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- Garg Sambhav (2011): "Business Ethics" Paper presented at the Annual International Conference for the All India Management Association, New Delhi, India, 19–22 June.

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- Kumar S. (2011): "Customer Value: A Comparative Study of Rural and Urban Customers," Thesis, Kurukshetra University, Kurukshetra.

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ASSURING QUALITY USING 6 SIGMA TOOL - DMAIC TECHNIQUE

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ABSTRACT

In today's world, customer is the driving force and their requirements are changing very constantly. That's the reason why, manufacturing units uses automated manufacturing processes for achieving high flexibility in production. Assuring quality on output from automated manufacturing process is becoming highly necessary now a days, as an error will have a huge volume of defective products to customers. Though many academic & research studies discusses on various tools in assuring quality, there are no standard set of procedures which needs to be followed for automated manufacturing process to achieve a quality output. This paper presents a case study on how a leading fuel injection equipment manufacturer eliminate its customer complaint using an automated manufacturing process which they obtained from a UK based manufacturer. The selection of that process is through the 6 Sigma Tool - DMAIC Technique & in this paper, it discusses on how transnational business (using two automated manufacturing processes) helps in achieving the result. This study is based on a wide variety of experimental and practical approaches, that have been now prevailing in the industry. The paper also discusses studies that show how it affects the performance of the particular industry and it concludes with a discussion of how, understanding quality tools can bring closer, some aspects of assuring quality through automated manufacturing processes.

KEYWORDS

Case Study, Two Automated Manufacturing Processes, 6 Sigma Tool - DMAIC Technique

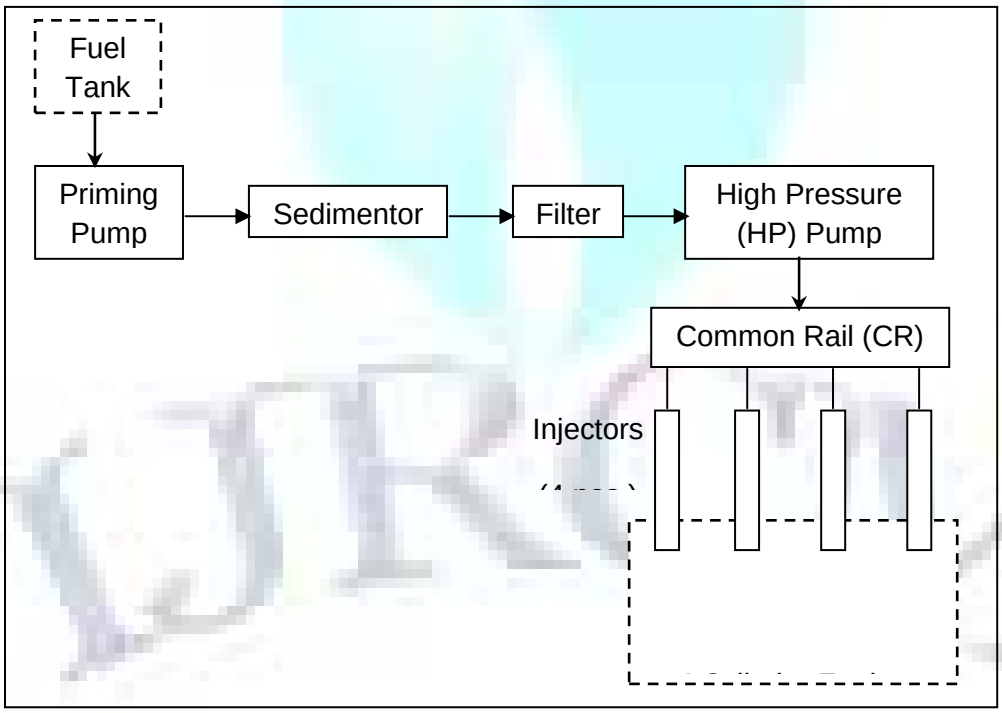
INTRODUCTION

In the initial stages on introduction of Common Rail Direct Injection (CRDi) application, the fuel injection equipment (fie) manufacturers have to had a tough call from the customers. In order to achieve stringent emission norms, fuel injection manufacturers need to have better spray from the injectors & it is only possible by reducing the diameter of the injector bore (diameter) size. Since the bore size is only 150 µm (0.15 mm), there was a high risk of injector blockage & in fact in some cases it reaches the customer. In this paper, a case study is being mentioned, on how the fuel injection manufacturers came out of the situation using an automated manufacturing process (explained with the help of 6 sigma tool - DMAIC technique).

