

Reducing Defects on Cam Shaft by Six Sigma Methodology

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Abstract: The efficiency of an IC engine is mainly depends on opening and closing of inlet and outlet valves. The valves are operated by cam shaft. So cam shaft must be free from defects to maintain proper combustion of a internal combustion engine. Thus we are focusing to reduce the defects and improving quality in the manufacturing process and operations of a cam shaft in manufacturing industry for different automobiles. In camshaft manufacturing the considerable defects are material selection, changing their mechanical properties while machining, temperature defects, casting defects, tolerances and surface roughness. So manufactured cam shaft has to overcome above defects for safe operating of valves. Six Sigma is a business technique and a methodical philosophy utilization of which prompts achievement in benefit through quantum gain in item quality, consumer loyalty and efficiency. The goal was to diminish the quantity of deformities to as low as 3.4 parts per million chances. Methodology used: DMAIC is one of the tool of six sigma used to improve the process and also to find root causes for any problem to reduce the defects occurring in any industry. we are using DMAIC tool to reduce defects and improve quality. DMAIC stands for define, measure, analyze, improve, control.

Keywords: Six sigma, DMAIC, defects per million opportunities, control charts, xbar chart.

I. INTRODUCTION

Introduction to six sigma: Six Sigma is an information driven procedure that gives devices and strategies to characterize and assess each progression of a procedure. It gives techniques to improve efficiencies in a business structure, improve the nature of the procedure and increment the primary concern benefit. It is an approach for process improvement and a measurable idea that looks to characterize the variety natural in any procedure. Any variety in process prompts open doors for blunder; open doors for mistake lead to dangers for item deserts. Item surrenders whether in a substantial procedure or an assistance lead to helpless consumer loyalty. By attempting to decrease variety and open doors for blunder the six-sigma technique at last lessens the

procedure expenses and increment consumer loyalty. At the most essential definition, six sigma is a factual portrayal for what numerous specialists call a "great" process. In fact, in a six-sigma process, are only 3.4 defects per million opportunities. In percentages, that means 99.99966 percent of the products from a six-sigma process are without a defect.

This paper presents the gradual application of the Six letter DMAIC (Define–Measure–Analyze–Improve–control) approach to eliminate the defects in an exceedingly cam shaft producing business. This has helped to scale back defects within the method and thereby improve productivity and on time delivery to client. throughout the live and analyze phases of the project, knowledge were collected from the processes to know the baseline performance and for validation of causes. These knowledge were studied through numerous graphical and applied math analyses.

Introduction to cam shaft manufacturing:

A camshaft is an inward piece of burning warmth motor is a gadget that controls both the contribution of fuel and the ejection of fumes vapor. It comprises of a few spiral cams, each dislodging admission or fumes valves. This camshaft is associated with the driving rod by means of belt, chain or apparatuses. This guarantees steady planning of the valves according to the movement of the cylinders.

Manufacturing process of a cam shaft:

Casting: By using different casting methods we can manufacture a cam shaft. But in casting process they are more chances to getting defects like hot tears, cold shut, shrinkage defects. However it is the important process to manufacture a cam shat.

Forging: Forged camshafts also are used sure enough high loaded diesel engines. These square measure created on computer-controlled shaping systems with integrated heat treatment.

Machining process: Machining process is necessary to give final dimensions of a cam shaft.



Machining process included in above camshaft is:

Turning and drilling: The raw casting part is placed inside the machine. Machining operations are done on the basis of dimensions required.

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Trigger milling: This operation is done on vertical cnc milling machine to get required trigger.

Turning: Journal bearings are machined in this operation.

Cnc grinding: By using cnc grinding machine cam lobes or profiles are grinded to required dimensions.

By using these process defect may occur in any in a industry. Thus we are focusing on defect occurs and to reduce defect occurring methods.

