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Quality Improvement during Camshaft Keyway Tightening Using Shainin Approach

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Abstract- *The two major challenges that industries are facing today are continuous improvement in productivity and quality of the product.* An alternative to the Classical and Taguchi experimental design is the lesser known but much simpler Shainin DOE approach. Shainin methods refer to a collection of principles, which make up the framework of a continually evolving approach to quality. *Bosch Production System (BPS) - one of the leading manufacturers in Diesel system equipments, has been successfully employing the strong statistical tool 'Shainin' for the root cause identification and Design of Experiments (DOE) techniques for analysis and optimization of the quality related issues. Shainin is popular tool being simplest to employ in the manufacturing related problem solving and very effective tool in identifying quality achievement hurdles. The present paper deals with one of the quality issues resolved by using Shainin methodology at Bosch Ltd, Banglore.*

Index Terms*- Shainin Methodology, Root Cause Analysis (RCA), Component Search, RedX*

I. Introduction

Diesel engines have become the most popular power packs for heavy duty vehicles and equipments such as trucks, tractors, passenger vehicles, gensets, etc. as the diesel is one of the most efficient and energy dense fuels available today [1]. Nevertheless, the diesel engine has several great advantages, the quality production and maintenance of critical components of engine system has become yet a challenging task. Diesel Fuel Injection Pump (DFIP) System- the heart of the diesel engine is one such critical system [2]. Nowadays, the quality of the product has become the dominant criteria to acquire the global market. BPS is the leader in quality production by deploying advanced quality measures in its manufacturing processes and thus, satisfying the customer [3]. It has been possible through continuous improvement and proactive quality maintenance techniques like Shainin System, Failure Mode Effect Analysis (FMEA), Six Sigma, etc., in the production processes. The quality of the product may be quantified in terms of money (INR), First Pass Yield (FPY), part per million (ppm), etc. There is a need to employ a simpler and efficient tool along with the traditional seven quality tools in order to achieve Six-sigma quality in manufacturing industries [4]. Failure of parts, products, or systems in the field can cause major damages - such as production loss, rework, warranty claims, and even image loss of the organization in the market.

1.1 Root Cause Analysis Techniques

Increasing reliability of products demands that the problems that arise during functioning of parts and products need to be identified, the root cause has to established, and finally, the problem needs to be solved. Defect in any part of a component results in manufacturing of the entire component by itself causing a serious problem. In this regard Loss Causation Mode and RCA methods such as Fishbone diagram, Shainin, Why-Why analysis, Failure tree analysis etc. have been very effectively used in the industries.

1.1.1 Shainin approach for problem solving

The Shainin- method starts with an assumption that there is one single root cause for the problem - or that this root cause has the largest contribution to the problem [5]. The goal is to find that root cause and understand it. The subsequent solution then becomes apparent. Shainin system could be effectively used for solving the problems with the theory that "there is a dominant cause for variation in the process output that defines the problem" and it is analogous to Pareto principle of 'vital few causes are the reasons for trivial many problems' Among the Shainin tools, factorial design and scatter plots are commonly known and used. However, the main differentiators of the Shainin tools are component search method, paired comparison method, product/ process search, and B *vs*. C analysis. The problem referred here as GreenY is classified under property, feature, defect or event.

2. APPROACH AND EXPERIMENTATIONS

The problem solving methodology Shainin technique follows the order of Focus-Approach-Converge-Test-Understand-Apply-Leverage, which has been discussed in detail in the following sections.

2.1 Focus

The focus of the project is from the business point of view. It is noticed that 2% camshafts produced are rejected and sent to rework due to keyway tightening during final inspection stage.

Camshaft undergoes several operations like keyway milling, taper grinding, cam grinding, carburizing, annealing, etc.,

Fig. 2.1 Illustration of problem statement (GreenY)

Fig 2.1 illustrates the position of the keyway on the camshaft. Camshaft keyway tightening is measured with plug gauge. The results of measurement is identified in terms of GO and NOGO. The component which is measured GO is accepted and the component with NOGO is rejected at the final inspection. The component which does not measures go will be sent to rework, which involves additional expenditure. The objective of the present work is to identify and eliminate the root cause (RedX) as referred in Shainin technique which is causing camshaft keyway tightening during the assembly process.

2.2 Approach

The effective utilization of the statistical tool and quickness of the root cause identification relays on the selection of samples with two extreme characteristics, that is WOW (worst of worst) and BOB (best of best). The type of problem that is being tackled is apparently limited to variation problems. Out of four GreenY types the present problem was identified as defect. The defect could have occurred during the process stage which could be easily identifiable and has a probability distribution which does not meet the demands.

