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CYCLE TIME REDUCTION OF GRINDING PROCESS USING SIX SIGMA METHODOLOGY

[1]ALOK B. PATIL, [2]DR. KEDAR H. INAMDAR

[1]Research Student, Mechanical Engineering, Walchand College of Engineering, Sangli, Maharashtra, INDIA, Email: alok4006@gmail.com

[2]Professor, Mechanical Engineering, Walchand College of Engineering, Sangli, Maharashtra, INDIA, Email: kedar.inamdar@walchandsangli.ac.in

ABSTRACT

Now a days for the cycle time reduction in the industries six sigma methodology is very famous and helpful. Also it is a systematic methodology to move towards defect less processes or production. It uses a detailed analysis of the process to determine the proposes of cycle time reduction and causes of cycle time deviation. "Define–Measure-Analyze–Improve–Control" (i.e. DMAIC) is the one of the approach from the various approaches adopted while following the six sigma methodology. 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. It uses a detailed analysis of the process to determine the causes of the problem and proposes a successful improvement. Cycle time reduction is nothing but the process improvement. Process improvement means the study the existing process and making the process changes to improve cycle time of production by keeping the quality of product, reduce process costs, accelerate productivity and etc. Most process improvement work so far has focused on defect reduction, but there is another point for process improvement work is cycle time reduction. Now a day's industries are facing the downtime problems during the production hours due to some technical or nontechnical issue like Cycle time Deviation. For the cycle time reduction through DMAIC approach there are some statistical analysis tools available such as ANOVA, Regression Analysis, EVOP, Process Capability Study, Pareto Analysis, etc. This paper presents the cycle time reduction using the DMAIC approach, as the DMAIC proved to be the most preferred technique for

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the defect identification and process improvement by use of various statistical tools. In this study the major problem was downtime occurred on the further operations in the period of last seven months. The 430 hours downtime was occurred in the seven months due to this the overall efficiency of the face grinding process is get down to 42%. Initially the overall efficiency of face grinding process is calculated based on the machine utilization percentage and the machine productivity over the available hours for production. Then the Pareto analysis was used to detect the critical issues causing the downtime and further they solved through the DMAIC approach.

INDEX TERMS: Six Sigma, DMAIC, Cycle Time Reduction, Downtime, Grinding Allowance, Cycle Time Deviation

1. INTRODUCTION

In real several manufacturing areas at present, real challenges are arising for the cycle time improvements of the manufacturing process or operation, also the challenges in quality improvements of the products, efficiency improvement of the machines, machine utilization improvement, etc. to do such improvement Six Sigma methodology is very helpful, and out of all the six sigma's approaches the DMAIC approach (Define–Measure–Analyze–Improve–Control) is very helpful for such situation.

Six Sigma is a well-structured methodology that focuses on reducing the various defects occurring in the processes as well as in the products. 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 methodology have two main methodologies DMAIC and DMADV. Define, Measure, Analyze, Improve, and Control (DMAIC)

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methodology was followed for process improvement and DMADV (Define, Measure, Analysis, Design Verify) was followed for product improvement.

Process improvement is nothing but the cycle time reduction because the process improvement means 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 of production.

1.1 DMAIC VS DMADV APPROACH

Despite the shared first three letters of their names, there are some notable differences between them. The main difference exists in the way the final two steps of the process are handled. With DMADV, the Design and Verify steps deal with redesigning a process to match customer needs, as opposed to the Improve and Control steps that focus on determining ways to readjust and control the process. DMAIC typically defines a business process and how applicable it is; DMADV defines the needs of the customer as they relate to a service or product.

With regards to measurement, DMAIC measures current performance of a process while DMADV measures customer specifications and needs. Control systems are established with DMAIC in order to keep check on the business' future performance, while with DMADV, a suggested business model must undergo simulation tests to verify efficacy.

DMAIC concentrates on making improvements to a business process in order to reduce or eliminate defects; DMADV develops an appropriate business model destined to meet the customers' requirements.

1.2 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

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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.

1.3 ADVANTAGES OF DMAIC APPROACH

Can realize 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.

