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Experimental Determination and Investigation into Manufacturing Process to Find Out Causes of Variation (Flatness) and Action Trials to Reduce Variation into Manufacturing Process

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Abstract: ***Manufacturing process is widely used for making/ giving shapes to components' as per requirement to fulfill intended purpose. This study discusses an experimental determination and investigation into manufacturing process to find out causes of variation (Flatness) and action trials to reduce variation into manufacturing process. But other factors are also involved into manufacturing process. In this experiment we worked on casting, machining process and/or design improvement to improve current condition of manufacturing process.***

1. Introduction

Machining:
It is the process which involves the material removal from any surface/ area of the object to impart specified shape or It may be defined as the activity in which a portion of material is removed by some mean to achieve required shape of the object. The final required shape may or may not be achieved in single step. The required shape may take multiple step of activity.

Flatness:
Flatness (as per GD & T) is very simple. It is commonly denoted with symbol that defines how the surface is flat regardless of ant other datum's or features.

It is widely used in the components (machined or non machined) where mating parts to be fitted or assembled. It is very useful feature which is to be defined on drawing wherever flatness is required on component. Flatness tolerance is always less that the dimensional tolerance associated with it.

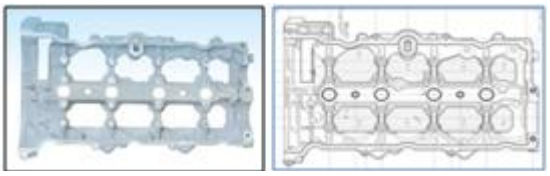
Requirement of flatness in any component
When you want to constrain the amount of waviness or variation in a surface without tightening the dimensional tolerance of said surface. Usually flatness is used to give a surface an even amount of wear or for sealing properly with a mating part. Commonly used on a fixture that must mate flush with another part without wobbling, but where orientation is not important.

In manufacturing and mechanical engineering, **flatness** is an important geometric condition for work pieces and tools.

2. Review of Past Process

So to conduct project work, a component was selected which consists of machining process and some critical product characteristics are required as per application. Engine part (Cover Cylinder Head), a component of cylinder head in car / four wheeler application.

Sketch/ Photograph of selected sample: The sample is selected considering application in engine/ transmission



2.1 Manufacturing Process of Selected Sample

The selected sample/work piece is made with Aluminum High Pressure Die Casting process, followed by material removal Machining (step wise machining) process, Dowel assembly process.

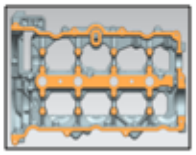
2.2 High Pressure Die casting Process

It is manufacturing process, which can be defined as in which molten metal is forced into a cavity or die under high pressure. Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity or die. The mold cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mold during the process.

2.3 Objective of the Present Work

Past history/ trend of Flatness more in selected sample, n= 100 parts checked at manufacturing line month wise by first

principle method for flatness characteristics and following is data
Specification (Considered)=
< 150 Microns → OK
> 150 Microns → Not OK

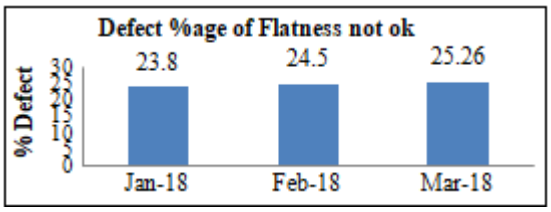
Photo/ Sketch	Inspection Method	Observation
	Continuous surface inspection using first principle (Plunger Dial+ Stand)	Approx 25% in-house found defective

Project Theme: To find out cause of variation & reduce variation in manufacturing process resulting in reduction of defective cases from 25% → Zero by experimental study & project work.

3. Experimental Setup

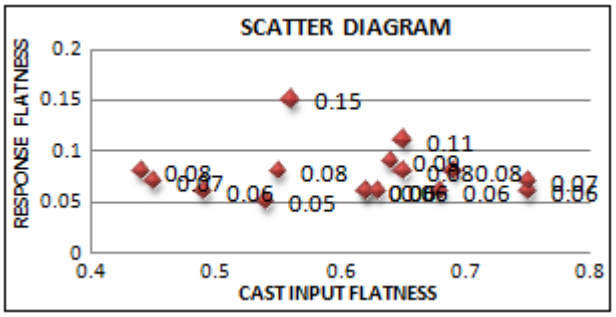
Data Collection and Statistical Analysis
To start with project work, we need to understand first Manufacturing process of the selected sample with sketch, as shown below:

3.1 Data Collection



Effect of Casting Process
Sample part is being made in two operations:
1) Casting
2) Machining.