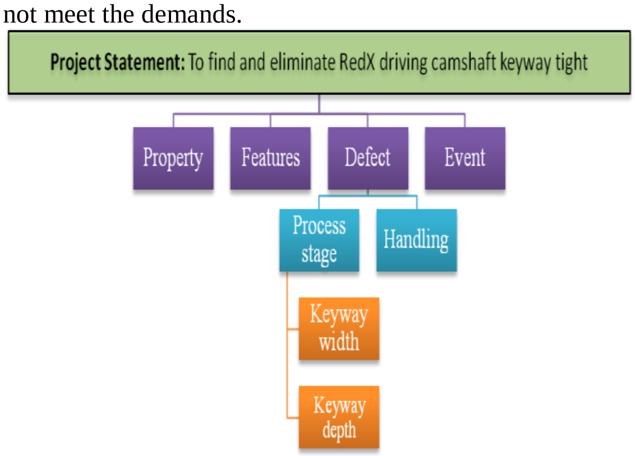

Fig. 2.2 GreenY categorization as 'Malfunction event'

The defined GreenY is 'keyway width' as shown in Fig. 2.2. It is difficult to analyze or use a technique to identify the RedX (dominant cause of variation) since the component undergoes several operations. Hence, each and every process has to be observed to identify the RedX. This problem could be efficiently handled primarily by doing validation of measurement system through Component search-0, followed by Component search- I, II and Paired comparison.

2.3 Converge

Converging towards RedX causing the GreenY has been achieved by Component search technique. The solution tree for the GreenY to determine the RedX is illustrated in Fig. 2.3. This solution tree guides in a right path to find and eliminate the root cause in a short duration.

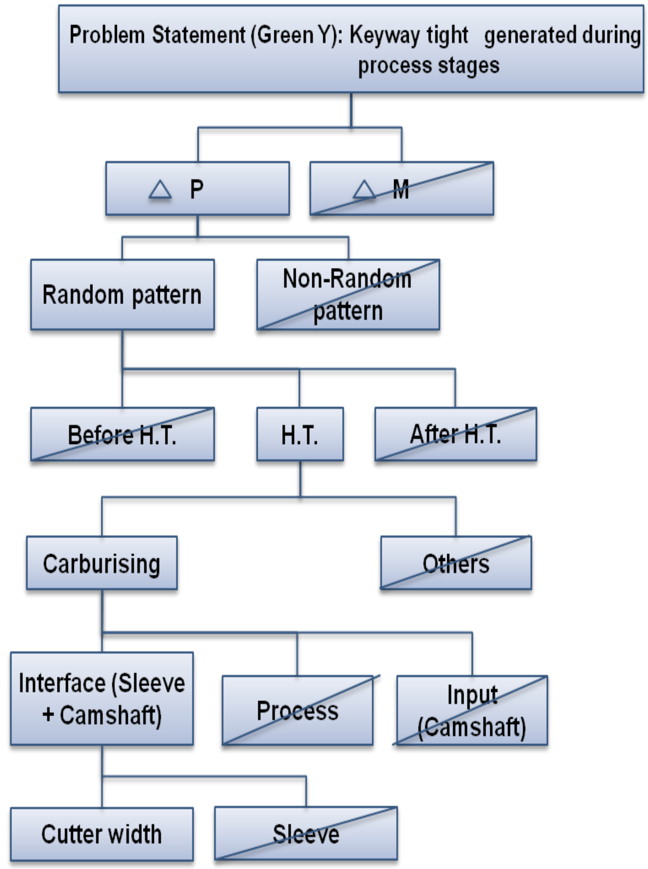

Fig. 2.3 Solution tree of the problem

Δ P is a process and ΔM is the measurement system.

Primary step during Converging process is to recheck the measurement system based on which the problem has been formulated. The solution tree defines the GreenY by eliminating all processes except at process with suspected source of variation. This can be done by Component search Stage-0 exercise. The result of the exercise is shown in Fig. 2.3 & 2.4.

