



REDUCTION OF REJECTION IN DIESEL FUEL INJECTION PUMPING ELEMENT

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Abstract

Quality has been one of the foremost challenges in the manufacturing industry, various statistical methods (like 8 Discipline steps, DOE, shainin) have been devised to improve quality and customer satisfaction, they also form an eminent part of CIP(Continuous Improvement Process) in BPS(Bosch Production System) this project was carried out in BOSCH INDIA, Bengaluru which is the leading manufacturer in Diesel Fuel Injection Pumps and its components.

A Diesel pumping Element incorporating Barrel and Plunger forms a vital part of Diesel Injection pump which is known as heart of diesel pump with mechanical clearance as its important parameter. Analysis was done on leak test and mechanical clearance, the rejections were found to be 20% of total production. Defects with highest percentage internal rejections were found as Head Clearance Less rejections 6.96%, Head Clearance More 6.34% and Sticky 4.38% Rejection in the year 2014. Reason for the causes is investigated and solution is optimized by improving the online Inspection Instrument which is basically controlled by pneumatics.

Introduction

Diesel engines have become the most popular muscle 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]. 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 8D (8 discipline steps), Shainin System, Failure Mode Effect Analysis (FMEA), Six Sigma, etc., in the production processes Complaints are expensive, both as direct and indirect costs; however, for this cost, companies can extract priceless knowledge, because complaints contain the direct Voice of the Customer (VOC). If complaints are transformed into knowledge about customers, they can provide a valuable amount of capital for enterprises. To explore this capital, companies must design, build, operate and continuously upgrade systems for managing complaints [4]. A definition of “complaint treatment” by Dee et al. [5] is: “A process that addresses issues that concern customers”. Other authors take a further look at management of complaints, defining it as: “Fixing the policies, systems, or protocols so that the problem would not occur for future customers” [6]. Complaint satisfaction is also interesting within the complaints treatment research, since to implement a system to handle complaints is no longer enough [7]. Such system must guarantee complaint satisfaction and customer retention [8]. Hallen and Latino [9] showed in their case study of a chemical manufacturer, that complaint feedback can be used to identify root causes of problems that lead to customer Dissatisfaction. Furthermore, the results of the case study showed that eliminating root causes of problems improves customer satisfaction [9].

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. 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.

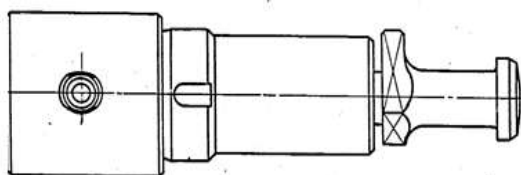


Fig: 1. Pumping element



Pumping element is the major part of the fuel injection system it is also known as heart of the diesel engine. It is similar to cylinder and piston which are called barrel and plunger respectively, it pumps the fuel in right time and right quantity. By the reciprocation of plunger inside the barrel which has an inlet port where the fuel enters at low pressure. Usually the pressure will be 5 Pa which is delivered by a low pressure pump. This is converted into high pressure by the element.

Method

Eight Disciplines Problem Solving Method (The 8D Methodology)

The 8D methodology involves teams working together in order to solve problems, using a structured 8 step approach to help focus on facts, instead of opinions.

The 8D method is efficient in developing proper actions in order to eliminate root causes and in implementing the permanent corrective actions to eliminate them. It also contributes to explore the system of control that allowed the escape of the problem. There are reports of the successful use of this methodology to deal with chronic recurring problems, mainly defects or warranty issues [10]. As a whole, this methodology was never intended to replace a systemic quality system. The 8Ds' objective is to face the problems and discover the weaknesses in the management systems that permitted the problem to occur in the first place. According to Rambaud [10], the major mistake in the attainment of the 8D methodology involves using a one-page problem-reporting effort. This misuse is often further exaggerated by requiring the report to be written within 24 hours. Some steps can take a few hours, while others can take weeks. In manufacturing, many persistent problems can occur only with a unique set of conditions, which calls for extensive studies and experiments