Effect of casting on machining process, analysis using scatter diagram
N= 16 parts casting flatness characteristics is measured and noted down in table with unique identification marking (sr. no.) on each part and same parts are offered for machining process. Again flatness is measured after machining process



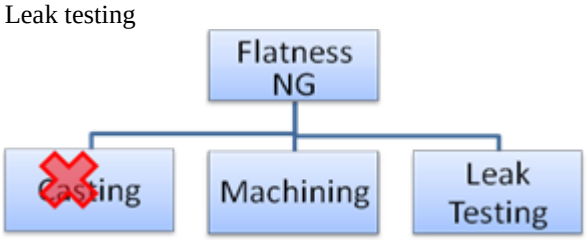
From scatter diagram study, Correlation coefficient is only 7%.

So, There is no correlation between flatness of input casting and flatness of output after machining. It depicts that there is no relation between casting input flatness on machining output flatness.

Effect of Leak Testing Process

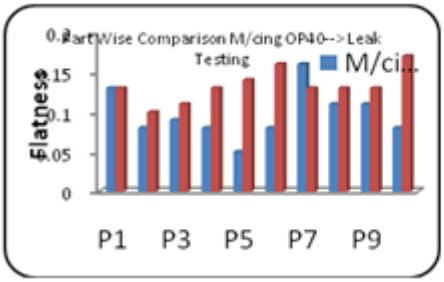
Sample part is being made in following operations:

1) Casting
2) Machining
3) Leak testing

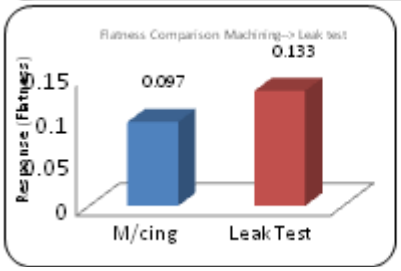


N= 10 parts machining flatness characteristics is measured and noted down in table with unique identification marking (sr. no.) on each part and same parts are offered for next leak testing process Now part wise comparison was plotted on graph for each part before and after leak testing process as shown below.

Paired Comparison of data



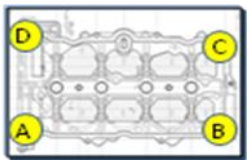
Part wise comparison of flatness observation before and after leak testing process



N=10 parts flatness average comparison before and after leak testing process

Arriving at Cause: The Flatness is measured at four locations of component/ sample under inspection for n=10 parts. The flatness is measured at 4 locations viz A, B, C, D

as shown in figure. The flatness values are noted in below table (3)



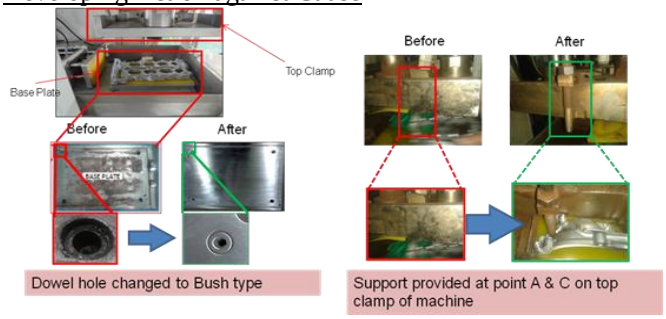
Multivariate analysis of data

Genba observation	Photo/ Sketch
1. Locating dowel at machine base plate observed loose and dowel hole shape found oval also.	
2. Point "A" & "C" overhang observed resulting into cantilever.	

Observations

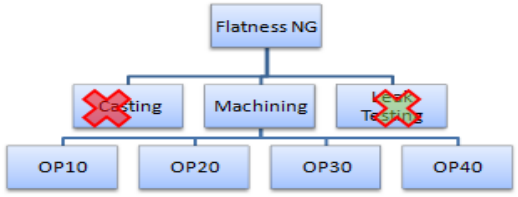
- Significant trend observed that Point A & C are mostly at lower side by >50µ.
- Genba (Actual working station) is observed and observations are noted down into table.
- The Multivari analysis clue of location A & C is also observed at Genba and found major observation of overhang.