II. LITERATURE SURVEY

- ❖ **Kunal Ganguly (2012):** Used DMAIC Six sigma Approach for the advance of the method for steel mill. He enforced Six sigma DMAIC during a giant atomic number 13 company to eliminate down time because of coil slippage throughout rolling at hot mill. The challenge for Company was to cater quick ever-changing export demand for the flat rolled product with its existing resources. He had used the six sigma DMAIC methodology to work out the comes CTQ characteristics. He outlined the doable causes, known the varied sources, established variable relationship and enforced management plans. Through his six sigma DMAIC project he might come through measurable results just like the cycle time was reduced, slippage drawback was eliminated, trials with wider widths were productive.
- ❖ **Hsiang-Chin hung and Ming-Hsien Sung (2011)** has used The DMAIC (define measure-analyze-improve-control) approach in company in Taiwan. By this system he solved associate underlying drawback of reducing method variation. So he might cut back high defect rate related to it. The results obtained were the reduced defect rate of tiny dish buns by seventieth from the baseline to its title. He has additionally bestowed plan concerning the factors that area unit chargeable for success of Six alphabetic character project during a food business.
- ❖ **Mohit Taneja, Arpan Manchanda (2013)** has used Six sigma Approach to enhance Productivity in producing business. In his paper he begins with an summary of Six sigma, followed by thorough literature review on Six sigma DMAIC phases, application of Six sigma in tiny medium scale industries and additionally in giant producing industries. He has additionally done literature survey on numerous Six sigma quality tools employed in the industries. These embody method capability analysis, bone Diagram, Two-sample check.
- ❖ **Tushar N Desai and Dr. R L shrivastava (2008)**, in their paper they need mentioned the standard and productivity improvement in an exceedingly producing enterprise through a case study. The paper deals with an application of Six letter of the alphabet DMAIC methodology in an business that provides a framework to spot, quantify and eliminate sources of variation in an operational method in question, to optimize the operation variables, improve and sustain performance viz. method yield with well-executed management plans. the method yield was improved as a results of implementing this technique. it's impact of improved and higher utilization of resources

and diminished variations. It conjointly helped in maintaining consistent quality of the method output

III. METHODOLOGY

DMAIC approach finds root cause problem in any industry and describe to focus on defects and defects possibilities. DMAIC means Define, Measure, Analyze, Improve, control.

Define Phase is the first phase of DMAIC approach. In this phase we have to know who are the material suppliers for manufacturing cam shafts and what type of machines they are used to manufacture and which type of manufacturing process they are using, finally customer is satisfying or not. So by using project charter we define these things to understand the manager or other officials.

PROJECT CHARTER:

PROJECT NAME: REDUCING DEFECTS OF A CAM SHAFT BY SIX SIGMA METHODOLOGY		
SPONSOR: CAM SHAFT MANUFACTURING INDUSTRY		
TEAM MEMBERS:		
NAME	ROLE	TIME COMMITMENT
Durga Prasad	Analyst	7 days
NON CUSTOMER STOCK HOLDERS:	IN SCOPE: reduce defects and improve quality	INTERNAL CUSTOMERS: MAHINDRA AND MAHINDRA, ASHOK LYLAND, CATERPILLAR ETC...
	OUT SCOPE: Proper functioning cam shaft in real time experience	EXTERNAL CUSTOMERS: customer's.....

Measure phase:

One of the initial steps of the measure stage is deciding the capacity of a procedure. This progression can be finished before a group officially leaves the characterize stage if the information expected to perform sigma level.

Failure modes and effective analysis: The Failure Modes and Effect Analysis is a tool which will be applied by a Six sigma in any part from outline to research. Often, operating with FMEAs in live as a result of it helps them establish risk priorities for numerous inputs and errors inside a method. Used properly, the FMEA uses general knowledge and team input to line the stage for root cause analysis within the next DMAIC part.

Collecting data: Creating a baseline metric for a method begins within the outline part, however groups cannot leave the live part while not a powerful understanding of current method performance.



Ideally, the team would have access to historical metrics for the method. In some cases, the team needs to collect knowledge from scratch.

Discrete data: Discrete data is categorical in nature; it is also referred to as qualitative data or attribute data. Discrete data falls into three categories: ordinal, nominal, and binary, or attribute, data; some data collected can be expressed in one or more of the discrete categories.

Continuous data: Continuous data is quantitative data and is measured in units.