D₀- The Planning Phase:

A project concerning to Quality cost/Rework cost reduction by eliminating the root cause

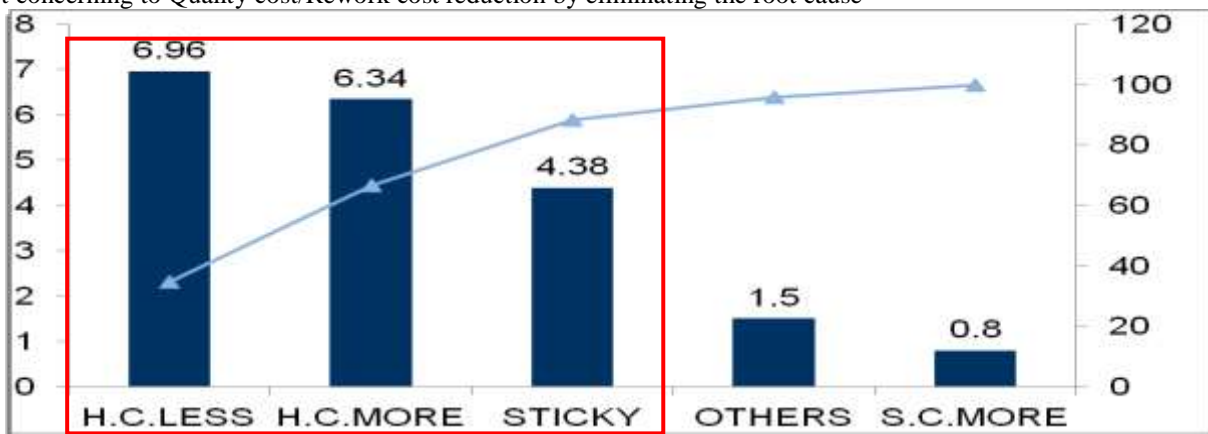


Fig 2 : Pareto Rejection of elements in year 2014

The Pareto graph denotes that the rejection rates of Head Clearance Less-6.96, Head Clearance More-6.34, Sticky-4.38, Others-1.5, Shaft Clearance More-0.8. In which predominant are Head Clearance Less, Head Clearance More and Sticky.

D₁- Establishing a team of people with product/process knowledge

Mr. NITHIN M R	PROJECT CO-ORDINATOR
Mr. DEVARAJU G R	PROJECT MANAGER
Mr. SRINIVAS C N	DEVELOPER
Dr H N DIVAKAR	TECHNICAL SUPPORT
Mr. MAADHU G	TECHNICAL SUPPORT
Mr. AKSHAY SETHI	CONTRIBUTOR
MR. INDRA SENA PATLOLLA REDDY	CONTRIBUTOR
MR. FILIX MIRANDA	FRONT LINE MANAGER



**D2- Describing the Problem in terms of (5W2H)
(5W2H)-Analysis**

	5W and 2H	Response
5 W	Who provides you this information?	BOSCH INDIA PVT Ltd. BENGALURU.
	What do you do after getting the required information?	ANALYSE FOR THE CAUSE OF INTERNAL DEFECT AND PROVIDE THE SUTABLE SOLUTION.
	Why you made this particular choice?	COST INCURED FOR REWORK WAS MORE AND EFFECTS CUSTOMER SATISFACTION.
	Where do you have the material?	IN MANUFACTURING OF ELEMENTS PRODUCTION DEPARTMENT
	When -At what phase of the process you inspect the product?	DURING THE ASSEMBLY OF THE PLUNGER AND BARREL OF THE DFIP ELEMENT.
2H	How do you decide whether the results are acceptable?	BASED ON THE LEAK TEST INSPECTION RESULTS.
	How many samples do you take during final inspection?	100% INSPECTION

D3- Development of Interim Containment Plan to isolate the problem from customer.
Machining tolerance is reduced.

Over checked or random checking with main inspection station.
Compared with standards room results till the solution is determined.