DETAILS ON FUEL INJECTION EQUIPMENT (FIE) PARTS

The product layout in the original vehicle condition is as mentioned in the table below. In that except fuel tank & 4 cylinder engine block, all other parts come under FIE

FIGURE - 1



LOW PRESSURE LINE

1. Priming Pump: It is used to remove the air blocks, just by priming this part. The air blockage is only be there when the fuel (diesel) get emptied completely.
2. Sedimentor: It is used to remove the water content present in the fuel. It is an optional part. In some area, there seems to be more water content in the fuel. In those areas it is highly advisable to use this.
3. Filter: This is used to remove the contaminants from the fuel. It is highly required as any contaminant above 150µm (0.15 mm) will block the injector.

HIGH PRESSURE LINE

1. High Pressure pump: It is also referred to as an HP Pump. Its main function is to produce a pressurize fuel to almost 1500 bar pressure

2. Common Rail (CR): It acts as an accumulator. It keeps the pressurized fuel from HP pump & will guide to injector in correct timing through a sensor.
3. Injector: It is used to spray the pressurized fuel to engine block, where the combustion takes place.

DMAIC TECHNIQUE

DMAIC (Define, Measure, Analyze, Improve, & Control) is an acronym that can be defined as the roadmap to process optimization and are the five phases of Six Sigma improvement.

D-M-A-I-C is structured as:

Define: Define the Customer, their Critical to Quality (CTQ) issues, and the Core Business Process involved.

Measure: Measure the performance of the Core Business Process involved.

Analyze: Analyze the data collected and process map to determine root causes of defects and opportunities for improvement.

Improve: Improve the target process by designing creative solutions to fix and prevent problems.

Control: Control the improvements to keep the process on the new course.

DEFINE

Fuel Injection Equipment (FIE) manufacturers get a tough call from the customers for some of the problems identified at their end. So, they decided to have a quality overview through 6 sigma quality initiative - DMAIC Technique. They define to eliminate / reduce the customer claims by increasing the product quality, which in turn will increase the customer satisfaction & also the sales order.

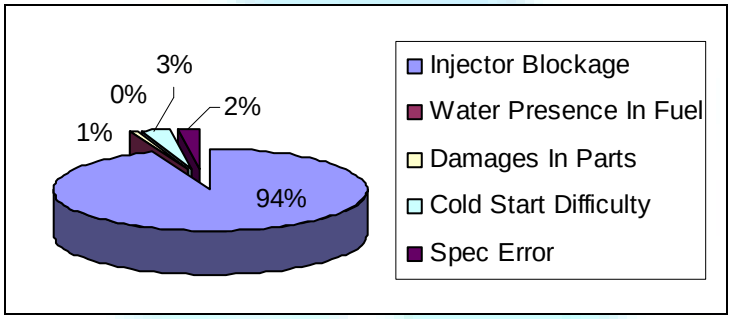
To start with, please refer the below mentioned problems which FIE manufacturers encountered from the previous year.

TABLE – 1

S. No	Customer Problem	Count / Cases	Claim Amt Per Count	Total Claim Amt
1	Injector Blockage	20	$ 500	$ 10,000
2	Water Presence In Fuel	2	External Factor	
3	Damages In Parts	1	$ 100	$ 100
4	Cold Start Difficulty	3	$ 100	$ 300
5	Spec Error	1	$ 250	$ 250
Total				$ 10,650

From the table, it is evident that number of problems from injector blockage is higher than the other claims. The claim amount for the same is high, as the cost of the injector is high. A better idea can be seen from the figure showing the claim percentage. 94% of the total claim amount is due to the injector blockage.