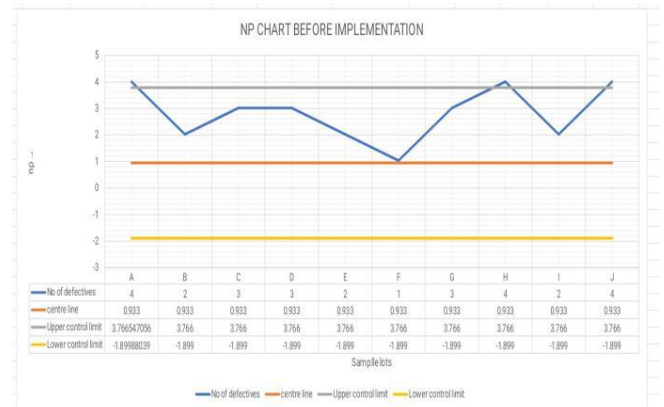
Numbers of defects found in manufacturing among three thousand inspected components are shown in below:

These are the defects found in 3000 components over a span of four days. First we are focusing on the defects that are undersized and oversized, various machined defects, casting defects in various lots. We collect data from different lots which are manufactured by different workers in different machines. Depending upon the lot we found various defects. A lot has **three hundred components**. By using the principles of statistical quality control we are defining the error which are occurred in different lots.

	A	B	C	D	E	F	G	H
1	Sample	Sample size	Sample	No of defectives	centre line	Upper control limit	Lower control limit	
2	A	300	A	4	0.933	3.766547056	-1.89988039	
3	B	300	B	2	0.933	3.766	-1.899	
4	C	300	C	3	0.933	3.766	-1.899	
5	D	300	D	3	0.933	3.766	-1.899	
6	E	300	E	2	0.933	3.766	-1.899	
7	F	300	F	1	0.933	3.766	-1.899	
8	G	300	G	3	0.933	3.766	-1.899	
9	H	300	H	4	0.933	3.766	-1.899	
10	I	300	I	2	0.933	3.766	-1.899	
11	J	300	J	4	0.933	3.766	-1.899	
12		3000		28				
13								
14			np	0.933333333				
15			p	0.009333				
16			standard deviation	0.944405				
17								

the thing is inadequate or it isn't faulty. The np control graph is utilized to decide whether the quantity of blemished things in a gathering of things is reliable after some time. The subgroup size (the quantity of thing in the gathering) must be the equivalent for each example. An item or administration is flawed in the event that it falls flat, in some regard, to adjust to determinations or a norm. You are tallying n things. A tally is the quantity of things in those n things that neglect to adjust to particular.

Sr.no	Defects	Frequency
1	Pin hole	2
2	Surface blow hole	2
3	Cold shut	3
4	Mis run	2
5	Mis match	1
6	Hot tear	3
7	Lack of cylindricity, roundness, straightness, surface finish, tolerance values	8
8	Machine condition (improper clamping of tool and work piece, tool breakdown)	3
9	Defect in intake and exhaust angles	1
10	Defect in real time operation	1
11	improper training of workers, feed speed, depth of cut	2



The above graph shows: The issue confronting parcels are A, H, J. These parts have greatest number of deformities similar to other's. So graphical portrayal is over the upper control breaking point of the diagram. With the goal that we need to discover the machines and laborers who are made these things. Additionally discover the blunder foundations for the deformity.

UCL speaks to upper control limit on a control graph, and LCL speaks to bring lower control limit. A control outline is a line chart that shows a nonstop image of what's going on underway procedure concerning time. Thusly, it is a significant instrument for factual procedure control or quality control.

X reference chart for neckline of a cam shaft:

The x-bar -outline quality control graphs used to screen the mean and variety of a procedure dependent on tests taken in a given time. As far as possible on the two talks are utilized to screen the mean and variety of the procedure going ahead.

