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Tool Modification in Turbine Manufacturing of Diffuser Bores by Adopting Six Sigma

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Abstract: **Manufacturing and service organizations attempt to improve their products and processes by decreasing variation, because the competitive global market leaves little room for error. Variation is the biggest enemy of quality that is defined and evaluated by customers. The traditional concept of quality is based on average measures of the process/product and their deviation from the ideal target value. This is what the Six Sigma approach strives to achieve. Invented by Motorola in the 1980s, Six Sigma has been applied to many manufacturing companies, such as General Electric (GE), DuPont, and Ford. It has proven to be a customer-focused, data-driven, and robust methodology to improve the process and reduce costs. Over the last 20 years, Six Sigma has been successfully implemented in many industries; Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes. It uses a set of quality management methods, The maturity of a manufacturing process can be described by a sigma rating indicating its yield, or the percentage of defect-free products it creates. A six sigma process is one in which 99.99966% of the products manufactured are statistically expected to be free of defects (3.4 defects per million). Motorola set a goal of "six sigma" for all of its manufacturing operations, and this goal became a byword for the management and engineering practices used to achieve it.**

Keywords—Turbine(steem); difusur bors; six sigma; (key words)

I. INTRODUCTION

A steam turbine is a mechanical device that extracts thermal energy from pressurized steam, and converts it into useful mechanical work. It is a rotary internal combustion engine to drive the generator as a prime mover for generation of power. The Diffuser is the main component of the turbine which is used for the control of steam flow by a lever mechanism. It is a mechanical device that is designed to control the characteristics of steam at the entrance to a thermodynamic open system. Diffusers are used to slow the steam's velocity and to enhance its mixing into the surrounding steam. In contrast a nozzle is often intended to increase the discharge velocity and to direct the flow in one particular direction. Flow through nozzles and diffusers may or may not be assumed to be adiabatic. Frictional effects may sometimes be important, but usually they are neglected. However, the external work transfer is always assumed to be zero. It is also assumed that changes in thermal energy are significantly greater than changes in potential energy and therefore the latter can usually be neglected for the purpose of analysis Every steam turbine has four diffusers, these diffusers are assembled on the steam turbine outer casing, as the casing is too big the machining and measurement of diffuser bore is complicated and time taking process.

II. PARTS OF STEAM TURBINE

A. Diffuser: It is a mechanical device that is designed to control the characteristics of steam at the entrance to a thermodynamic open system. Diffusers are used to slow the steam's velocity and to enhance its mixing into the surrounding steam. In contrast, a nozzle is often intended to increase the discharge velocity and to direct the flow in one particular direction.
Flow through nozzles and diffusers may or may not be assumed to be adiabatic. Frictional effects may sometimes be important, but usually they are neglected. However, the external work transfer is always assumed to be zero. It is also assumed that changes in thermal energy are significantly greater than changes in potential energy and therefore the latter can usually be neglected for the purpose of analysis.

B.Nozzle: The nozzle expands steam of comparatively low velocity and high static pressure within considerable increase in velocity. The nozzle is so positioned as to direct the flow of steam into the rotor passage.

C.Casing Shell or Cylinder: The turbine enclosure is generally called the casing although the other two names are in common use. The nozzle and guide are fixed on casing, which in addition to confining the steam serves as support for the bearings. Sometimes the word cylinder is restricted as a cylindrical form attached to inside of the casing to which the guides are fixed.

D.Throttle or Stop Valves: The throttle and stop valves are located in the steam supply line to the turbine. The stop valve is hydraulically operated quick opening and shutting valves designed to be either fully opened or shut. On small turbines the stop valves may be manually operated but in any case is intended for emergency use or when fully shut down. The throttle valve is used in smaller turbines in addition to stop valve as a means of regulating steam flow during the starting or stopping the operation.

2.1 Introduction to Six Sigma:

Six Sigma is originated from the Motorola Corporation. The concept was created by Motorola Inc. in the 1980s and was initiated by the engineers conclusion, which stated that

"New products, often failing to meet customer expectations, could be produced error-free from the very beginning."