2. GRINDING OPERATION

The study was conducted at a leading manufacturer of Bearings of DGBB (Deep Grove Ball Bearing), TRB (Taper Roller Bearing) types. Fig.1 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.2 shows the 3D bone structure of the DDS face grinding

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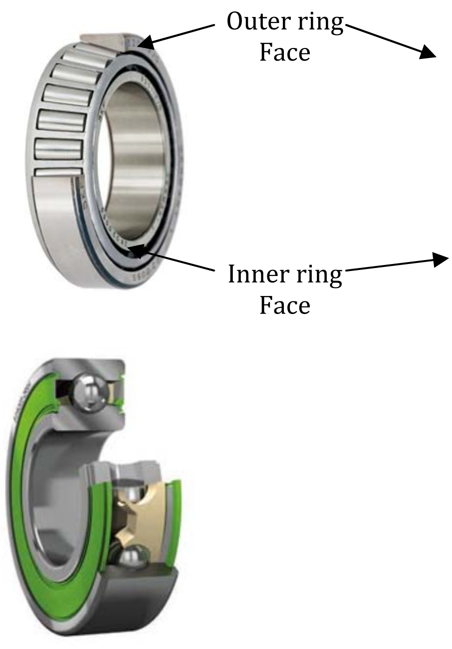
machine present at the firm. The DDS face grinding machine means Double Disk face grinding machine, this DDS machine contains two vertical spindles with two grinding wheels placed as shown in Fig.2. There are two pressure plates placed one at entry side and another at exit side, also there are two guide rails present to guide the ring flow from entry to exit side. The two grinding wheels are rotated opposite to each other.



(a) (b)

Figure 1: (a) Deep Grove Ball Bearing, (b) Taper Roller Bearing

For face grinding operation of inner and outer rings of both Deep Grove Ball Bearings and Taper Roller Bearings, the +0 to -50 μm tolerance on the width of the rings is allowable. To achieve this tolerance the grinding allowance is provided on the width i.e. excess material is provide on the face side of the bearing rings, it is of +150 to +250 μm for each type of bearing rings. This excess material is at the turn stage after the heat treatment growth this grinding allowance goes to +200 to +300 μm. This excess material is removed through face grinding operation. This face grinding operation is done in number of passes with one final finishing pass. As per the machine capability and to get reliable quality from the process the machine can remove ~250 μm at once.

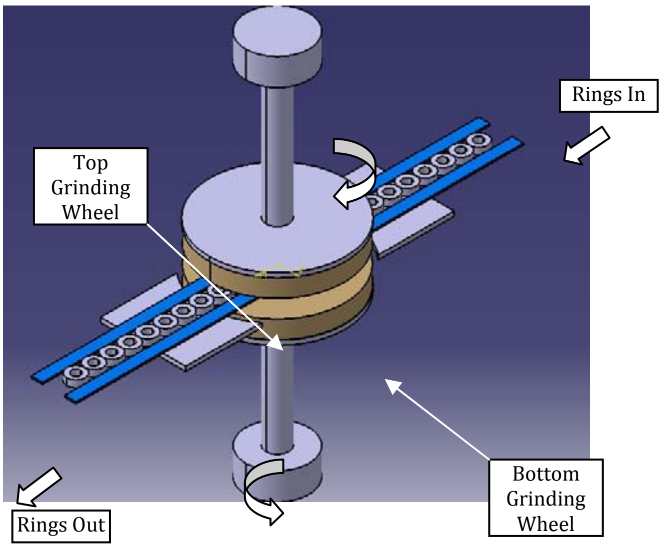


Figure 2: Bone Structure of DDS face grinding machine (Drawn in CATIA-V5)

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If the target size is achieved in 3 passes, then out of that 3 passes the first two are rough passes in which 100µm material of width is removed and remaining 40 to 50µms material is removed in last one i.e. in finishing pass.