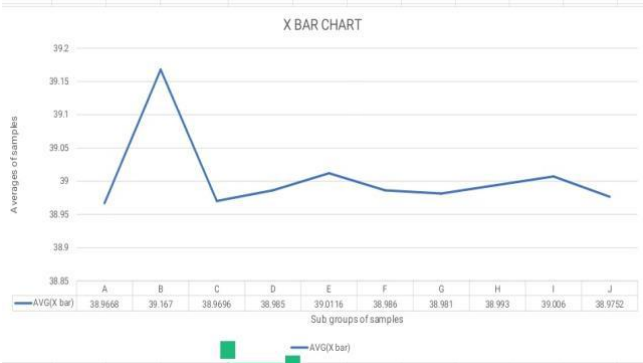
Implementing control charts for finding process variations in lots.

NP chart before implementation before implementation:

An np control graph is utilized to take a gander at variety in yes/no sort qualities information. There are just two potential results: either

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In the event that a point is out of as far as possible, it demonstrates that the mean or variety of the procedure is wild; assignable causes might be suspected now. On the x-bar graph, shows the amazing mean and as far as possible. No of tests are taken from the parcels and information ought to be ought to be examined to discover mistakes in process fabricating. Information dissected ought to be demonstrated as follows.



	A	B	C	D	E	F	G	H	I	J	K
1 Lot	X1	X2	X3	X4	X5	AVG(X bar)	Range	X double bar	UCL(+3 sigma)	LCL(-3sigma)	
2 A		38.97	38.959	38.973	38.962	38.97	38.9668	0.014	39.00412	38.82702608	
3 B		38.977	39.961	38.964	38.959	38.974	39.167	1.002	39.00412	39.18121392	38.82702608
4 C		38.978	38.964	38.965	38.965	38.976	38.9696	0.014	39.00412	39.18121392	38.82702608
5 D		38.976	38.986	38.984	38.969	39.01	38.985	0.041	39.00412	39.18121392	38.82702608
6 E		38.969	39.07	38.969	38.97	39.08	39.0116	0.111	39.00412	39.18121392	38.82702608
7 F		38.97	39.01	38.963	39.02	38.967	38.986	0.057	39.00412	39.18121392	38.82702608
8 G		38.968	39.03	38.965	38.978	38.964	38.981	0.066	39.00412	39.18121392	38.82702608
9 H		38.973	38.959	39.08	38.979	38.974	38.993	0.121	39.00412	39.18121392	38.82702608
10 I		38.974	38.978	39.1	38.989	38.989	39.006	0.126	39.00412	39.18121392	38.82702608
11 J		38.974	38.973	38.964	38.997	38.968	38.9752	0.033	39.00412	39.18121392	38.82702608
12											
13											
14											
15											
16											standard dev 0.05903131

The problem facing lot is **B**. These lots have maximum number of defects comparable to other's. So that graphical representation is above the upper control limit of the graph. So that we have to find the machines and workers who are manufactured these items. Also find the error causes for the defect.

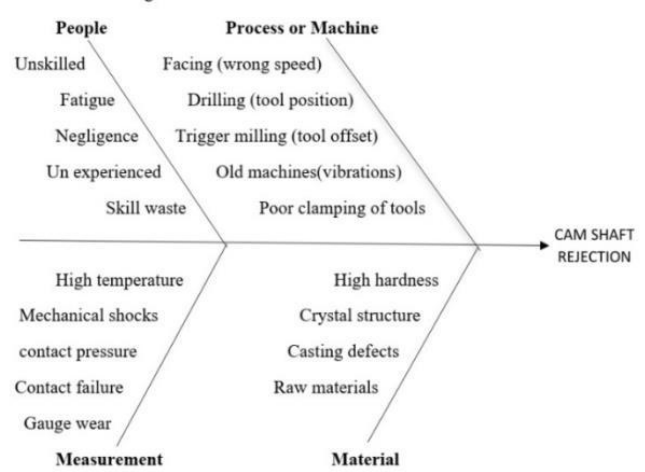
UCL represents upper control limit on a control chart, and LCL represents lower control limit. A control chart is a line graph that displays a continuous picture of what is happening in production process with respect to time. As such, it is an important tool for statistical process control or quality control.