FIGURE - 2



Claim due to water presence in fuel is an external factor as the customer is required to use the Sedimentor provided by the company, for removing the water present in the fuel. Even though problem including specification error & damages of part is there, the contribution of the same towards total claim is very less and also, it won't affect functionally to the vehicle.

MEASURE

The measurement for the customer problems have been done through Quality Function Deployment (QFD).

QFD is a comprehensive quality system that systematically links the needs of the customer with various business functions and organizational processes, such as marketing, design, quality, production, manufacturing, sales, etc., aligning the entire company toward achieving a common goal.

Here in this case study, based on the customer voice, a Quality Function Deployment (QFD) is being made to analyze and to solve the customer problem.

FIGURE - 3

RELATIONSHIPS

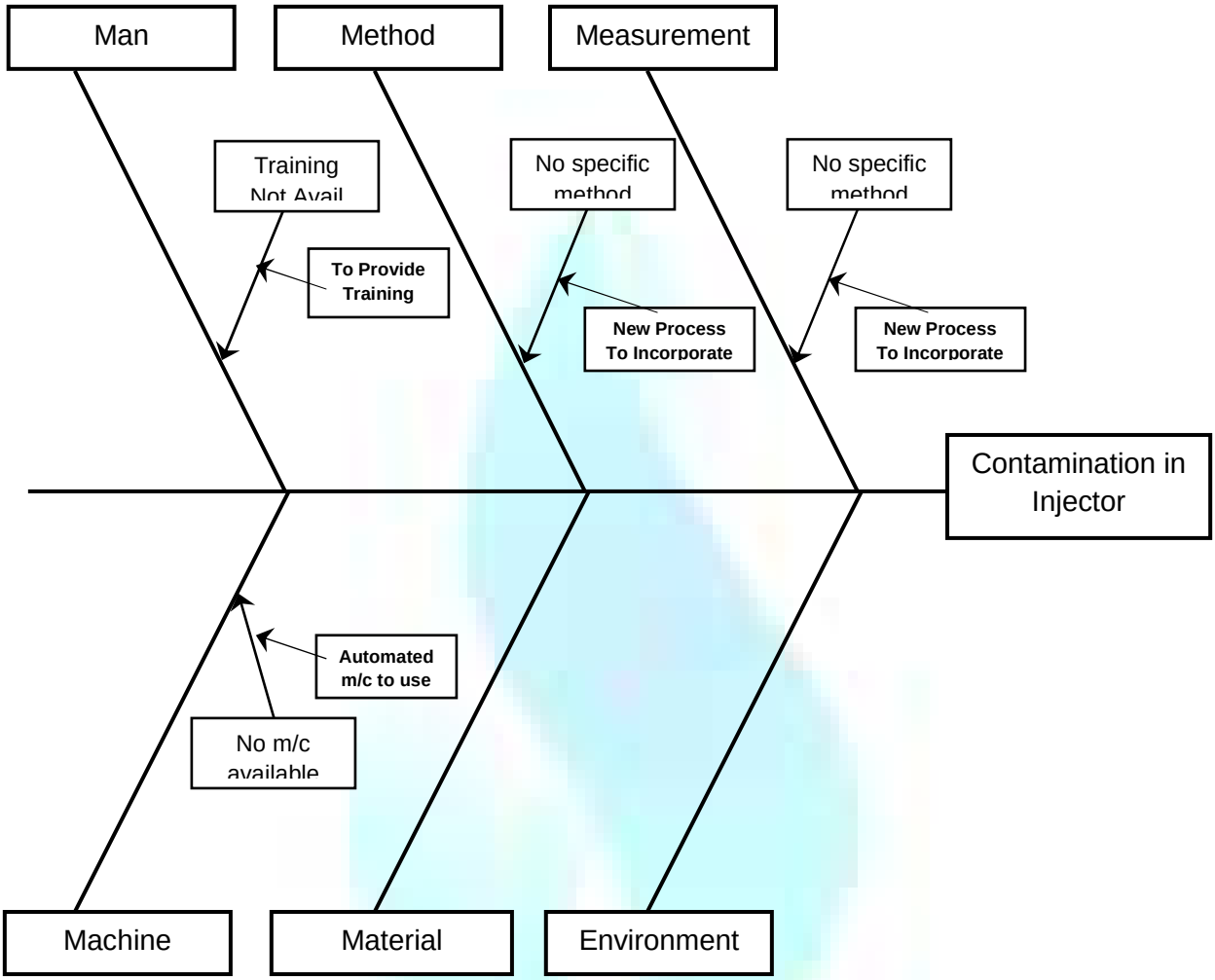
◉ Strong Relationship (10)
○ Some Relationship (5)
△ Weak relationship (2)
No mark, no relationship (0)

