NOISE REDUCTION IN FUEL INJECTION PUMPS OF TRACTOR ENGINES USING 'IS AND IS-NOT APPROACH'

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Abstract

An industry makes fuel injection pumps for tractor engines. Recently it was observed that the fuel injection pumps were making too much noise in the engines. The problem-solving techniques of industrial engineering were used to solve this problem. One such simple but powerful problem-solving technique is the 'is and is-not' approach. This technique was used to identify the root cause of the increased noise of the fuel injection pumps. Once the cause was identified, the problem was rectified. Thus the industry was able to reduce the noise of the fuel injection pumps.

Keywords: *Fuel injection pumps, Control rack, Wire over dimension readings, Rack & Pinion mechanism, Rack milling process, is and is-not.*

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1. INTRODUCTION

The fuel-injection system is responsible for supplying the diesel engine with fuel. To do so, the injection pump generates the pressure required for fuel injection. The fuel under pressure is forced through the high-pressure fuel-injection tubing to the injection nozzle which then injects it into the combustion chamber. The fuel-injection system includes the following components and assemblies: The fuel tank, the fuel filter, the fuel-supply pump, the injection nozzles, the high-pressure injection tubing, the governor, and the timing device (if required). The combustion processes in the diesel engine depend to a large degree upon the quantity of fuel which is injected and upon the method of introducing this fuel to the combustion chamber.

The most important criteria in this respect are the fuel-injection timing and the duration of injection, the fuel's distribution in the combustion chamber, the moment in time when combustion starts, the amount of fuel metered to the engine per degree crankshaft, and the total injected fuel quantity in accordance with the engine loading. The optimum interplay of all these parameters is decisive for the faultless functioning of the diesel engine and of the fuel-injection system.

2. REJECTION STATUS OF THE PUMPS

2.1 Internal Rejection of Pumps at the Plant

A graph of rejections for the pumps types 939, 941 and A08 as of months July 2015 to December 2016 is in Figure 1. The X-axis of the graph shows months in which the rejections of the pumps are seen at the plant of the company after the assembly of parts and the Y-axis shows the percentage of the rate of rejections for all the three pumps respectively. The figures for the total number of pumps assembled per month with the corresponding rejection rates for all the three pump types respectively are displayed in Table 1.

2.2 Rejections of the Pump during Engine Testing at the Customer End

A graph of rejections for the pumps types A08, 939 and 941 as of months August 2015 to March 2016 is as shown in Figure 2. The X-axis of the graph shows months in which the rejections of the pumps are seen at the plant of the company after the assembly of parts and the Y-axis shows the percentage of the rate of rejections for all the three pump types respectively.