Analyze phase:

Root cause analysis: . One of the fundamental activities of a DMAIC phase is analyze phase. Analyze phase is performed by the entire team with help from identified subject. Root cause analysis is used to identify root causes for problems or defects. when a team has reached the analyze phase without a clear idea of primary causation it will lead to improper vision of the finding of problems

1. Fish bone diagram
2. Pareto chart

Fish bone diagram: The chart lets focus on a conceptualizing



procedure that produces thoughts regarding conceivable issue causes, composes those potential outcomes in a sensible way, and lets groups imagine the data to recognize needs, patterns, and connections between thoughts. At the point when utilized as a group movement, the fishbone outline empowers interest and contribution from all colleagues, which builds the opportunity of laying the primary work for a practical and unique arrangement. It finds sensible reason to surrenders.

Above fish bone diagram:

Material stage:

First Stage of rejection possibility is selecting a wrong category raw material i.e. material has high hardness (high Brinell's hardness number). During the casting of the molten metal various defects are possible due low or high processing temperature in furnace i.e. changing of crystal structure. Pouring the molten metal in to the die possible out come defects are misrun,, hot tears. While solidification defects like cold shut occurs. Due to misalignment of dies mismatch defect occurs.

Processing or machining stage:

During machining improper clamping and fixing of tools in holders occurs lack of tolerance values, geometrical defects like lack of straightness, roundness, concentricity and circularity. Due to usage of old machines poor tolerance values are obtained.

Measurement stage:

While measuring the components dimensions the desired component should maintain certain contact pressure, due to lack of contact pressure rejection may possible for sensitive gauges whose working principle is similar to pneumatic gauges i.e. back pressure. Using of GO and NOGO gauges a certain number of components is measured if a cause of possibility to wear of gauge. It will allow neither minimum limit of part or maximum limit of part. Usage of electrical gauges whose working principles are resistance, inductance and magnetism due to low contact area spaced i.e. worker negligence gauges terms above work part is a defect.

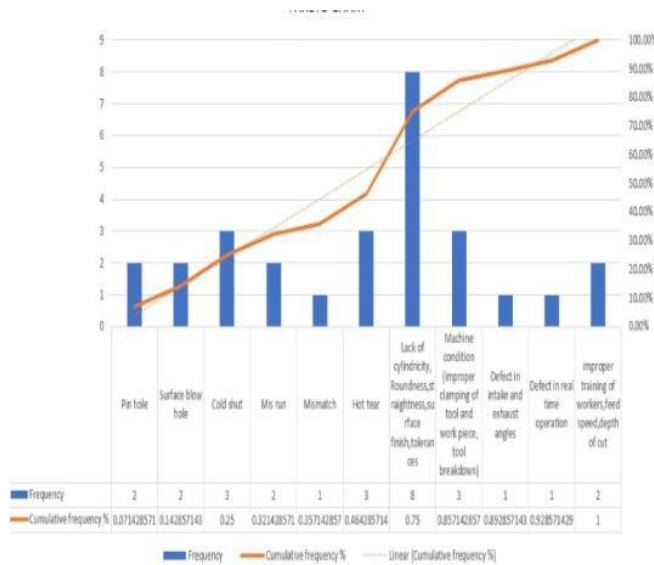
People stage:

Heavy shift works for workers cause a fatigue that leads to poor performance while working. Some what negligence while measuring a component leads to add a rejection piece. Improper training of workers leads to poor performance in a industry.

Pareto chart:

The Pareto principle, conjointly referred to as the 80/20 rule, says that twenty percent of the causes result in eighty percent of the consequences. this is often conjointly referred to as the law of the important few: the important few inputs drive the bulk of the outputs. The pareto principle is best displayed employing a Pareto chart, that could be a graphical illustration of knowledge components.

in no	Defects	Frequency	relative frequency	Cumulative frequency %
1	Pin hole	2	2	0.071428571
2	Surface blow hole	2	4	0.142857143
3	Cold shut	3	7	0.25
4	Mis run	2	9	0.321428571
5	Mismatch	1	10	0.357142857
6	Hot tear	3	13	0.464285714
7	Lack of cylindricity, Roundness, straightness, surface finish, tolerances	8	21	0.75
8	Machine condition (improper clamping of tool and work piece, tool breakdown)	3	24	0.857142857
9	Defect in intake and exhaust angles	1	25	0.892857143
10	Defect in real time operation	1	26	0.928571429
11	improper training of workers, feed speed, depth of cut	2	28	1