D4- Identification of Root Causes and escape point causes that could explain why the problem has occurred.
This is done by using ISHIKAWA which enable clear understanding of the linkage between the various causes and the end result, effect is the result of quality of product cause means an factor which may influence the effect this influence can be direct or indirect, it helps to present all possible causes which may have any relationship with the result or effect

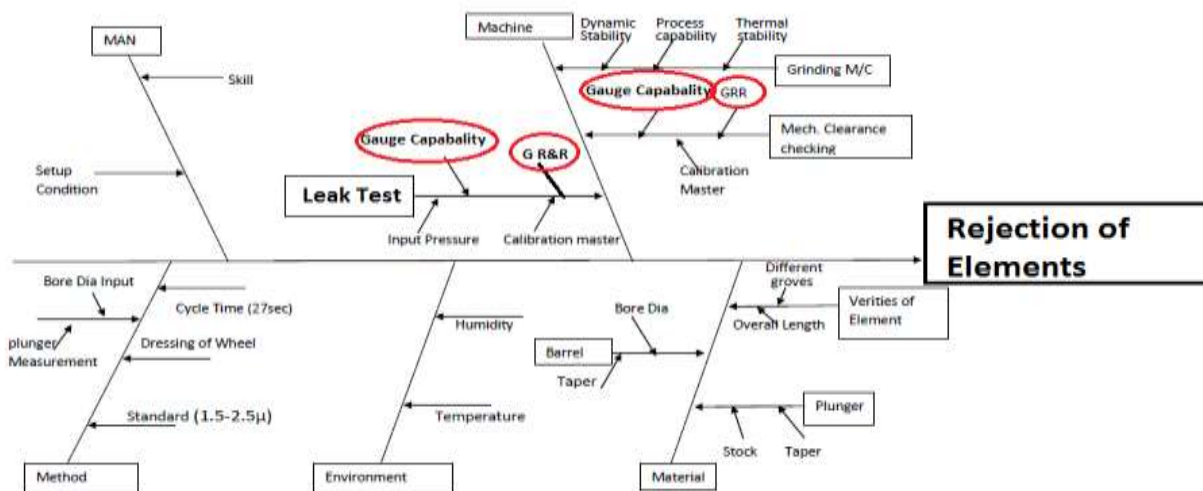


Fig. 3. Fish Bone/Ishikawa Diagram Analysis



Ishikawa diagram was drawn by gathering the members from different departments who are involved in the process, Brainstorming was conducted and the significant causes was determined as

1. Requirement of improvement in inspection instruments
2. Design specification
3. Improvement in fixture

Various statistical analyses such as Regression, Best-subset show that the correlation between mechanical clearance and leak test is very less requires improvement, Gauge Capability and Gauge R&R clearly denote the failure of instruments to meet the standards. As the input feed given to the finish match grinding machine is based on the online inspection of mechanical clearance and leak test are the base for the production of elements.

