5%	58.4%	64.8%	59.8%	55.2%	62.5%	63.8%

From the Table. I the efficiency of face grinding machine DDS Cell is nearly 20% less than the other face grinding machines can conclude that DDS cell is one of the major bottleneck from Face and OD department. So DDS cell is the first Bottleneck for the downtime problem from F-OD department in the firm.

C. *Step 3- Analyze*

Pareto analysis of bottleneck machine DDS cell form Jan-July 2013 is carried out to find the hours lost as there is a 430Hrs downtime in Face-OD grinding department. Fig.4 shows the pareto graph for machine DDS Cell. The pareto graph drawn for hours lost on the DDS cell face grinding process is drawn using the "Minitab 16" software.

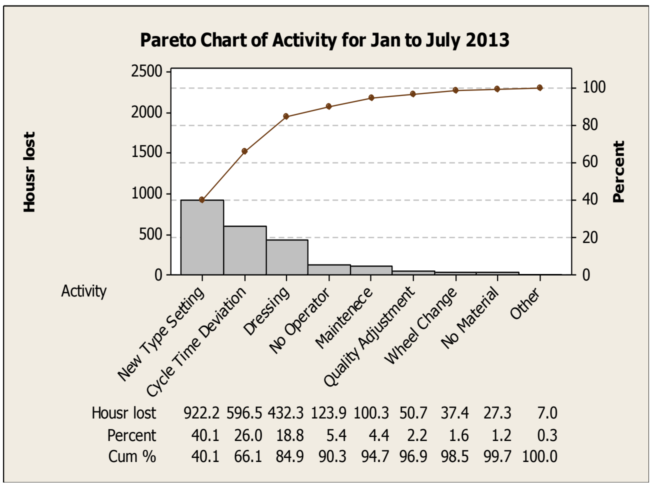


Fig. 4. Pareto Chart for the Downtime of DDS face grinding machine

From Pareto analysis it is observed that 20% of the activities causing the 80% effect for making the DDS cell machine bottleneck. The three main hours lost reasons are as follows:

i. New Type Setting (Product Changeover Time)

ii. Cycle Time Deviation

iii. Dressing Operation

Hence to improve the performance of the DDS cell it is required to work on these three causes.

D. Step 4- Improve

The main objective at the end of this stage is to complete a test run of a change that is to be widely implemented. Teams and stakeholders devise methods to address the process deficiencies uncovered during the data analysis process. Groups finalize and test a change that is aimed at mitigating the ineffective process. Improvements are ongoing and include feedback analysis and stakeholder participation.

In the proposed study, the cycle time reduction issue is take for the improvement. The Cycle time deviation means the number of hours required more than that of the standard hours required to produce the same quantity of rings. The cycle time deviation is given in terms of hours lost, from the pareto analysis it is seen that near about 26% of total down time is occurred due to the cycle time deviation on the DDS face grinding machine.

There are the two ways to reduce the cycle time deviation of the face grinding process. One is to optimize the input parameters of the machine to get proper production output rate. The input parameters of the DDS face grinding machine are ring feeding rate (m/min), top and bottom grinding wheel velocity (rpm) and top-bottom grinding wheel compensation (µm). With help of the Taguchi's design of experiments method, the number of runs are performed on process or machine and by analyzing the result one can fix the input parameter to prevent the cycle time deviation of the DDS face grinding machine.

TABLE II. Dimensional changes of the 6311bearing type inner and outer rings after the grinding allowance reduction

Type: 6311	Before GA Reduction	After GA Reduction
	Finish Ring Face (width) Dimension	
Finish size	29mm	29mm
	Turned Ring Face (width) Dimension	
Basic turned size	29.20mm	29.10mm
Max. turned size	29.25mm	29.14mm
Min. turned size	29.15mm	29.06mm
Max. GA	***0.250mm***	***0.180mm***
Min. GA	***0.150mm***	***0.100mm***

Second way to prevent cycle time deviation is to reduce the face grinding allowance present on the bearing inner and outer rings. This reduction can be done on the basis of the heat treatments growth of the bearing ring in its width. In the proposed case study this second way is chosen to reduce the cycle time deviation. As in the firm the face grinding is done in the 2-3 passes, hence by reducing the grinding allowance, one can reduce the number of passes required to manufacture finish ring indirectly the production time required per pass is get eliminated and the standard production rate is achieved.

The inner and outer ring of Deep Grove Ball Bearing (DGBB) type 6311 is one of the bearing type had the cycle time deviation in face grinding operation. Cycle time deviation means, to produce finish rings of this type requires more time than that of the standard production time. Initially there were three passes to be done to meet the tolerance of 0 to -100µm on width of size 29 mm. The old width grinding allowance on inner ring was +250 µm and on the outré ring +300 µm. This grinding allowance is the addition of the turned ring grinding allowance pulse heat treatment growth.

As machine carried the three passes, in first pass material removed was ~150µm, in second pass was ~100µm and in last finish pass was ~50µm material was removed. By reducing the face grinding allowance the number of passes get reduced. Table. II shows the Dimensional changes of the 6311bearing type inner and outer rings after the grinding allowance reduction.

E. Step 5- Control

The objective of the last stage of the methodology is to develop metrics that will help leaders monitor and document continued success. Six Sigma strategies are adaptive and on-going. Adjustments can be made and new changes may be implemented as a result of the completion of this first cycle of the process. At the end of the cycle additional processes are addressed or the initial project is then complete.

After completing the Improve phase, factors affecting the cycle time deviation of the face grinding process on the bearing inner and outer rings were proposed. The actions proposed were implemented in the manufacturing process. The results of these improvements were monitored in Control phase. A control plan was prepared which is the major action of this phase. This control plan consisted of all the actions that were proposed for reducing the cycle time deviation of the DDS face grinding machine. It included training and certifying the operators, employees, maintenance plan preparation, regular inspection, and preparation of control charts. And thus from Fig.4 it can be observed that the goal set of reducing or preventing the downtime bottleneck issues were achieved.

V. CONCLUSION

Industries have to deal with a host of problems related to productivity and quality control. Substandard productivity hampers the internal customer demand of the products which directly affects the company targets. Organizations have to suffer huge losses which are not easy to cope up with. Thus there is a need to improve the process simultaneously keeping in mind the quality and the productivity of the product. Six Sigma can be effectively applied and the existing business processes can be improved and made error free, downtime free. Six Sigma provides statistical proof to each and every action, thus helping making decisions more efficient. It can work even with less number of readings in the database. Thus Six Sigma is completely an industry oriented methodology of quality and productivity improvement.

In the presented case study the downtime was much higher, i.e. ~9% of total working hours of firm for seven months. The firm had to sustain the downtime cost and the wastage of the man-hours. Establishing the relationship between the issues for the downtime and the effect of these issues is a challenge in a complex system like the one discussed above. The decision of using Six Sigma methodology proved to be facile. Pareto graph was implemented to find all the key issues that are causing the downtime. Thus there was significant improvement in the productivity and losses the firm incurred.

ABBREVIATIONS

DMAIC:	Define, Measure, Analyze, Improve and Control
DMADV:	Define, Measure, Analyze, Design, and Verify
DGBB:	Deep Grove Ball Bearing
TRB:	Taper Roller Bearing
DDS:	Double Disks
GA:	Grinding Allowance

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