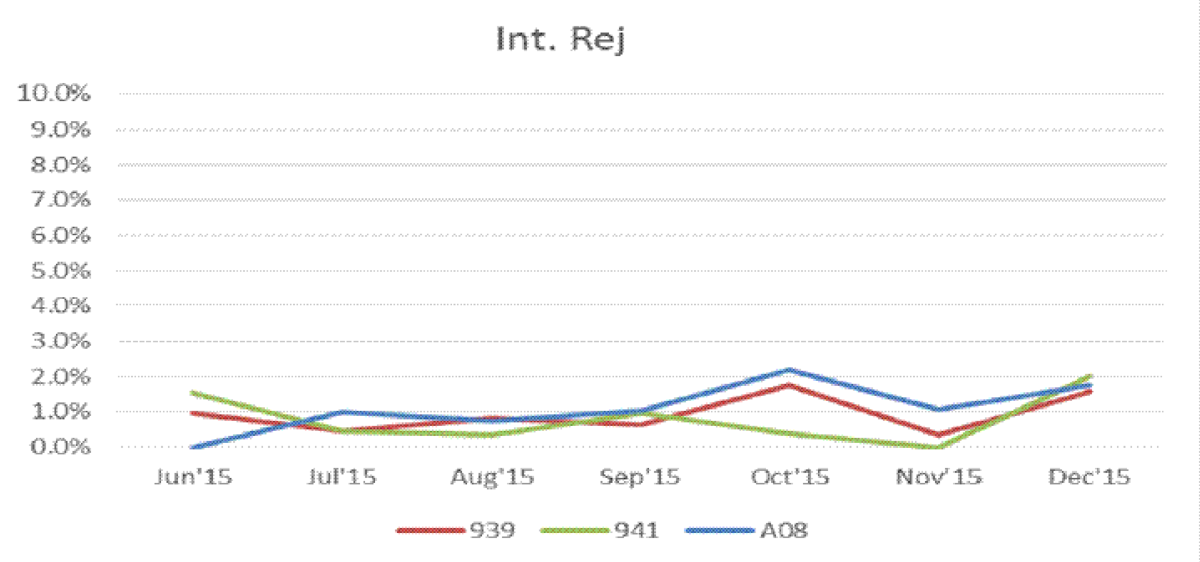

Fig 1: Rejection rate of pumps at the plant

Table 1: Internal rejection of pumps at the plant

INTERNAL REJECTION OF PUMPS AT THE PLANT									
MONTH	A08 TYPE PUMP			939 TYPE PUMP			941 TYPE PUMP		
	ASSY	REJ	% REJ	ASSY	REJ	% REJ	ASSY	REJ	% REJ
JUN	24	0	0%	515	5	1%	592	9	1.5%
JUL	1098	11	1%	640	3	0.5%	671	3	0.4%
AUG	1243	9	0.7%	619	5	0.8%	572	2	0.3%
SEP	964	10	1%	640	4	0.6%	624	6	1%
OCT	962	21	2.2%	968	17	1.8%	803	3	0.4%
NOV	649	7	1.1%	301	1	0.3%	5	0	0%
DEC	399	7	1.8%	63	1	1.6%	150	3	2%

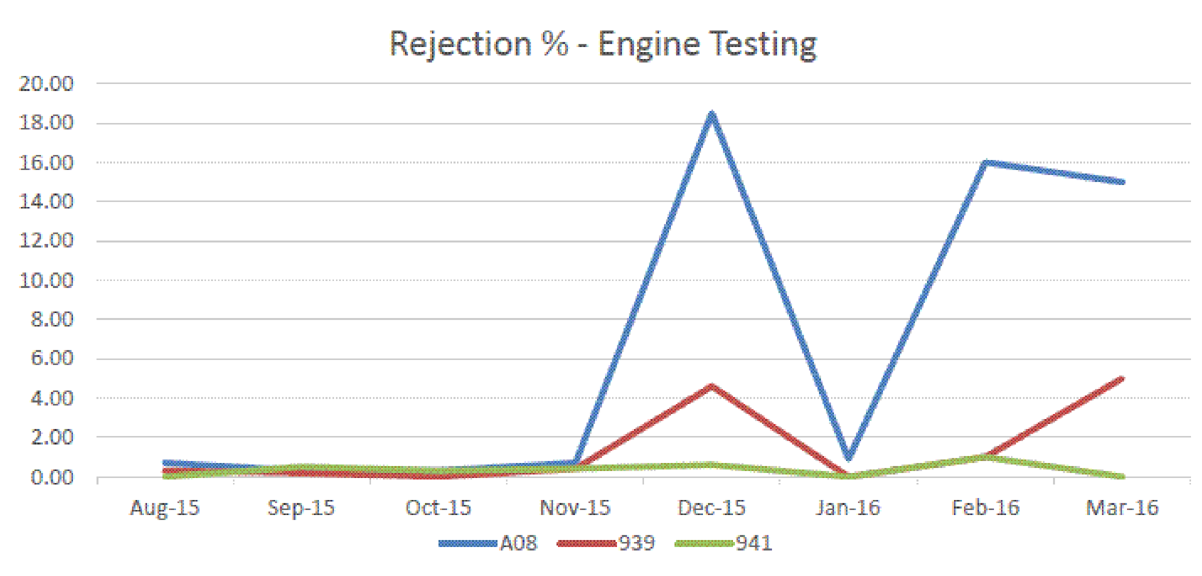

Fig 2: Rejection of pumps during engine testing at the customer end

The figures for the total number of pumps assembled per month and their corresponding rejection rates for all the pump types respectively are displayed Table 2. From the graph it is very well evident that the rejection rate of the pumps A08 and 939 start to arise somewhere in the mid of November and hitting the peak of rejections of about 18.5% and 4.6% respectively for both types in the month of December and then subsiding to a reduction in the rejection rates subsequently in the month of January 2016. Similar trend of occurrence was also seen arising back again in the mid of January, with the peak of rejections reaching 16% in February and dropping down to a % of 15 in the month of march for the A08 pumps as shown from the graph. Hence this particular pump type results with the highest number of rejections overall compared to the 939 type. By comparisons made with the target and actual state standard graphs and analysing on how the