- The new approach involves controlling, measuring and improving the capability of processes in order to "build" products or services free of any kind of defects.
- The introduction of a Six Sigma quality program means much more than just measuring failure rates.
- The implementation of Six Sigma includes introducing and incorporating a wide range of tools and methodologies into an organization in order to improve performance and, as its ultimate purpose, significantly improve profits.
- Successes attributed to Six Sigma were facilitated by the recent and increasing availability of electronic technologies such as automatic process monitoring, accessibility to large databases and rapid transfer of information plus the availability of statistical packages which took the rigor out of manual and laborious computations.

One of these common characteristics is a widespread focus on processes and the existence of accompany-wide language for describing the capability of processes.

- Six sigma is an important structured program for improving business processes and, as many voices pretend, it represents the latest " incarnation" of the quality movement.
- The basic idea behind the six sigma philosophy is to continuously reduce product and process variation.

The expected outcomes of six sigma efforts are:

1. Computer stimulation,
2. Short cycle manufacturing,
3. Part standardization and supplier qualification,
4. Supplier statistical process control,
5. Participative management practices,
6. Design of experiments, measurement system analysis,
7. Failure mode and effect analysis.

2.2 Six Sigma Methodology:

A. Define:

1. Identify the project which gives maximum potential to either improve customer satisfaction or reduce costs.
2. Scope the project.
3. Identify the teams
4. Define goals and project milestones

B.Measure:

1. Select the characteristic critical –to- quality (CTQ)
2. Define performance standards
3. Validate measurement system

C.Analyze:

1. Establish product capability
2. Define performance objectives
3. Identify variation sources

D.Improve:

1. Screen potential causes
2. Discover variable relationship
3. Establish operating tolerances

E.Control:

1. Validate measurement system
2. Determine process capability
3. Implement process controls

2.3 Process Capability:

If we sample a group of items periodically from a production run and measure the desired specifications parameter, we will get subgroup sample distributions that can be compared to that parameter's specification limits. Two examples of this are represented below. The diagram on the left in figure 2.3.1 shows a series of sample distributions that fall inside of and outside of the specification limit.

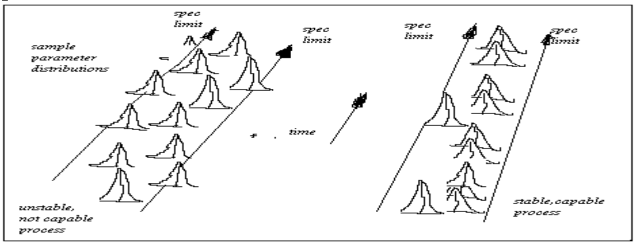

Fig. 2.3.1: Distinction between stable and unstable processes

Process capability can be expressed with an index. Assuming that the mean of the process is centered on the target value, the process **capability index Cp** can be used. Cp is a simple process capability index that relates the allowable spread of the spec to the measure of the actual, or natural, variation of the process, represented by six sigma, where sigma is the estimated process standard deviation.Fig.2.3.2 and Fig.2.3.3

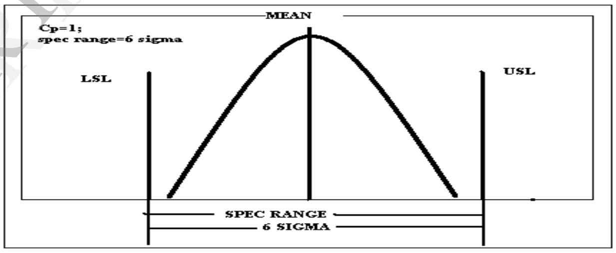

Fig. 2.3.2: Process with mean centered

If the process is in statistical control, via "normal" SPC charts, and the process mean is centered on the target, then Cp can be calculated as follows:

$$Cp= (USL-LSL)/6\ sigma$$

Cp<1 means the process variation exceeds specification, and a significant number of defects are being made.

Cp=1 means that the process is just meeting specifications. A minimum of 3% defects might be made if the process is not centered on the target values.

Cp>1 means that the process variation is less that the specification; however, defects might be made if the process not centered on the target value.