Improve phase:

Sources of defects and their measures:

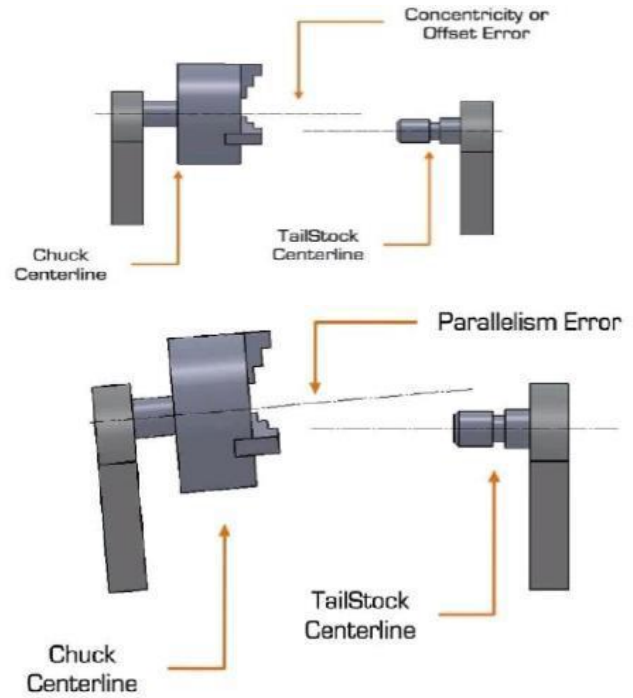
Errors due to misalignment: Measurements past resistance limits; mistaken shape/geometry of the machined part. A few issues emerge in machines when the chuck/collet isn't appropriately lined up with the tailstock or apparatus holder. These issues add to an enormous number of blunders created therefore in the workpiece geometry.

Legitimate arrangement of axle, workpiece and the apparatus expands proficiency of a machine.

There are two sorts of misalignment:

- 1) Centreline misalignment
- 2) Angular misalignment

Centreline Misalignment:



Angular misalignment

Corrective measure is proper alignment tests are conducted regularly i. e weekly once. This will improve efficiency of a machine to produce correct dimensions.

Error due to improper clamping of fixtures and vices: It will affect the particular piece.

It will leads Poor surface finish, harm to tool holder and insert, dimensions not in tolerance limit.

Improper clamping of piece of work offers rise to magnified vibrations between the piece of work and therefore the cutting implement. As a result, the surface quality of the piece of work is diminished, dimensions might transcend the indicated tolerances and therefore the tool holder and insert would possibly get broken. Therefore, correct clamping of piece of work is vital for top potency.



Error due to chatter: Chatter affects the complete batch of the workpieces created. It happens as a result of 2 reasons:

- A. Poor set up
 - B. Improper insert installation
- Damage to tool, dimensions on the far side tolerance limit, breakdown of machine.

Chatter may be a resonant development wherever the machine or piece of work vibrates.

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Chatter is liable for the eruption generated in machines. It additionally causes unwanted violent vibrations in



machines. Chatter reduces tool life. It decreases the accuracy and lifetime of machine.

There are 2 sorts of chatter:

1. Tool chatter.
2. Workpiece chatter.

Tool Chatter: Tool Chatter: In tool chatter, the machine and cutter vibrates and transfer the vibrations onto the piece of work. .

Work piece Chatter: In piece of work chatter the wall of the piece of work is vibratory. it's common in elements with skinny walls. it's causes additional severe issues as compared to tool chatter.

Increasing or decreasing what proportion the tool stands out will cut back the vibrations by dynamic the frequency. Dynamic the deflection of tool reduces the likelihood of exciting chatter.