A graph of rejections for the pump type A08 as of November 2015 is shown in Figure 3. The X-axis of the graph displays the days of the month in which, a higher rate of rejections for the pump type that was recorded on a daily basis after the assembly operation. The Y-axis shows the total number of productions and the corresponding rate of rejections of the pump type per day.

The figures for the total number of pumps produced per day and their rejection rates are all displayed in the table below. The month of November has been taken as a basis to project on the highest number of rejections recorded on a month which showed to have risen drastically over a period of time. The total number of productions for the pump type has varied from day to day as per requirement. In particular, on the 11th of this particular month a rejection rate as high as 93% i.e. 40 out 43 numbers had been recorded.

Table 2: Rejection of pumps during engine testing at the customer end

REJECTION OF PUMPS DURING ENGINE TESTING AT THE CUSTOMER END									
MONTH	A08 TYPE PUMP			939 TYPE PUMP			941 TYPE PUMP		
	ASSY	REJ	% REJ	ASSY	REJ	% REJ	ASSY	REJ	% REJ
JUN	802	4	0.5%	789	3	0.4%	405	2	0.5%
JUL	617	3	0.5%	697	3	0.4%	689	4	0.6%
AUG	1051	7	0.7%	630	2	0.3%	512	0	0%
SEP	1037	3	0.3%	848	2	0.2%	652	3	0.5%
OCT	934	3	0.3%	537	0	0%	306	1	0.3%
NOV	601	4	0.7%	274	1	0.4%	278	1	0.4%
DEC	417	77	18.5%	388	18	4.6%	356	2	0.6%
JAN	107	1	0.9%	92	0	0%	0	0	0%
FEB	486	78	16%	218	2	1%	177	2	1%
MAR	565	85	15%	406	20	5%	0	0	0%