Developing Action against Cause



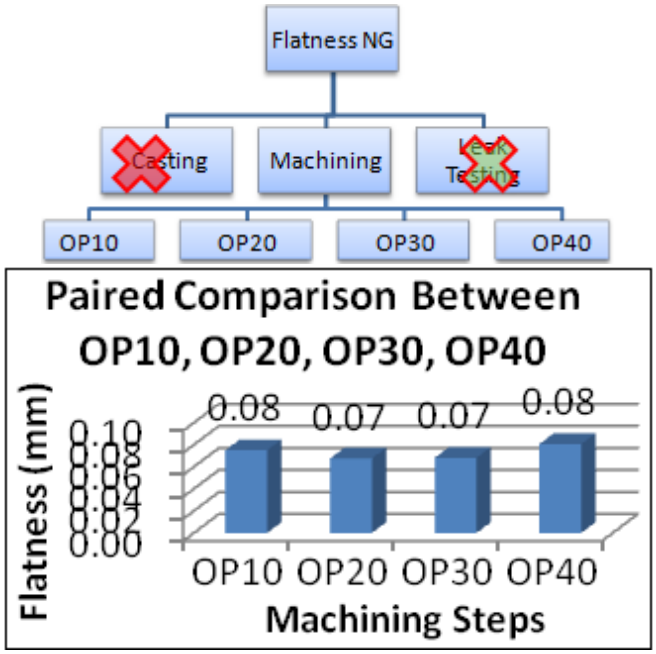
Effect of Machining Process (Process to process)

Again analysis carried out to reduce flatness further: It is studied that part is made up into four machining steps naming from operation 10 →Operation 20 → Operation 30 → Operation 40 (normally denoted as OP10 → OP20 → OP30 → OP40) as shown below



To analyze further, Paired comparison tool applied and described as, Flatness response is measured for n=10 parts after each machining step (Viz OP10 to OP40) and recorded

The average observation is plotted into Graph (Paired Comparison) to find out effect of step machining.



Observation:

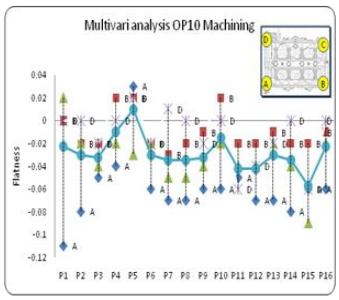
- Paired Comparison summary signifies that there is no significant effect on flatness from OP10→OP20, OP20→OP30, OP30→ OP40.
- It is observed that Flatness at OP10 (First step machining) itself is more, which is not changes significantly in subsequent process.

So, Further deep drive analysis is carried out at OP10 flatness using flatness measurement at four location.

The flatness observations are plotted on graph (Multivari Analysis) to know the variation with part. The Multivari analysis shows that

1) Part to part variation is significant (Blue round dots)
2) With in part variation (Vertical line) is significant and location A is mostly at bottom side of graph.

Multivariate analysis:



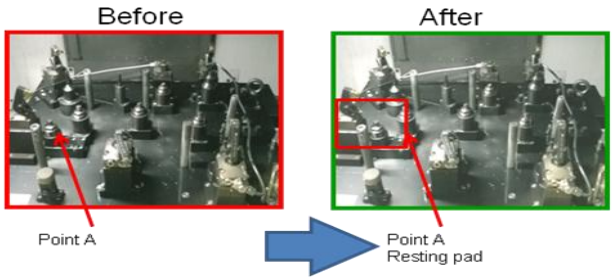
Gemba observation	Photo/ Sketch
1. Fixture resting pad height at location A observed less.	
2. Part flatness variation at different points observed before & after clamping.	

From multivari analysis it is observed that most of cases Point "A" is significantly lower and other points are continuously varying from part to part.

- The Multivari analysis clue of location A is also observed at Genba and found rest pad (resting point of casting reference into Fixture) is found with less height w.r.t. drawing.

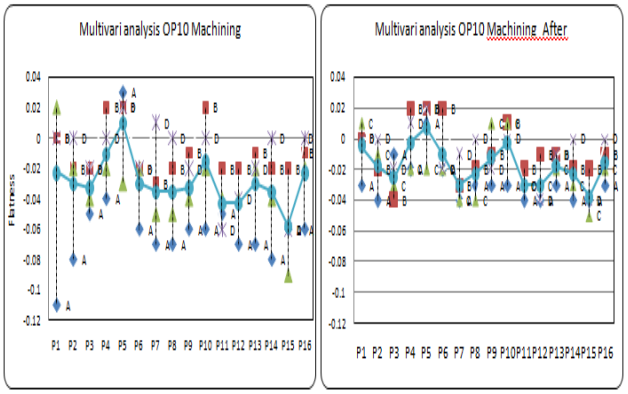
- The flatness of part is measured before and after clamping to know variation/ effect of clamping on part shape, No significance observed.