Corrective Measures:

1. Reduce feed rate
2. Choose additional positive chip breakers

Error due to unacceptable chip control: The long wiry chips created when turning are incredibly tricky in activity and creation. Whole chips twist around the workpiece. In this way, the administrator needs to invest more energy in expelling chips expanding the process duration.

Chips joined to instrument, undesirable signs of segment's surface

Chip edges are commonly hot and sharp, subsequently represent a hazard to the worker. Moreover, chips can haul along the parts, making harm the workpiece. Besides, the apparatus can likewise break if the chip is stuck between the front line and the workpiece as the device continues cutting the chip.

Arrangements:

1. Increase feed rate
2. Use increasingly positive chip breaker
3. Select littler nose range

Error due to poor surface finish: Poor surface of work piece is extremely undesirable issue, particularly in production of good items with high grade surface end demand.

Spotting of error: Poor surface roughness

Causes:

1. Feed rate too nice for nose radius
2. Low cutting speed
3. Poor cut action

Solution:

1. Scale back feed rate
2. Use larger nose radius insert

3. Increase cutting speed

4. Choose a lot of positive chip breaker

Errors due to incorrect insert selection:

Insert plays a very important role in metal cutting operations. Selection of the correct geometry, nose radius and tolerances of the insert is important to get high efficiency in production. There are two parameters to keep in mind while choosing an insert:

1. Insert geometry
2. Nose radius

Spot to error: Vibration in cutting operation

Errors due to wrong tool offset: Wrong tool offset usually ends up in workpieces having dimensions well on the far side the tolerance limits. Entire batches of production will go wasted because of wrong tool offset.

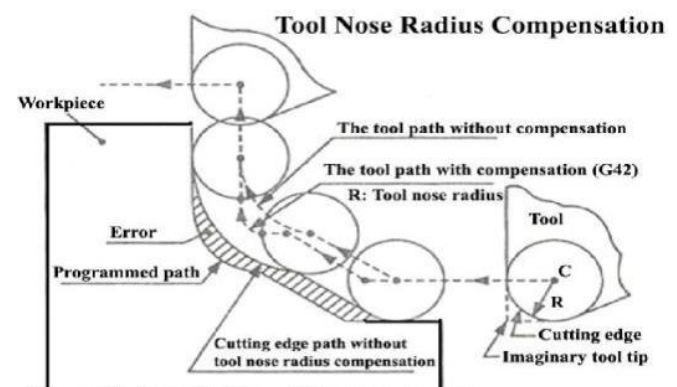
To spot error: Dimensions out of tolerance limits

Tool Offset: The machine should be told the number the machine zero and element numerical quantity. The element of offset between zero points is that the start line of the machining operation on the work piece at X, Y and Z axis.

Tool Nose/Cutter Nose Radius Compensation: In edge operation, the half program is developed for the cutter path with relevance the centre of the tool instead of the purpose on the boundary wherever the particular cutting takes place. At the time of writing a locality program, a cutter of appropriate diameter is chosen and program is developed for centre line of the cutter. however once actual machining is completed, if a cutter of smaller diameter is employed, it'll lead to a bigger work piece and if a cutter with larger diameter is employed, it'll lead to a smaller work piece.

Corrective Measure:

1. Tool offset compensation ought to be properly taken and with improved techniques.
2. Nose radius compensation with the right nose radius worth ought to be input.



Errors due to incorrect program: This type of error is caused by worker negligence.

Errors due instruments: High sensitivity and lack of precession in instruments leads to errors. This may lead to defect of a product. Due to wear of slip gauges, gauges dimensional accuracy is changed so error outcomes may possible.

Due to lack of current and voltage shut downs instrument may loss its precisional values. Workers negligence may lead to parallox errors.

Control measures: Regular monitoring and maintaining the instruments properly in condition may reduces defects. Workers training programs may be conducted time to time.

Control phase:

To control these problems, checking of the camshaft is done after passing through each workstation. So that if any defect may occur it will be immediately acknowledged. Proper actions to eliminate problems will be taken. It will help to find the reason for defect at the time of its origin itself and it will also help to improve and make corrections on the machine itself.