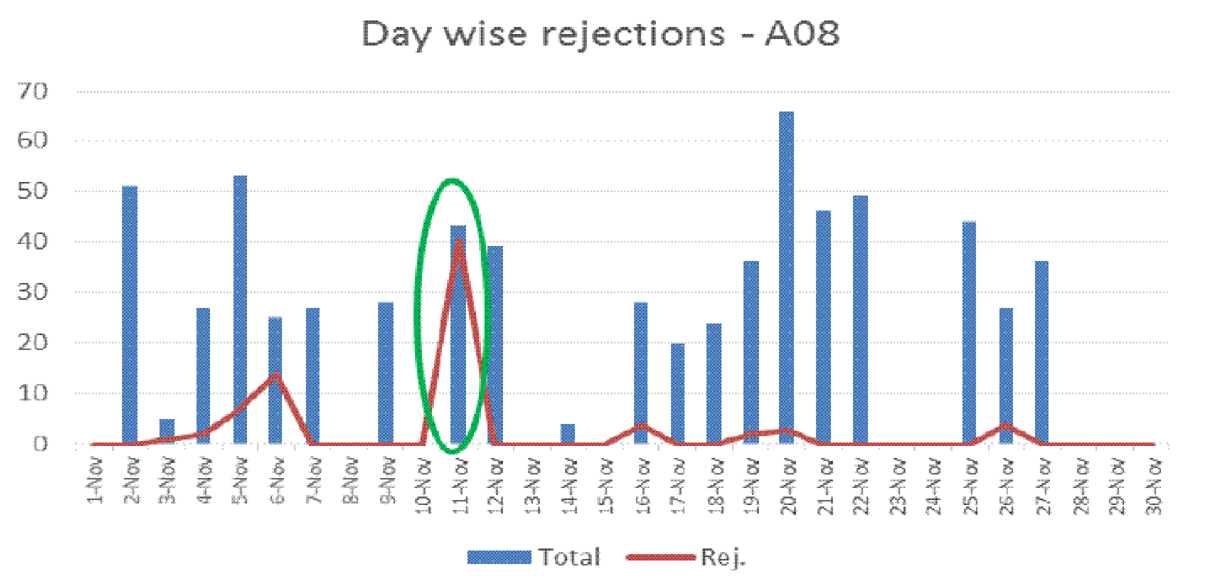

Fig 3: Daywise rejection of pumps for a particular month

Table 3: Daywise rejection of pumps for a particular month

A08 TYPE PUMP - DAYWISE REJECTIONS			
DATE	TOTAL PRODN	NO OF REJECTIONS	% OF REJECTIONS
01-Nov-15	0	0	0%
02-Nov-15	51	0	0%
03-Nov-15	5	1	20%
04-Nov-15	27	2	7.4%
05-Nov-15	53	7	13.2%
06-Nov-15	25	14	56%

07-Nov-15	27	0	0%
08-Nov-15	0	0	0%
09-Nov-15	28	0	0%
10-Nov-15	0	0	0%
11-Nov-15	43	40	93%
12-Nov-15	39	0	0%
13-Nov-15	0	0	0%
14-Nov-15	4	0	0%
15-Nov-15	0	0	0%
16-Nov-15	28	4	14.3%
17-Nov-15	20	0	0%
18-Nov-15	24	0	0%
19-Nov-15	36	2	5.6%
20-Nov-15	66	3	4.5%
21-Nov-15	46	0	0%
22-Nov-15	49	0	0%
23-Nov-15	0	0	0%
24-Nov-15	0	0	0%
25-Nov-15	44	0	0%
26-Nov-15	27	4	14.8%
27-Nov-15	36	0	0%
28-Nov-15	0	0	0%
29-Nov-15	0	0	0%
30-Nov-15	0	0	0%

Facts Collection from the Graphs and Tables – IS & IS NOT Approach

- The initial facts collection is based on contrast ''IS-IS NOT'' approach in which the actual state of the factors in the form of what could be the issue and what could not are both compared and an inference is drawn from it.
- Therefore the contrast shows that the problem is with the A08 pump type, with its predecessor being the pump type 939 and the problem is not in this case is for pump type 941.
- Both the pumps face rejections but the extent to which the rejections are observed between them varies.
- It was also seen that the issue had suddenly started when A08 pump was introduced for 40.8 Hp application.
- It could also be seen that the pump type A08 appears to have the highest rate of rejections compared to the 939 pump type.
- This helps in defining the fundamental problem.

'IS & IS NOT' APPROACH

The entire Summary is based in the form an approach known as IS and IS NOT. The approach has been generally used by the quality department of the automotive industry. According to this approach the facts are collected in a structured way by using the key questions on "what, where, when, who and how many" has shown to be of great help. The answers to the basic questions on

- What exactly is the problem?
- Where exactly is the problem observed?
- When exactly is the problem observed?
- Who observed the problem for the first time?
- How often exactly does the problem occur?
- How much/many is/are affected? are

all documented in a tabular form under the so called "Is"-column.

Under the heading of "The problem is not" a search for a comparable/similar facts is made.

- What (situations, processes, sequences, functions, defects, deviations, errors)
- Where (countries, regions, plants, departments, processes, lines, workplaces, work steps, positions on the object)
- When (months, weeks, days, times/periods, shifts, chronological rhythms)
- Scale (quantities, rhythms, intervals) that are not, but could be, affected by the problem. Important here is the stress on the second clause "but could be", i.e. only relevant areas are included in the demarcation, otherwise one would become lost in the variety of possibilities. There must be at least one difference or special feature, otherwise the IS-NOT areas would also be affected by the problem. The template of the approach is shown below.