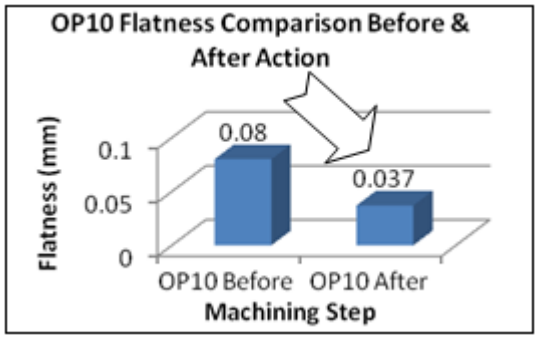
Developing action against cause:



Resting pad height increased by 0.04mm at Point A

Validation of Cause: The flatness is measured for n=16 parts after action taken at same 4 locations and multivari analysis and found significant improvement in OP10 flatness.



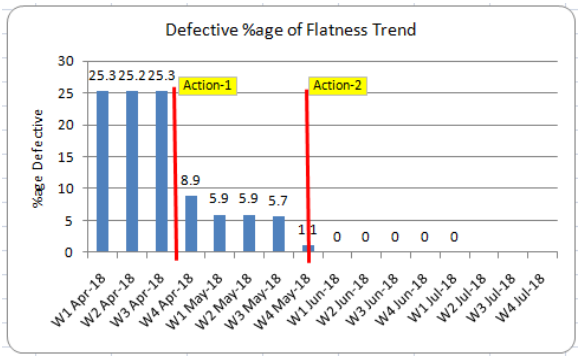


Summarization of actions:

S.No.	Main Cause	Corrective action
1	Leak test machine base plate locating pin hole wear out & Overhang at points A & C.	Leak testing machine base plate locating dowel hole repaired by providing bush. (Bush is provided as wear part instead of wearing base plate) External support at point "A & C" provided to avoid overhang.
2	Fixture resting pad height at location A less & stress at different points before & after clamping.	Resting pad height increased by 0.04mm at point A in OP10 machining fixture. (Rest pad heights designed as per part geometry/ dimensions)

4. Observation and Calculation

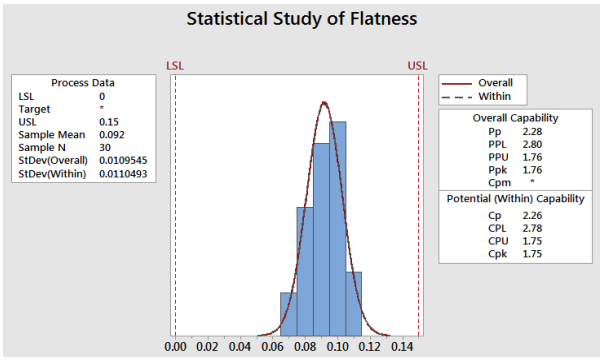
(a) Results after study & its Monitoring



After action(s) implementation, flatness variation (more) defectives reduced from 25% → Zero (till now).

(b) Validation of results:

After complete study n=30 continuous parts are taken, measured for flatness and Statistical Process Control (SPC) study is conducted to verify project results and defect PPM (parts per million).



The results as follow:

Legend	Specification	Observation	Judgment	Remarks
Cp	> 1.67	2.26	OK	As per AIAG Manual of SPC 2nd Edition
Cpk	> 1.67	1.75	OK	

Uniqueness of the Project

- This activity was requiring high skill and deep analysis.
- All graphs (Multivari analysis, Scatter plot /diagram etc.) made by using Microsoft excel only.

Statistical tools used

- Scatter diagram → To establish effect of input
- Tukey's Test → To establish effect of input flatness on output flatness
- Multivari Analysis → To find out Positional & Temporal variation

5. Conclusions

(a) Conclusions of defectives reduction

1. Productivity increase by 25%	
Daily Production	500 Nos.
Daily Loss	25% of Production
Daily Quantity Loss	(500x0.25)=100 Nos.

(b) Conclusions of cost benefit

2. Cost benefits of manufacturing cost:	
Manufacturing cost per piece	605 Rs.
Monthly Loss Cost	(25x100X605)=1512500 Rs.
Yearly Loss Cost	(1512500x12)=18150000 Rs.
Total Cost Benefits	18150000 Rs. = 181.5 Lakh Rs

3. Handling and inspection cost saving	
Inspection cycle time	75 sec
Cycle time saving per day	(75/60x100)=125 min.
Monthly time saving	(125x25)=52 Hrs.
Yearly time saving	(52x12)=624 Hrs.
Inspection cost per hour	50 Rs/-
Yearly Cost Saving	(50x624)=31200 Rs= 0.31 Lakh

6. Scope for Future Work

This study defines the reason for variation in process through statistical means and systematic actions at process/activity to reduce process variation.

Application: Any critical/ functional components, mainly applicable for;

- Transmission parts
- Engine parts
- Chassis parts of any automobile, transportation vehicle, aerospace etc.

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