After taking the measures the defects are reduced to some extent as shown in below. We can't prevent all the defects, by taking some defect prevention by regular monitoring of workers, machinery and equipment like gauges, and no go gauges can control the defects rate.

By using the six sigma tools like statistical quality control we can monitor the process is going on control or out of control. The data should be taken from the work processing and analyzed in control charts like p charts and NP charts.

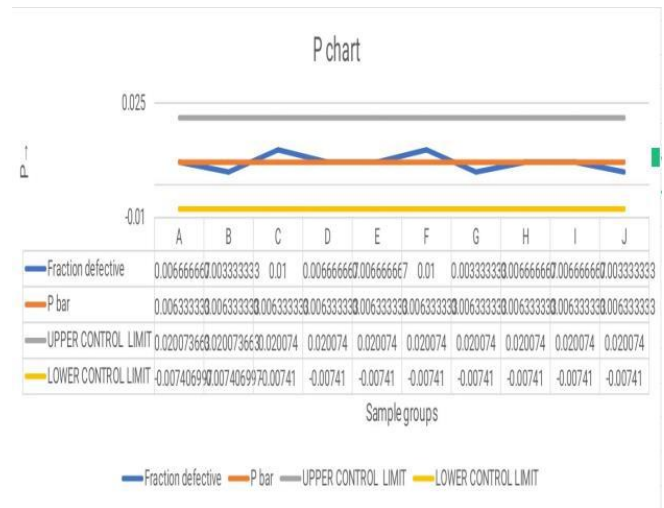
After implementing various improvements defects are somewhat reduced are shown in above.

In the below p chart there is no indication above or below of upper control limit, and the lower control limit. So the process is going on control. Continuous monitoring of data which is developed at work stations should be checked. If any non-conformance is detected, instructions regarding needed actions to undertaken, should be also included. Over time, such a plan should be updated.

NP CHART AFTER IMPLANTATION PROCESS:

From the above chart there are no points crossing the upper control limit and lower control limit. So process in control throughout the production of that batch.

A	B	C	D	E	F	G
Sample	Sample size	Sample	No of defectives	centre line	Upper control limit	Lower control limit
A	300	A	2	1.899	6.021891194	-2.222091194
B	300	B	1	1.8999	6.021891194	-2.222091194
C	300	C	3	1.8999	6.021891194	-2.222091194
D	300	D	2	1.8999	6.021891194	-2.222091194
E	300	E	2	1.8999	6.021891194	-2.222091194
F	300	F	3	1.8999	6.021891194	-2.222091194
G	300	G	1	1.8999	6.021891194	-2.222091194
H	300	H	2	1.8999	6.021891194	-2.222091194
I	300	I	2	1.8999	6.021891194	-2.222091194
J	300	J	1	1.8999	6.021891194	-2.222091194
			3000	19		



IV. DEFECTS PER MILLION OPPORTUNITIES:

$$\text{Defects per million opportunities} = \frac{\text{Total defects observed} \times 1000000}{\text{Total opportunities}}$$

$$\text{Defects before implementation} = \frac{28 \times 10,00,000}{3,000} = 9000$$

$$\text{Defects after implementation} = \frac{19 \times 10,00,000}{3,000} = 6000$$

V. RESULT

Before the process defects are 28 in number I,e 9000 defects per million opportunities.

After the process defects are 19 in number I,e 6000 defects per million opportunities

Defects are some extent reduced

VI. CONCLUSION

It is known that in a manufacturing industry lot of defects may raise due unusual reasons, it may poorly satisfy the customer results less profitable. Some times defects may be accountable to profit. A defect reduces quality life of the product. We calculated that how many defects are produced in the lot in a cam shaft manufacturing organization . The number of defects produced in batch are **twenty eight**. A batch consist of **three thousand components**. We applied six sigma tools and techniques to reduce defects as minimum as possible. By using six sigma **DMAIC** methodology defects are reduced to 19 number. So their by reduction in defects in million opportunities. The study reports quality improvement through reduction in defects. The defects produced per million opportunities nine thousand number decreased to six thousand defects. So the process is under **four sigma i**, e 99.38 perfect defect free.



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