Table 4: 'Is and Is-not' approach facts collection

	IS*(Predecessor)	IS	NOT IS
Pump	939	941	A08
Engine	E3.215	E3.215	E3.234
Engine Rating	37 Hp @ 2200 rpm	34 Hp @ 2200 rpm	40.8 Hp @ 2200 rpm
Volume	2150 cc	2150 cc	2340 cc
Application	Tractor PT 439	Tractor PT 434	Tractor PT 439 DS plus

Table 5: 'Is and Is-not' approach

WHO	IS	IS NOT (But could be?)	CONTRAST
Is the Problem with	Customer (tractor manufacturer)	Other Customers	No claims from any other customers so far
Observed the failure at the engine level	Customer	Company	Customer rejection report during engine testing for pump types
Observed the failure at the (pump level)	Company	Customer	Performing shainin trials on good & bad pumps by swapping them
Observed the failure at the (component level)	Company	Customer	Performing shainin trials by swapping components between good & bad pumps
HOW MANY	IS	IS NOT (But could be?)	CONTRAST
Pumps showed failure in total during the engine testing in November?	77/678	601/678	Particular month where highest rejection rates were noticed drastically
A08 pumps showed failure from June 2015 to March 2016 during engine testing?	265/6617	6352/6617	A08 pumps showed failure from June 2015 to March 2016 during engine testing
939 pumps showed failure from June 2015 to March 2016 during engine testing?	51/4879	4828/4879	939 pumps showed failure from June 2015 to March 2016 during engine testing
941 pumps showed failure from June 2015 to March 2016 during engine testing?	15/3375	3360/3375	941 pumps showed failure from June 2015 to March 2016 during engine testing
WHERE	IS	IS NOT (But could be?)	CONTRAST
Is the problem observed?	F002 Z11 A08, 939 Pump	941 Pump	The rejection rate of each pump is observed.
Is the object with defect?	Control Rack meshing with the pinion	Gear segments meshing & other components of the pump	Meshing of CR & gear segments show fluctuations in noise & cause vibrations
Is the defect at the component (From Analysis)?	Wire Over Dimension (9.25 - 0.08mm)	Run out, dimension, parallelism	Pump Components measurements show a contrast in WOD
Specifically is the problem in the component?	Lower Specification of WOD	Higher Specification of WOD	All good pump component measurements show WOD on the higher end side compared to bad pump comp measurements
In the Control Rod WOD Normal process is observed failure?	Milling	Blackening, Buffing, Bend removal	CR milling shows large process variation
Is the component observed with failure? (From analysis)	HMT machine 7616	Kirloskar machine 6025	Machine 7616 reconditioned due to the various issues identified
In the machine is the object observed with failure? (From	Fixture, spindle, machine bed	Other Process Parameters	Fixture deformation or taper affects the control rack

analysis)			dimensions
In the machine is the problem again observed? (From analysis)	Spindle RPM & Run out	Other Process Parameters	Cutting speed affects the control rack dimensions, as cutting speed is proportional to cutting force
In the machine is the problem again observed? (From analysis)	Table movement	Other Process Parameters	Machine table movement is jerky against the ideal condition
WHAT	IS	IS NOT (But could be?)	CONTRAST
Has been the Problem with	In-House Manufacturing Process	Supplier pre-parts	Measurements of the pre-parts before milling, after milling, after blackening & after bend removal show that supplier pre-parts are not the issue
Is the issue leading to the failure?	Process	Measurement	Isoplot shows process is the issue, not the measurement
WHEN	IS	IS NOT (But could be?)	CONTRAST
Object with defect observed first, where geographically was the observed or claimed object with defect?	Customer End	Company	Pumps were identified with high fluctuations in noise at the customer end initially, as and when there were engine tests run on the vehicles resulting with the engine not running smooth
Was the object started showing more no of defects? (At pump level)	November 2015	August 2015 - October 2015	A08 rejection rate gradually peaks and subsides over a period of time along with the type 939 with a similar pattern observed, but to a lower extent of rejection rate
Again trend, repetition, rhythm of occurrence observed?	January 2016	March 2016	Similarly there is a trend or a repetition in the rejection rate peaking & subsiding over a period of time

3. CONCLUSION

Multi-vari analysis helps in increasing quality by reducing process variability and aligning customer's expectations, providing financial returns to the management by avoiding the defect and rejection rates. The application of shainin trials have also been effective in finding out the project area at the initial level. These techniques used by shainin are increasing to be widely used as a method for problem solving by the quality department of various manufacturing firms worldwide. In this context, this project has been carried out for finding the root cause. The actual parameters were identified and the improvement in the required areas were proposed and made.

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