Present scenario at online inspection

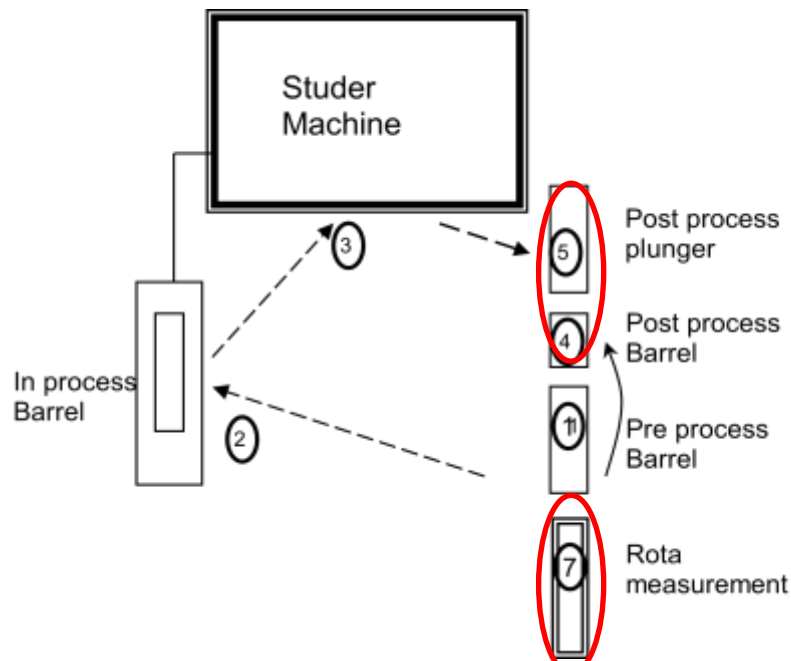
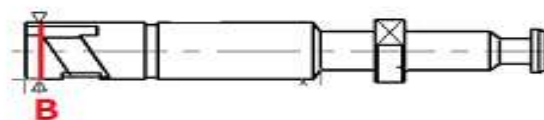
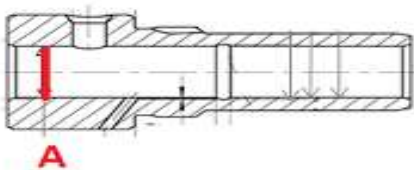


Fig4 :Finish Match Grinding Machine With Online Inspection

Sequence of Operation

- 1) Measure barrel diameter.
- 2) Transfer the value to IPG amplifier.
- 3) Grind plunger to suit the input barrel diameter.
- 4) Transfer the barrel from 1 to 4. (Post process).
- 5) Unload plunger from machine to the LX gauge.
- 6) Measure the clearance and taper between the defined points.
- 7) Rota checking for 1pcs/100pcs, Set the clearance as per rota median.
- 8) Give feedback/input to the finish match grinding machine

A. Mechanical Clearance Inspection



A-B = Mechanical Clearance

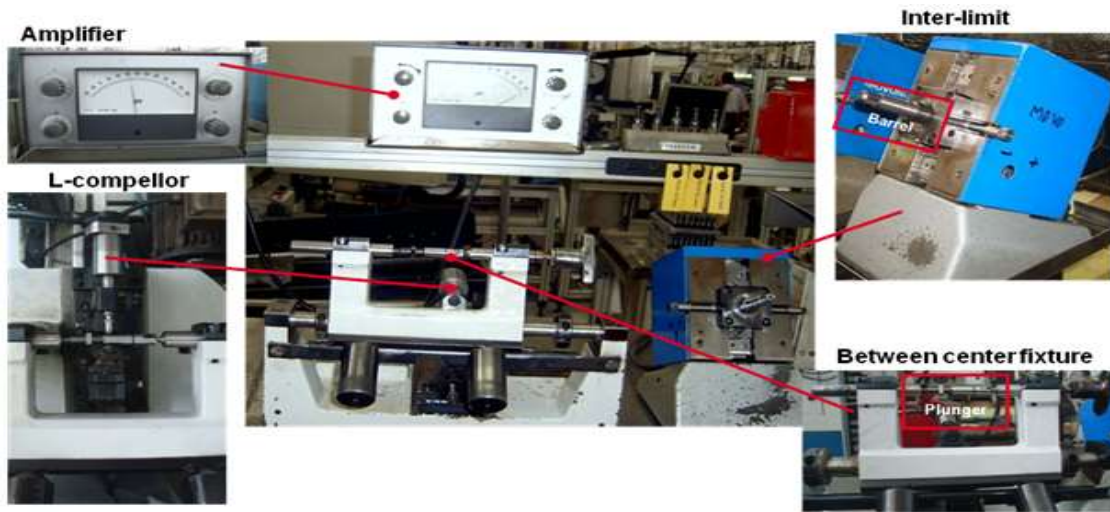


Fig: 5.Mechanical Clearance Checking instrument Set-Up.

The Mechanical Clearance between barrel and grinded plunger is measured to be within the tolerance limit*(2-3.5µm) and is measured in the set-up shown in figure:5, The barrel is placed in the inter-limit which reads the bore diameter of the barrel and the plunger is placed between centre fixture and when they are measured using an L-compeller the clearance will be displayed in the Analog Amplifier.