While Cp relates the spread of the process relative to the specification width, it does not address how well the process average, X, is centered to the target value. Cp is often referred to as process "potential".

Cpk measures not only the process variation with respect to allowable specifications; it also considers the location of the process average.

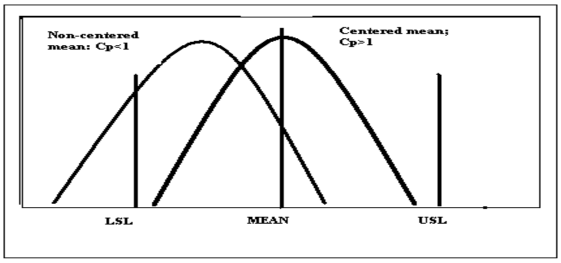

Fig. 2.3.3: Process with mean shifted

Cpk is taken as the smaller of either Cpl or Cpu

Cpl = (X- LSL) / 3 sigma where X is the process mean

Cpu = (USL-X) / 3 sigma where X is the process mean

Many companies are establishing specific process capability targets. They may typically start with 1.33 for supplier qualification and have an expected goal of 2.0. If the process is near normal and in statistical control, Cpk can be used to estimate the expected percent of defective material.

III. MACHINING OF DIFFUSER BORES

3.1. Description: Diffuser bores machining is critical operation in the casing. It has been observed that deviation in dimensions of the bores is leading to rework of mating parts and delay in not only completion of the diffuser bore, but also contributing to the delay in the project.

Target:

To Avoid the Delay Completely by Conformance to Drawing Sizes. In order to avoid the delay due to variations in manufacturing of diffuser bores we need to adopt some techniques to minimize the deviations to drawing sizes. Six Sigma is a statistical measure of variation. Full six sigma equals to 99.9997% accuracy

Its methodology splits into five steps:

1. ***Define:*** Defining the main reasons for the problem
2. ***Measure:*** Measurement of the problem using past data
3. ***Analyze:*** Analyzing the problem using cause and effect diagram
4. ***Improve:*** Modifications and changes to be done depending upon the problem
5. ***Control:*** Controlling of the changes made in improvement.

3.2 Define:

A.Background to the Problem:

The casing of the steam turbine is too big. Machining and measurement of diffuser bore is complicated and time consuming process. The main aim in the process of manufacturing is to get accurate dimensions of the machined part irrespective of the operator on the machine. This could not be achieved due to various reasons. It has been observed that deviation in dimensions of the bores is leading to rework of mating parts and delay in not only completion of the diffuser bore, but also contributing to the delay in the project. The machining of diffuser bore is done on the SIEMENS Horizontal Boring machine which is manually operated. The measurement of the bores is noted by the skilled operator using stick micrometer.

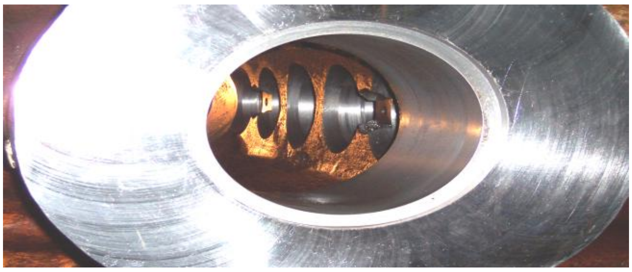

Fig. 3.2.1: View of Diffuser Counter – Bores

B.Diffuser Counter – Bores:

The photograph 3.2.1 shows the diffuser counter bores of the steam turbine outercasing.Machining of these holes is complicated. The above shown are the access points for fixing the boring bar for spot facing of the diffuser bores. The cutting tool should be placed in the boring bar slot from the opening provided at the sides as shown in the photograph.3.2.2