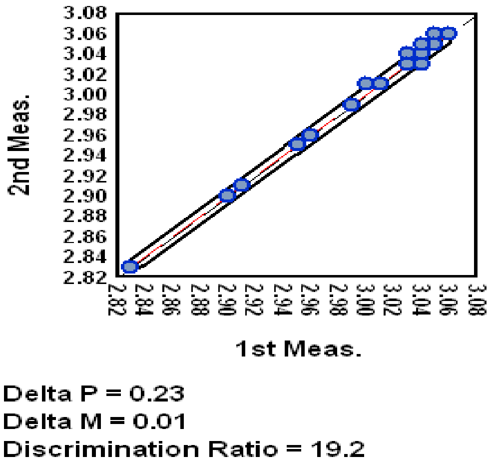

Fig. 2.4 Result of Component search stage-0

During measurement, variation can't be ruled out due to unavoidable vibrations. From the component search stage- 0 as shown in fig2.4 the discrimination ratio is found to be 19.2 which is greater than 6 suggesting that the problem at hand is not due to measurement system.

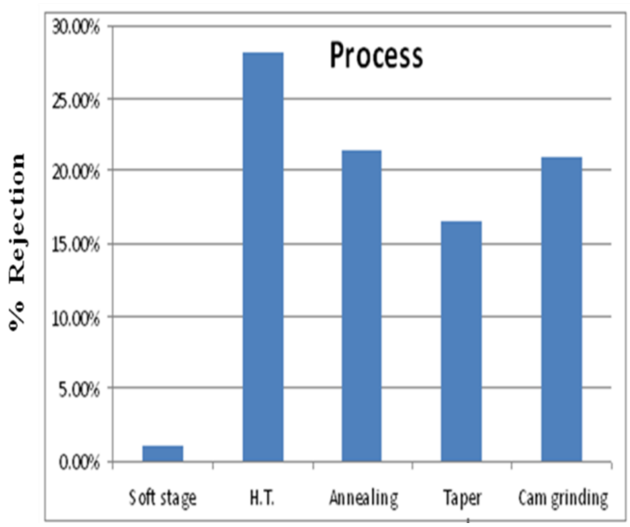

Fig. 2.5 Component search Stage –I and II

To identify the RedX an attempt as been made to identify PinkX (second most important cause for variation) & Pale PinkX (third most important cause for variation) are investigated. Accordingly the possible cause of variation in the process during heat treatment process is investigated and same is shown in Fig 2.5. It can be observed that heat treatment process is resulting in maximum percentage of rejection of camshaft and hence is taken as RedX. Heat treatment involves the carburising of camshaft. To avoid carburising of keyway a protective cap called sleeve is used on either end of the camshaft. Possibility of diffusion of carbon into the keyway due to improper capping is investigated. It was found that the protective caps are not posing any problem. Sleeve is posing a problem & eliminated.

Table1. Full factorial

Trials	Cutter	Sleeve	% Rej. @ Carburizing	% Rej. @ Final Inspection
Trial 1	CS	CS	17%	1%
Trial 2	CS	DS	4%	1%
Trial 3	**DS**	CS	0%	0%
Trial 4	**DS**	DS	0%	0%

DS = Driveshaft; CS = Camshaft

Paired comparison of cutters for Drive shaft cutter(which drives the shaft) and camshaft is carried out. It is observed that using drive shaft cutter results in 0% rejection and camshaft resulting in 2.5% rejection. The cutters are interchanged and this resulted in 0% rejection of camshaft also. To substantiate the above results a set of experiments based on full factorial design is conducted and results are shown in table 1. This table suggests that using a driveshaft cutter results in 0% of rejection irrespective of the using of drive shaft sleeve or camshaft sleeve. Further investigation showed that drive shaft cutter width is 4.07 mm and camshaft cutter width is 4.045 mm as shown in table 2.

Table.2. Cutter width of different family of variants

Family	Camshaft	Drive shaft
Cutter width in (mm)	4.045	4.07

Fig 2.6 shown is the concept diagram which represents the rejection percentage of camshaft due to keyway tight while using camshaft (CS) cutter and driveshaft (DS) cutter. From table1 and fig 2.6 it is concluded that cutter width is a RedX.

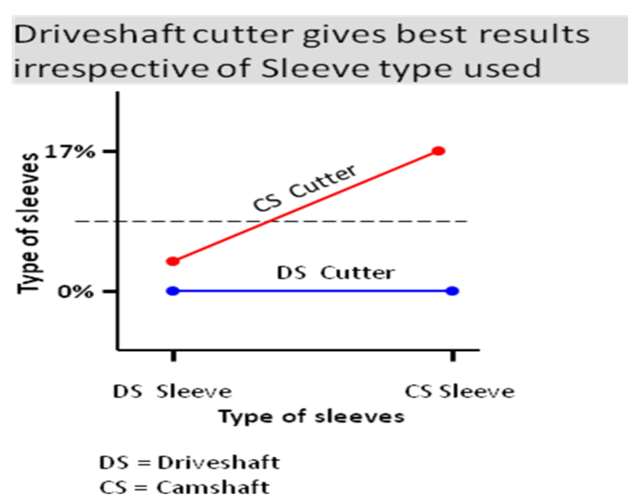

Fig. 2.6 concept diagram

3. RESULTS AND DISCUSSION

3.1 Test

From the past data it was established that camshaft with 4mm keyway width had 1.5% rejection and camshaft with 3mm keyway width showed 2.5% rejection, where as the driveshaft showed 0% rejection under the same circumstances.