The concerns in this process are:

Gauge Repeatability & Reproducibility is very high.

Gauge Capability Is Less than 1.33.

Elements will be in mechanical contact which may affect the quality of the element.

Leak inspection

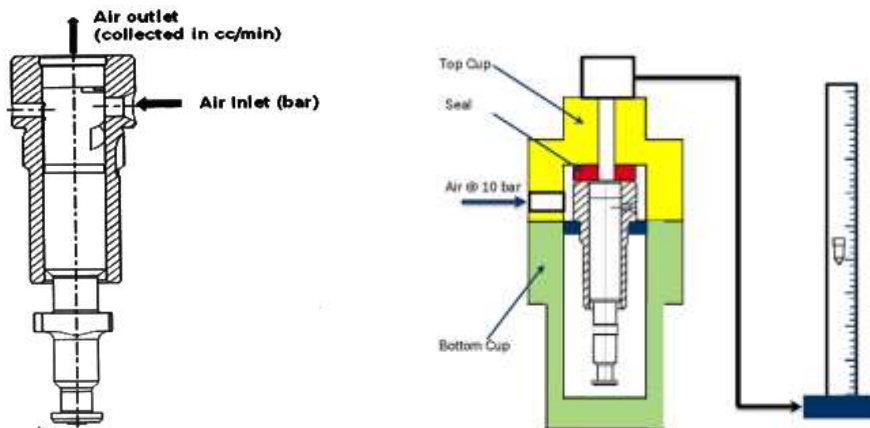


Fig: 6.Rota test set-up

Leak test is done by placing the element in the fixture and clamping the top cup with the sealing as shown in figure. When the high pressure air (10-15 Bar) is passed through the inlet hole of the element due to the clearance between barrel and plunger leak will occur this is measured using a Rota Glass tube meter in terms of cc/min, which works on the principle of Bernoulli's theorem.

The concerns of the gauge are:

The least count is 20cc/min which should be less than 5cc/min.

Gauge repeatability and reproducibility is high.

Gauge capability is less than 1.33.

Pseudo rejection is high.



D5- Choosing and verifying Permanent Corrections (PCs) for Problems Through pre-production programs which resolve the problem.

Improvement of inspection technique

The above analysis clearly denotes that the requirement of improvement in online inspection techniques is to reduce the rejection rate in elements as it is in the loop of production. By improving the clearance measuring and leak testing devices the input given to the Finish Match Grinding machine will be optimized. The pneumatic clearance checking device and leak testing device using differential pressure gauge are solutions to the above requirement.

Principle of differential pressure gauge

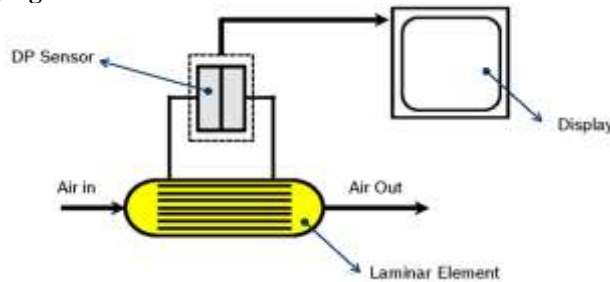


Fig: 7.Principle of Operation.

In this the air is passed through the laminar element and the difference in pressure is measured by the Differential Pressure sensor actuated by the diaphragm which is converted to low voltage signal and is in turn obtained in the digital display unit.

Mechanical clearance inspection



Fig: 8.Pneumatically operated Clearance checking device

The Clearance between barrel and ground plunger is measured to be within the tolerance limit and is measured in the set-up shown in figure. The barrel is placed in the mandrel which reads the bore diameter of the barrel and the plunger is placed in slot which contains air nozzle through which 3Bar pressure air is passed. Due to the differential pressure the dia of plunger and bore dia of barrel will be measured and the difference is calculated. The output is shown in the form of bar graph which has upper and lower limit detection system for rejection.