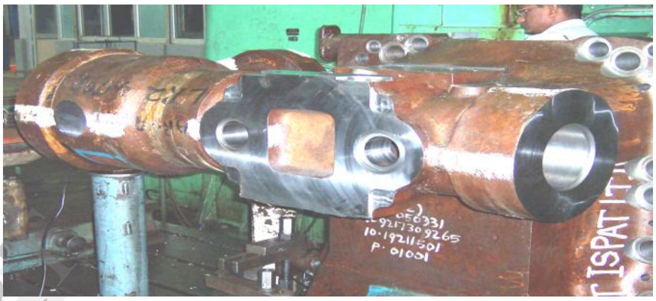

Fig.3.2.2: Access to Diffuser Counter Bores

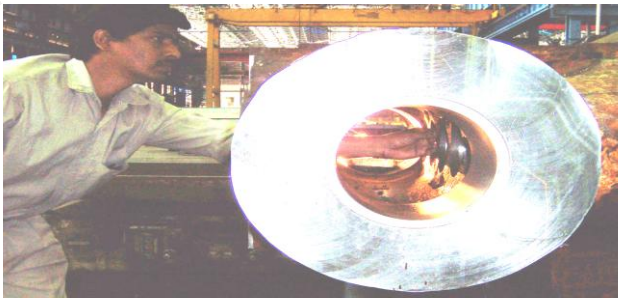

Fig.3.2.3: Fixing of Tool to Boring Bar and Difficulty Faced by Operator

Fixing of tool on the boring bar is complicated task as shown in the photograph and also the measurement of the counter bore should be done blindly even by a skilled operator just by feeling. This is done using a stick micrometer.fig.3.2.3

3.2 Measure:

Measurement of Previous Results

1. Seven casings have been manufactured in the year 2005-06.
2. The data of all seven casings have been collected and analyzed.
3. The data is presented in the following table.

A.Data for Casing Manufactured:

Sl. No	Project	Specifi cations	Bore dimensions			
			1	2	3	4
1	Thai Carbon	100 H11	100.23	100.13	100.09	100. 07
2	Mandidee p	150 H11	150.07	150.05	150.78	150. 15
3	Bhushan Steel	104 H11	104.42			
4	EID Parry	104 H11	104.63	104.19	104.21	104. 43
5	Sail	165 H11	165.05	165.04	165.01	165. 01

Table.3.2.1 Data for Casings Manufactured 2005-06

B.Data before Process Change:

Total no. of casings checked : 29

No.of casings not meeting specifications : 16

DPMO (Deflections per million operations): 551,724

Million operations include drilling holes, boring with different dimensions, machining of parting plane, slotting and grooving of all the turbine casings manufactured.

Sigma Rating: 1.35

This sigma rating is given by a software named "IN-DEPENDENCE OF SIX SIGMA", which was developed by Motorola Corporation.

3.4 Analyze:

A.Analyze of the Probable Reason:

1. Boring bar run-out measured.
2. Tool rests on a line contact on the boring bar and hence there is likely to be a play on the tool. This problem is exacerbated because the tool has to be fixed blindly by the operator.

FIG.3.4: Boring bar showing placement of the tool

B.Analyze Results:

- Line contact of tool
- Boring bar run out
- Ensuring proper fixing of tools.

3.5 Improvement:

Improvement Recommendations and Comments

- To change boring bar
- To modify the tool
- To alter the geometry of tool holding on boring bar

A. Major Action Items:

- To procure/ use a new boring bar and check run out before putting to use
- To modify boring bar and ensuring proper tool geometry

B.Major Road Blocks and Issues:

- Age of the machine

3.6 Ideas Generated:

1. Boring bar to be modified
2. Modify basic design of the bores
3. Cutting tool to be modified by reducing the radius
4. New telescopic tool holder to machine the bores

A.SUGGESTED METHOD & SUGGESTED MODELS:

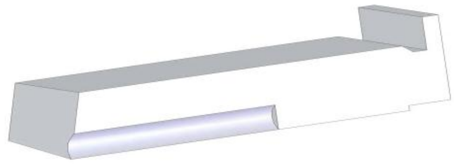

FIG .3.8 Modified Square Cutting Tool with Step

B.Modifications to Boring Bar with Tool

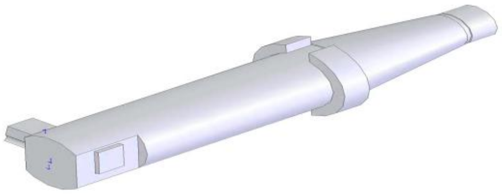

FIG .3.9 Modified Boring Bar with Modified tool

C.Details of Monnet Ispat Diffuser Bores:

