Influence and Effect of Manufacturing on Nozzle Performance

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Abstract - *In appropriate function of nozzle will lead to waste of manpower and material resources. In the environment of global competition, customers are becoming more demanding about all deliverables especially on Delivery, Quality& Price. Experimental work involves optimization of nozzle geometry and manufacturing process, so as to enhance the performance of nozzle on functional test bench. Work aims to reduce the rejection of nozzles on test bench below 1% of total parts produced and to achieve above mentioned deliverables. With the help of problem solving technique such as data collection, DOE (Design of experiment) tools root cause is found. Prior to experimentation error in measurement system is eliminated by ISO plot. From Paired comparison of 8 good & 8 bad nozzles, SSV's (Suspective source of variation) are found such as guide clearances, body form, body delta and beta factor. Trials were taken to reconfirm the SSV's. Range derived from experimentation of SSV's is used for validation. After required necessary action taken, nozzles are tested on Test bench to confirm the yield of the action taken.*

Key Words:* *Body form, Body delta, DOE, Nozzle geometry.

1. INTRODUCTION

The Diesel Engine is used in various aspects i.e. from Goods and passenger transportation, power generation, cranes etc. Ever stricter requirements for lower fuel consumption and reduced emissions call for better solution. The key elements affecting this process in a diesel engine is the fuel injection system (FIS) where an injection nozzle plays an important role in dispersion of the fuel. There have been studies on Injector Nozzle explaining the critical parameters of Nozzle and their effect on performance. F.J.Salvador et al [1], explained, nozzle with lowest inclination angle and highest hydro-erosion level has 15% more mass flow rate and 8% more effective velocity as compared to nozzle with the highest inclination and lowest hydro-erosion level .V. Lazarev et al [2], explained, with decreasing the height of top cylindrical precision interface from 10 mm to 5 mm leads to increase in the mass flow rate of the leakage from 0,43 kg/h to 0,6 kg/h.Weidi Huang at al [3], studied Needle lifts in diesel nozzle under different injection pulse durations. Nozzle liquid jet dynamics is affected by needle lift and injection pressure irrespective of needle opening or closing. Insufficient needle lift under the short injection-pulse duration may affect mass flow rate.

With the help of studies, critical parameters of nozzle and manufacturing were found which may be suspective source of variation, leading to rejection of nozzles on test bench. It is observed that given design parameters or tolerances at design stage may not yield the required result. So as to enhance the yield, manufacturing tolerances may need to be optimized. Shainin's DOE methodology is used to find the SSV's. Validation is done by comparing to confirm the cause.

2. ELIMINATION OF PROBLEM IN MEASURMENT SYSTEM

ISO plot is used to verify the impact of measurement system. Wide range of parts is considered, out of tolerance parts are also measured and repeatability of measurement is determined.

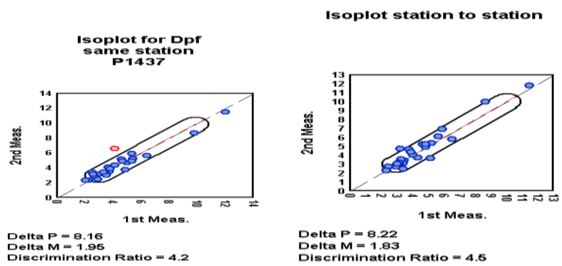

Chart- 1: ISO plot of functional test bench stations

$$Discri\min ation\_ratio = \frac{Delta\_P}{Delta\_M}$$

In the Fig. 1 ISO plot discrimination ratio is less than 6 which is minimum condition to conclude that measurement system is ok.

3. TO VERIFY EFFECT OF TOP FACE SEALING

A Flatness and waviness checking of 8 good and 8 bad parts is done on the Zygo machine for top surface of the nozzles. This is aimed to obtain data in table1. which would reveal the effect of top surface profile of the nozzles on the guide leakage (Dpf) rejection. The Zygo machine test provides the data of the top surface such as the Flatness, Waviness and Surface roughness of both the body and the needle.

Table -1: Observation and end Count table for body flatness and waviness

Observation table

Sr No.	Flatness	Waviness
B1	2.028	1.395
B2	1.976	0.106
B3	1.824	0.127
B4	1.934	0.124
B5	2.313	0.32
B6	2.064	0.474
B7	3.016	0.955
B8	3.248	1.454
G1	2.261	0.157
G2	2.905	0.146
G3	3.238	0.362
G4	2.96	0.142
G5	1.937	0.148
G6	1.713	0.148
G7	1.718	0.099
G8	1.827	0.138

→

End Count Calculations

Sr No.	Flatness
G6	1.713
G7	1.718
B3	1.824
G8	1.827
B4	1.934
G5	1.937
B2	1.976
B1	2.028
B6	2.064
G1	2.261
B5	2.313
G2	2.905
G4	2.96
B7	3.016
G3	3.238
B8	3.248

Count-3

Sr No.	Waviness
G7	0.099
B2	0.106
B4	0.124
B3	0.127
G8	0.138
G4	0.142
G2	0.146
G5	0.148
G6	0.148
G1	0.157
B5	0.32
G3	0.362
B6	0.474
B7	0.955
B1	1.395
B8	1.454

Count-5

BODY FLATNESS

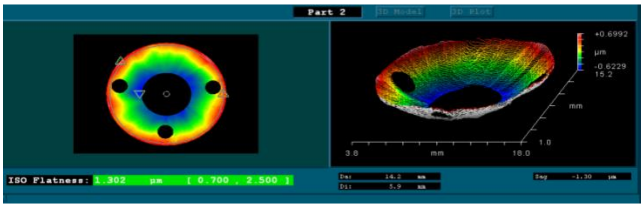

Chart- 2: View of display from ZYGO machine for Body Flatness.