3. BACKGROUND

The grinding process under consideration is a special purpose process which was specially developed for forming the faces of the bearing ring. The name of this special process is known as face grinding operation on the bearing inner and outer rings. The operations performed in the firm on turned (i.e. raw ring) inner and outer rings 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 operation i.e. the Heat treatment of the turned ring is done and then the face and OD grinding is done by separate machines and for the 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 as shown in Fig.2. 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. In this paper out of the two bottleneck issues the cycle time deviation is focused. The cycle time deviation removed with help of the DMAIC approach.

4. CYCLE TIME REDUCTION

As the study aimed at cycle time reduction of the existing face grinding

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process, DMAIC approach is considered [3], it consists of five phases that are namely: Define, Measure, Analyze, Improve and Control.

Any 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 member to collect the data related to problem and begin the search for various causes of the problem.

Table -1: Rational reconstruction of the DMAIC procedure

Define: Problem selection and benefit analysis **D1**. Identify and map relevant processes. **D2**. Identify stakeholders. **D3**.Determine and prioritize customer needs and requirements. **D4.** Make a business case for the project.
Measure: Translation of the problem into a measurable form, and measurement of the current situation; refined definition of objectives **M1**. Select one or more CTQs. **M2.** Determine operational definitions for CTQs and requirements. **M3.** Validate measurement systems of the CTQs. **M4**. Assess the current process capability. **M5.** Define objectives.
Analyze: Identification of influence factors and causes that determine the CTQs' behavior **A1.** Identify potential influence factors. **A2.** Select the vital few influence factors.
Improve: Design and implementation of adjustments to the process to improve the performance of the CTQs **I1.** Quantify relationships between Xs and CTQs. **I2.** Design actions to modify the process or settings of influence factors in such a way that the CTQs are optimized. **I3.** Conduct pilot test of improvement actions
Control: Empirical verification of the project's results and adjustment of the process management and control system in order that improvements are sustainable **C1.** Determine the new process capability. **C2.** Implement control plans.

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In Analyze phase, the collected data are analyzed, 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 gain of the project is sustained. 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 states [5]. Table-1. Shows the flow diagram of the DMAIC approach with its five main phases.

In the study presented, the six sigma's DMAIC approach is applied to diagnosis the probable bottleneck issues of face grinding operation downtime in machine performance and successfully reduced one of the issue. In proposed study only the second issue of cycle time deviation is considered for the improvement. The following sections explain the methodology applied for the purpose [6].

4.1 DEFINE PHASE

Define is the first phase of the DMAIC methodology of Six Sigma. The purpose is to define the project team's understanding of the problem to be addressed and the output is stated in the project charter. In the charter, the team normally indicates the objectives of the project, expected timeline, scope, and members of the team. Also created during this phase is a suppliers, inputs, process, outputs, customers (SIPOC) diagram that identifies the process being examined, the inputs to and outputs of the process, and the relevant suppliers and customers to ensure that team members acquire a bird's-eye view of the project. Another important aspect of the define phase is the gathering of voice of the customer data. The Six Sigma project team is focused on finding out directly from customers what they want and how well the current process meets their needs.

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. The firm works for 24 by 7 hours with three shifts first and second each of 8 hours and third shift of 7.3 hours, so

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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 improvements have to be done. By doing this we can reduce the downtime of the other channels.

Key Objectives: The Main two key objectives to solve the cycle time deviation problem of the DDS Cell face grinding machine are as follows:

- Grinding allowance reduction.
- Reduction in Grinding Pass

4.2 MEASURE PHASE

The measure phase establishes techniques for collecting data on the current performance of the process identified in the define phase. 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]. This phase is used to determine sources of variation and serves as a benchmark to validate improvements. A detailed process map is also created in this phase together with indications of possible variations existing within the process.

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-2. This gives the month wise efficiencies of all the Face grinding machines of the department.

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 Face and OD department in the firm.

Table -2: Month wise efficiencies of the face grinding machines

M/C No.	Month Efficiency (in %)						
	Jan	Feb	Mar	Apr	May	Jun	Jul
DD	41.	42.	46	44.	42.	44.	41.