COUNTER BORE DIA	DRWG SIZE	ACTUAL SIZE
1. 100 H11	100.10/.00	100.05/.07
2. 100 H11	100.06/.08	
3. 100 H11	100.05/.08	
4. 100 H11	100.04/.05	
5. 104 H11	104.10/.00	104.06/.08

All dimensions were found within specification

Table.3.2. Details of Monnet Ispat Diffuser Bores

IV. STATISTICAL ANALYSIS OF PERFORMANCE IMPROVEMENT

4.1 Data after Implementation of Suggested:

Method the action points identified was implemented during 2007 in 01 Heavy Machine Shop and the Results obtained are presented below:

Number of Counter bores produced: 9

Defects : NIL

A. Chi-Square Test:

Expected counts are printed below observed counts

	Performance before	Performance After	Total
Bores Produced	29 31.67	9 6.33	38
Defects	16 13.33	0 2.67	16
Total	45	9	54

Chi-Sq = 0.225 + 1.123 + 0.533 + 2.667 = 4.547

DF = 1, P-Value = 0.033

B.Chi-Square Test:

Comments about statistical Analysis of Performance before and after:

1. As a general rule, when p-value is less than or equal to 0.05, we conclude there is a statistical difference between the populations represented by samples.
2. 1n this case, the p-value is less than 0.05 so we can conclude that improvement is statistically significant.

4.2 Results improved in Project

<u>Measure:</u>

***Opportunity*: Any defect on diffuser bore during the manufacture**

Defect: Non-conforming diffuser bore dimension

Before Process Capability

DPMO: 551,724 Sigma: 1.35"

"After" Process Capability

DPMO: 0 Sigma: 6.0

Target Process Capability

DPMO: 55,170 Sigma: 3.1

A.Analyze Results:

a) Line contact of tool
b) Boring bar run out
c) Ensuring proper fixing of tools.

B.Results after Implementation:

a) New boring bar used. Run out checked and under control.
b) Boring bar modified to ensure surface contact with tool.
c) Tool geometry checked and dimension ensured prior to counter-bore operation.

C.Data after implementation:

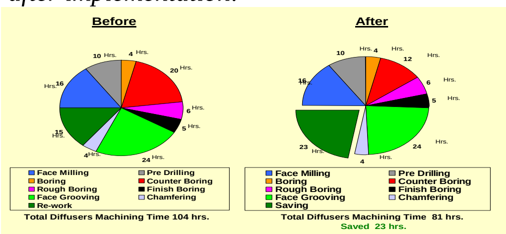

Fig.4.2.1 Data after implementation.

D.*Control of Process:*

a) The boring bar and the tools are assigned new number.
b) All the existing tools are being re-corrected, based on the sequence of casings to be received in shop floor, with the changed boring bar dimension and profile.
c) Necessary changes to be incorporated in the process sheet
d) A chart prepared and kept on machine to identify the tools to be used for various sized of counter-bores.

4.3 Financial Benefits:

a) Decrease in the cost of labor
b) Reduction in wastage of material
c) Time Delay of project is reduced

4.4 Non-Financial Benefits:

a) Exclusive tool for each dimension ensures that the dimension computation is not required every time and eliminates errors in computation.
b) Step in boring bar ensures surface contact and accuracy in blind fixing by operator
c) Operator is very satisfied with the current process since all holes meet Engg spec.

V. CONCLUSION AND FUTURE TRENDS

Although Six Sigma originated in the manufacturing industry, it has been successfully adopted by many other public or private sectors, from financial services to health-care delivery and management, from information technology to knowledge management. The successful implementation over 20 years supports the hypothesis that basic thinking and methods that are used in Six Sigma have lasting values, even though they may be marketed by new names in the future. Ideas can be integrated with other productivity improvement methods, for example, the recent focus on Lean Six Sigma. The methodology will continue to show their endurance in the global business environment.

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