Body WAVINESS

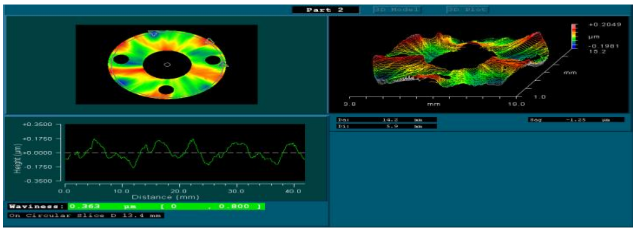

Chart- 3: View of display from ZYGO machine for Body Waviness.

It reveals no involvement of Surface finish parameter on the Dpf (guide)rejections. As a result the possibility of involvement of this parameter in the guide leakage is eliminated.

4. FINDING OF SSV'S: PAIRED COMPARISON

The tool used in primary stage is "PAIRED COMPARISON'. This tool uses a small sample consisting of good parts and bad parts to further narrow down the range of potential sources of variation. Here 8 BOB(Best Of Best) and 8 WOW(Worst Of Worst) parts are collected and then their parameters are checked again on the nozzle assembly benches. Following are some data from tests.

Table - 2: Observation table of all SSVs on Nozzle assembly bench.

Sr No.	Dpf	Body Delta	Needle Delta	Needle Form	Body Form	FSP Seat	FSP Mid	FSP Top
B1	5.56	0.5	0.8	-0.51	0.29	2.5	2.9	2.7
B2	5.43	0.7	0.4	0.13	0.56	2.9	2.7	2.1
B3	5.43	0.5	0.5	0.08	0.02	2.6	2.7	2.4
B4	5.65	0.4	0.5	0.05	0.06	2.7	2.9	2.7
B5	5.57	0.7	0.4	-0.06	-0.48	2.6	2.8	2.2
B6	6.55	0.5	0.6	-0.04	-0.37	2.5	2.8	3
B7	5.37	0.2	0.4	0.15	0.15	2.9	2.7	2.6
B8	5.67	0.8	0.6	0.23	0.18	2.9	2.6	2.3
G1	3.44	0.5	0.8	0.38	-0.39	1.9	2	2
G2	2.67	0.3	0.4	0.11	-0.5	2.5	2.4	2.5
G3	2.97	0.4	0.7	-0.05	-0.37	1.8	2	2.1
G4	1.53	0.2	0.5	0.24	0.05	2.5	2.1	2.3
G5	2.6	0.4	0.5	-0.34	-0.34	1.9	2	2.3
G6	2.53	0.4	0.9	0.12	-0.25	2.2	2.2	2.3
G7	2.73	0.4	0.6	0.21	-0.15	2.2	2	2.1
G8	2.52	0.3	0.6	-0.15	-0.32	2.3	2.3	2.5

Following data table gives us a complete idea of the end count pertaining to No's of trials taken for data collection

Table 4: Count Values for Assembly Parameters.

PAKO Bench	Body Delta	Needle Delta	Body Form	Needle Form	FSP Seat	FSP Mid	FSP Top
Trial 1	7	2	6	3	16	16	7
Trial 2	14	4	5	4	16	16	3
Trial 3	12	2	11	5	16	12	5
Trial 4	16	7	10	3	16	9	6
Trail 5	12	2	9	5	16	14	6

Thus, 4 SSV's brought to light by paired comparison were as follows: FSP SEAT, FSP MID, BODY FORM, BODY DELTA.

4. TO VERIFY MAIN EFFECT: FULL FACTORIAL

The daily rejected random samples of nozzles were collected from the final test line. Rejected nozzles were checked on nozzle assembly bench. It gave the range of values of SSV.

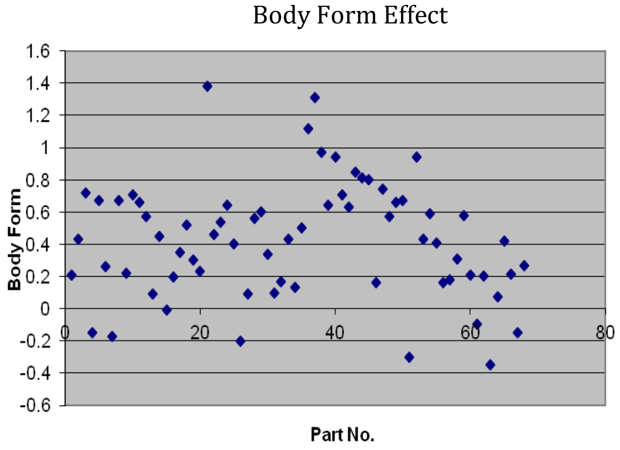

Chart- 4: Body Form versus Rejected Parts.