Leak test inspection

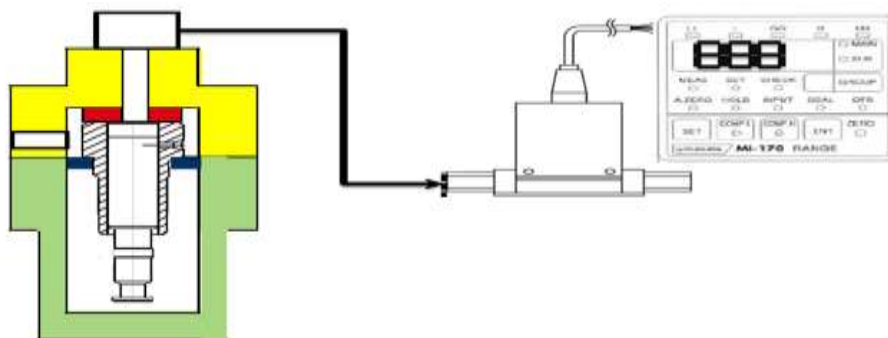


Fig: 9. Fukuda Meter Leak Testing device



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Leak test is done by placing the element in the fixture and clamping the top cup with the sealing as shown in figure. When the high pressure air (10-15 Bar) is passed through the inlet hole of the element due to the clearance between barrel and plunger leak will occur. This is measured using a FUKUDA meter which works on the principle of differential pressure of laminar element.

D-6- Implementation and validation of PCAs: The implementation of the two inspection instruments will ensure the good correlation between mechanical clearance and leak test.

Table:1 Performance Check for Mechanical Clearance Checking Instrument

Parameters	Current	Better
Principle of working	Mechanical 2-point	Pneumatic annular
Gauge capability	<1.33	>1.33
Gauge repeatability & reproducibility	36% ☹️	16% 😊

Table:2 Performance Check for Leak Testing Gauge

Parameters	Current	Better
Principle Of Working	Bernoulli's	Laminar differential pressure
Gauge Capability	<1.33	>1.33
Pseudo Rejection	HIGH	LOW
Gauge Repeatability & Reproducibility	24% 😊	9% 😊

The above tables clearly shows that by the improvement of inspection we will have the gauges which are according to the requirements trials were taken with the improvement for one finish match grinding machine for 15 days and rejection was found to be reduced.

D-7- Corrective Actions:

Implementation should be done on all the machines by horizontal deployment and the process should be standardized.

D-8- Congratulating the Team: Recognizing the collective efforts of the team

Nithin.M.R	M Tech Scholar	PERFORMANCE TEST, ANALYSIS AND PROVIDING VALUED SUGGESION
DEVARAJU.G.R	SENIOR MANAGER MFE BOSCH	INITIATION, PLANNING, EXECUTION, MONITORING, CLOSURE OF PROJECT
SRINIVAS.C.N	SENIOR MANAGER MFE BOSCH	PROJECT DESIGN AND DEVELOPMENT
AKSHAY SETHI	GRADUATE APPRENTICES	PERFORMING TEST AND CARRYING OUT PROJECT TEAM RESPONSIBILITY
INDRA SENA PATLOLLA REDDY	GRADUATE APPRENTICES	PERFORMING TEST AND CARRYING OUT PROJECT TEAM RESPONSIBILITY
H.N.DIVAKAR	Prof AND Head I&P E DEPT NIE MYSORE	ESTABLISHING PROJECT SUPPORT TECHNOLOGY STANDARDS
MAADHU.G	ASST PROF I&P E DEPT NIE MYSORE	ENSURES TECHNICAL ENVIRONMENT IS IN THE PLACE AND OPERATIONAL



Conclusion

By the improvement of the inspection techniques the accuracy of measurement was increased by which the in process assembly defects and improper input to the Finish Match Grinding was reduced. These overall defects in the production of pumping element were brought down by 36%. The quality of the pumping element in turn of the pump is increased and the customer trust was increased.

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