S NO	CUSTOMER NEEDS	Relative importance	Contamination in Injector ↓	Fuel Contamination ↓	Water presence in Fuel ↓	Cold start ↑	Part Damages ↓	Part spec error ↓	No rust formation ↓
1	Driveability Issue	10	◉	○	○	○		△	△
2	Safety Features Functioning	10	○						
3	Easiness on Part Availability	3	△	△	△		○	◉	△
4	Good Exterior Look	3					◉		
5	Durability (Long Life)	10	○						○
Target Value			< 100						
Technical Importance	Absolute		206	56	56	50	45	50	76
	Relative		1	3	3	4	5	4	2
Remark			Need to Improve	External Factor		Minor Issues			No problem reported

ANALYZE

The major problems have been analyzed through Cause & Effect Diagram (Fish Borne Diagram).The Cause & Effect (CE) diagram, also sometimes called the 'fishbone' diagram, is a tool for discovering all the possible causes for a particular effect. The major purpose of the CE Diagram is to act as a first step in problem solving by generating a comprehensive list of possible causes.

FIGURE - 4



IMPROVE

From above CE Diagram, following improvements need to be done

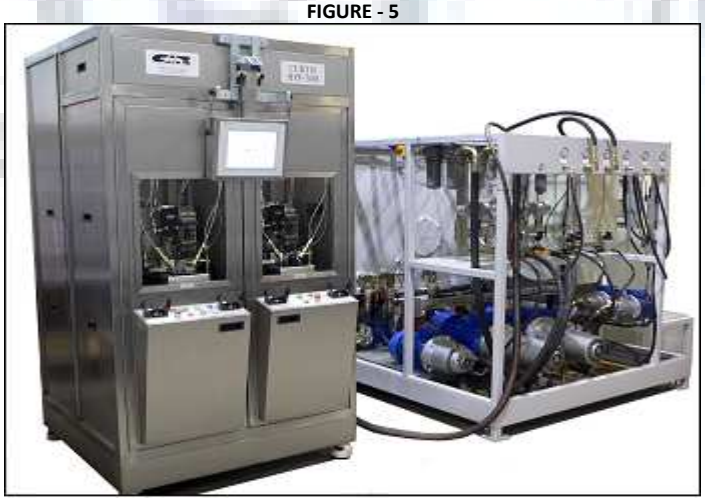
MACHINE CONCEPT

Incorporating a new automated manufacturing process, which can be used to remove the contaminants in the range of 150µm (0.15 mm) from the parts & also removes the blockage of the injector.

Since this is a special purpose for the company, an intensive study have been conducted & it was decided to give the quotation for developing the same to an organization which had an expertise in this. And thus its planned to give a quote to M/s Curtis - UK to build an automated manufacturing process, which will satisfy the needs. And its planned to be a joined project. Based on so many trials, it came with a model Curtis HPF 300 Flushing Machine. Details of the same being mentioned below.