Further trials have been carried out by using driveshaft (DS) cutter for camshaft (CS) keyway milling with DS and CS sleeves in two different batches. Each trial batch consisted of 100 numbers of camshafts. The above table.1 shows details of the trial batches carried out in the project and results are tabulated with respect to their change in either cutter or sleeve. From these trails, it is suspected that the camshaft cutter width is 25µm less than that of DS cutter. So, a tolerance relaxation of 8µm in terms of prepart keyway width is considered. Increase of cutter width by 15 µm has been suggested in order to eliminate the keyway tight problem.

The validation results of the trials carried out with new set of cutters having different widths is shown in fig2.7 & fig 2.8 respectively for 4mm & 3mm keyway width. From the results, it is observed that cutter width change would yield better results both to 4mm & 3mm keyway width.

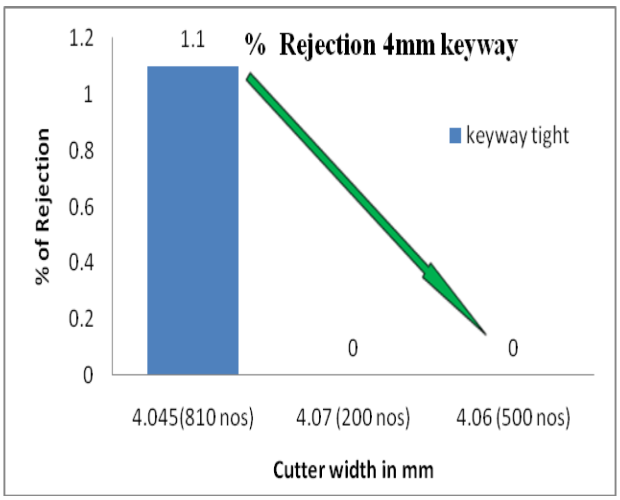

Fig. 2.7 validation of results for 4 mm keyway

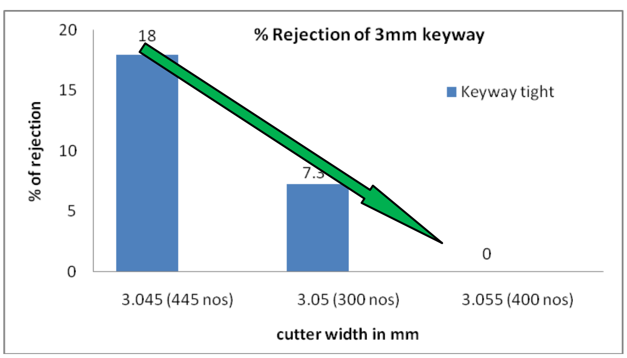

Fig. 2.8 validation of results for 3 mm keyway

3.2 Understand

From the above it can be observed that an increase in cutter width by 10 microns in case of 3mm keyway and 15 microns in case of 4 mm keyway would result in bringing down the camshaft rejection due to keyway tight. Table 3 shows the suggested cutter width for 0% rejection of camshaft and the cutter width currently used which is resulting in 2.5% rejection of camshaft due to keyway tight.

Table.3 comparison of cutter width with current and suggested

Family	Used on	Cutter width (current) in mm	Cutter width (suggested) in mm
Camshaft (339902555)	3mm Keyway	3.045	3.055
Camshaft (339902555	4mm Keyway	4.045	4.06

4. CONCLUSIONS AND SCOPE FOR FUTURE WORK

Following conclusions have been drawn from the experimental result and discussion.

- Shainin technique was found to be simple and strong statistical tool to handle problems during manufacturing of components.
- Changing the cutter size for milling 3mm and 4 mm keyway has resulted in 0% rejection of camshafts due to keyway tight.

5. SCOPE FOR FUTURE WORK:

- The entire process of milling of keyways on camshafts on monthly basis is to be monitored to consolidate the results that have been arrived at.
- Care has to be taken to avoid PinkX that is keyway tightening that could occur due to handling damages.
- . Effect of PinkX and Pale PinkX is to be investigated in order to completely leverage the problem.

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