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S Cell	4 %	5 %	%	1 %	7 %	2 %	2 %
DDS 544	66.2 %	61.7 %	64.2 %	60.3 %	62.0 %	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 %

4.3 ANALYSIS PHASE

The purpose of the analyze phase is to allow the project team to target improvement opportunities by taking a closer look at the data to determine the root causes of the process problems and inefficiencies. This involves discovering why defects are generated by further probing into the key variables (identified in the previous measure phase) that are most likely to cause process variation. Statistical analysis is a key component of this phase and used to demonstrate and confirm these relationships.

The Analyze phase deploys a number of tools for collecting team input and conducting objective experiments to identify or confirm top causes. The most commonly used of these are -

- Pareto Chart
- Fishbone Diagram
- 5-Why
- Hypothesis Testing
- Regression Analysis
- Time Series Plots
- Multi-Vari Analysis
- Histograms
- Scatter Diagrams
- Tree Diagrams
- PFMEA

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. Chart-1. shows the pareto graph for machine DDS Cell. The pareto graph drawn for hours lost on the DDS

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cell face grinding process is drawn using the "MINITAB 16" software.

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:

- New Type Setting (Product Changeover Time)
- Cycle Time Deviation
- Dressing Operation

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

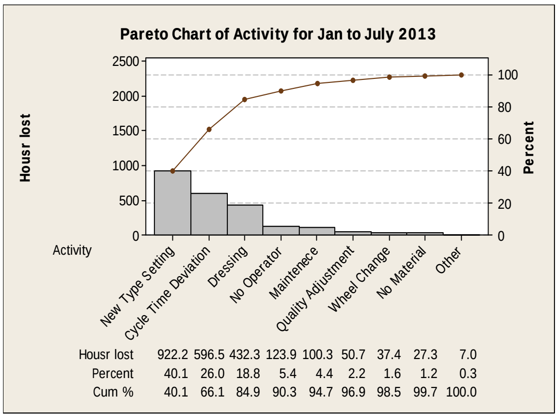

Chart 1: Pareto Chart for the Downtime of DDS face grinding machine

4.4 IMPROVE PHASE

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 numbers of runs are performed on process or machine and

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by analyzing the result one can fix the input parameter to prevent the cycle time deviation of the DDS face grinding machine.

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.

Table -3: Dimensional changes of the 61902 bearing type inner and outer rings after the grinding allowance reduction

Type 61902	Status	Face		GA		GA reduction Face (mm)
		Turn Face Size (mm)	Finish Face size (mm)	Min (mm)	Max (mm)	
OR	Actual	7.300	7.000	0.200	0.300	-
	Proposed	7.180	7.000	0.130	0.230	0.120
IR	Actual	7.300	7.000	0.200	0.300	-
	Proposed	7.180	7.000	0.130	0.230	0.120

The inner and outer ring of Deep Grove Ball Bearing (DGBB) type 61902 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 7 mm. The old width grinding allowances on inner ring was +300 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 gets reduced. Table.3 shows the dimensional changes of the 61902 bearing type inner and outer rings after the grinding allowance reduction.

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4.5 CONTROL PHASE

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.

5. 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 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

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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.

Table 5.3: Number of passes reduced due to grinding allowance reduction

Bearing Type	**Grinding Allowance**		**No. of Passes**	
	Before	**After**	**Before**	**After**
OR-61902	200 to 300 µm	180 to 210 µm	3	2
IR-61902	200 to 300 µm	180 to 210 µm	3	2

Table. 4 shows the cycle reduction of the 61902 bearing type i.e. from now onwards when this type is come for the production it requires only 2/3rd time of the old standard production time, means the 1/3rd cycle time reduction is achieved.

ABBREVIATIONS

DMAIC: Define, Measure, Analyze, Improve, 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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BIOGRAPHIES

	Alok B. Patil is currently student of second year M. Tech (Mechanical Engg. specialization Production Engineering). He is completed his graduation in Mechanical Engineering in 2011 from Pune University, Maharashtra, India.
	Dr. Kedar H. Inamdar is working in Department of Mechanical Engineering, Walchand College of Engineering, Sangli. He has published more than 80 technical papers in various national / international conferences as well as journals. His area of interest is in quality control and he acquired patent related to it.