Curtis HPF 300 Flushing Machine

FIGURE - 5



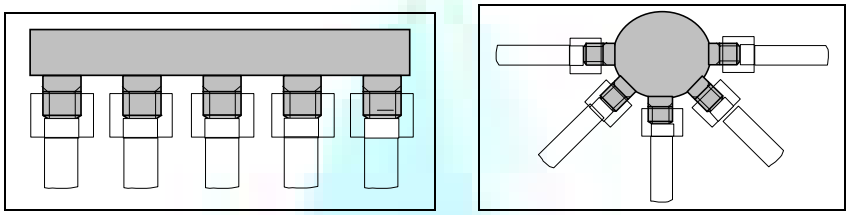
HIGHLIGHTS

- The processes in the machine (position of lance & opening and closing of valves which allow the flow of test oil through each ports) can be controlled using the PLC.
- High stability in pressure generation through servo control (better than ±0.5 bar)
- High Lance Positional accuracy using PLC (linear ± 0.5 mm; rotational ±1°)
- Sequence of up to 64 steps can be used through the PLC.
- Suitable to use in a clean room environment.
- High pressure up to 300 bar can be generated for flushing operation
- Intense cleaning using a lance arrangement for not having any contamination above 150 µm (0.15 mm)

DESCRIPTION

Designed primarily for diesel injection system rails, the system is capable of cleaning both spherical and linear rails (figure for both mentioned below) and has been adapted for other components.

FIGURE - 6



Oil at variable pressures is flushed through the components and a lance arrangement directs high pressure oil at specific locations where intense cleaning is required. Rails with greatly varying internal orifices may be tested with no modification to system. Suitable for use in a clean room environment, with the power pack unit housing the main fluid reservoir with filtration external to the room. The machine has two independent stations each capable of running a separate product simultaneously. The flexible cycle start sequence will allow twin load/unload, individual load/unload or single load/unload. The NC control of the lance allows static and dynamic linear and rotational positions to be set and dynamic interpolation between linear and angular positions to be achieved. The frame is of stainless steel construction with tooling blocks etc being electro-plated as appropriate. The flushing machine has a footprint of approximately 1.3m x 1.3m excluding the power pack.

METHOD CONCEPT: (for Automated Manufacturing Process through PLC)

Best method to be used in the automated manufacturing process, so that a consistent quality achievement is possible from the same.

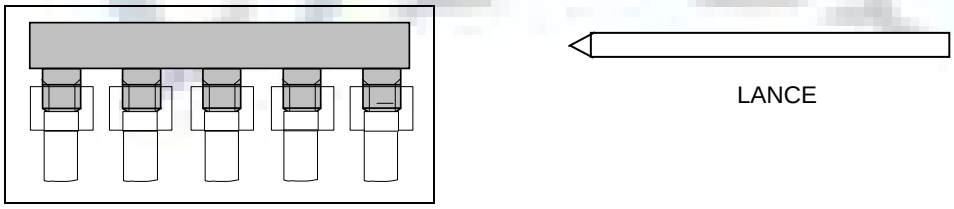
Before finalizing on the final method to be used in the Curtis machine, a number of trials have been made to make sure, which one is the best. The best is revealed in 2 ways.

- After Curtis flushing operation, no contaminants above 150µm (0.15 mm) should be present in the product
- The operation need to give a consistent quality through out.

The inside cleanliness of the product is very critical, as it is the area through which the diesel fuel flows in original customer end condition & there is where the original product cleanliness required. For that, 'lance' is being used in the Curtis, which will go inside the product & it can move up & down and also rotate inside. Also, it has a provision to spray the test oil in high pressure, through the tip of the lance

FIGURE – 7

FIGURE - 8



Keeping this in mind & after a number of trials, the sequence to be followed in the Curtis machine is being finalized as below

a) The operator need to clamp the product in the Curtis machine & press start button in the machine to start operation.

b) Now 7 valves (5 ports-1 inlet and 4 outlet & 2 corners-used to assemble the sensors) will close the common rail. The valves can be opened & closed as per the PLC program.

c) As a 1st operation of machine, the lance will enter the rail through the corner valve & it will go a total movement inside the rail till the end & come back to the initial port position. During the movement of the lance, it will have a rotary motion & the pressurized test oil (of about 2 bar) will have a flushing

operation. This process will take away contaminants from total internal area. During the movement of lance, all the 5 valves (1 inlet & 4 outlet valves) will be open & corner 2 valves will be closed. This allow the contaminants of the flush out of the common rail.

d) After this the lance will flush at each 5 valves (1 inlet & 4 outlet valves), one by one, starting from the farthest valve. This will again flush out the particles which got attached at the corners of the 5 valves (1 inlet & 4 outlet valves). During this process, only the port on which lance is flushing will allow out flow & all the remaining 4 valves out of 5 valves will allow inflow of test oil. This again take out maximum flush out of contaminants.

e) As a last operation, the lance again will have a total movement inside the rail, to flush out contaminants completely. This is similar to operation (c).

MEASUREMENT CONCEPT

Even if the machine is being availed to achieve the target of removing the contaminants, it has to be cross checked through measurements. This also helps to improve the process & won't allow to deteriorate the quality of the product.

It is as important as a Curtis flushing operation, as this only give feedback for improvement & correction. So for this, a specialized testing equipment is being used to check the cleanliness of the product. In this regard, after so many trials the company decided to go for Pall cleanliness checking cabinet. Pall PCC 42 Component Cleanliness Cabinet is used for the determination of component cleanliness.

MAN CONCEPT

The sequence which needs to be followed by the person using the automated machine & also by the person who is assuring it, have to be developed. The persons who are operating Curtis machine needs to be well trained before doing their work. He may be required to know all the activities & precautions which he need to follow.

CONTROL

In this, we need to see how to sustain the quality of the product for ever & to control the possibility of any contamination in the products. For that various parameters have been identified both in the Curtis machine & Pall cabinet. Also, need of a clean room is a must for ensuring the same.

Curtis Flushing Machine Control Parameters:

a) The filter membrane present in the Curtis machine need to be changed once in every 4 months or within doing 10,000 flushing operations, whichever earlier.

b) The test oil used in the machine needs to be changed once in every 6 months or within doing 20,000 flushing operation, whichever earlier.

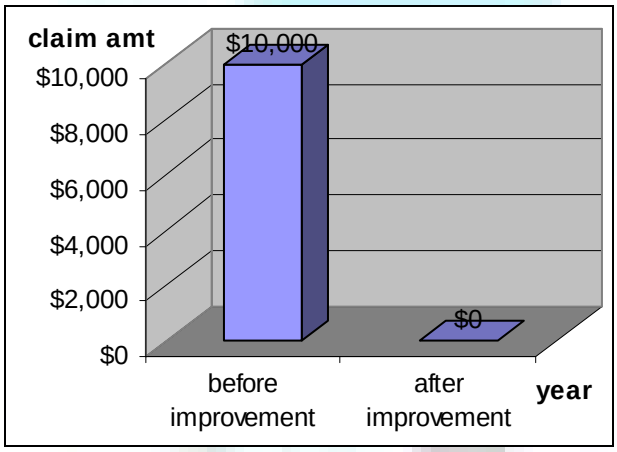
c) The operator needs to use clean gloves always, which helps to prevent cross contamination. Also, they should not wear the same gloves after removing the same.

d) The parts needs to be correctly placed in the fixture. It should not damage the parts, while doing so.

CONCLUSION

An automatic manufacturing process came into being for getting maximum output with consistent quality & reliability. But a well structured sequence is required for a successful identification of choosing the automatic manufacturing process. For that reason, DMAIC technique - a 6 sigma tool, plays a crucial role. In the paper, it mentioned on how a transnational business helps in achieving the customer needs. Because of this, the claim amount from the customer due to injector blockage has been reduced to zero in the subsequent year. Refer the graph below.

FIGURE - 9



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