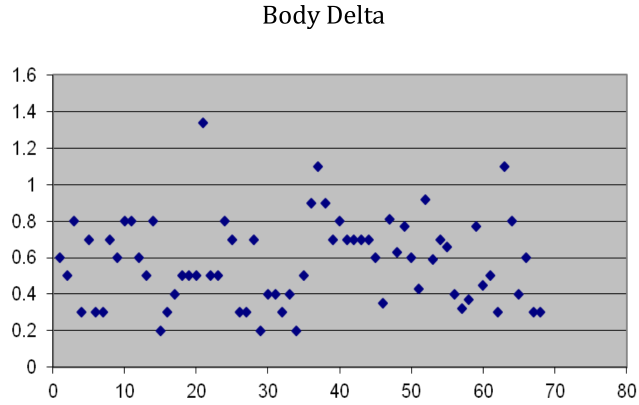

Chart- 5: Body Delta versus Rejected Parts

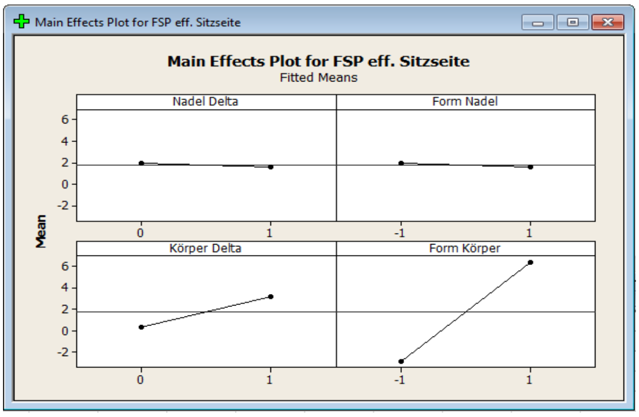

Chart- 6: Main effect plot of factors on FSP seat.

It was interesting to note that the daily rejected WOW parts which were later monitored in nozzle assembly bench gave the range of values of SSVs i.e. Body Form and Body Delta, obtained from fig 4 & 5. As a result a specific band or range was highlighted in which the values of these parameters were consistently lying. Fig 6 Shows body form and delta have the effect on FSP. The range of the SSVs highlighted is as tabulated below.

Table 5: Ranges are defined from experiment for SSVs.

Parameter	BOB Range	WOW Range	Validation Program
Body Form	-0.31 to 0.06	0.14 to 1.05	-1.2 to 0.1
Body Delta	0.2 to 0.4	0.5 to 1.1	0 to 0.4
FSP Seat	2.2 to 2.5	2.6 to 3.2	1.7 to 2.5
FSP Mid	2.2 to 2.5	2.6 to 3.0	2.0 to 2.6

5. TO VERIFY EFFECT OF NEEDLE LIFTS

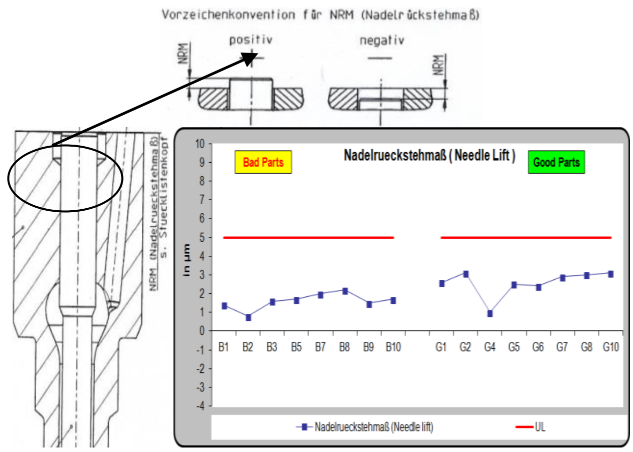

Chart- 7: Needle lift with respect to body surface.

Chart 7 clearly reveals that needle lift have no effect on rejection .

6. RESULTS AND DISCUSSIONS

With the derived values of SSV's changes was done in the program. Nozzles produced were passed through the test line, the effect of control parameters and result are plotted as below.

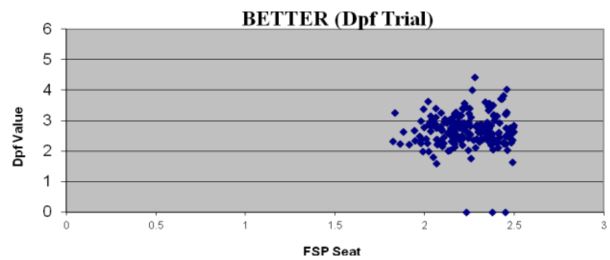

Chart- 8: Dpf Values versus FSP seat (BOB)

Chart 8 Shows, all parts produced were within the specification i.e. 0% rejection. It implies that FSP seat max value should be 2.5.

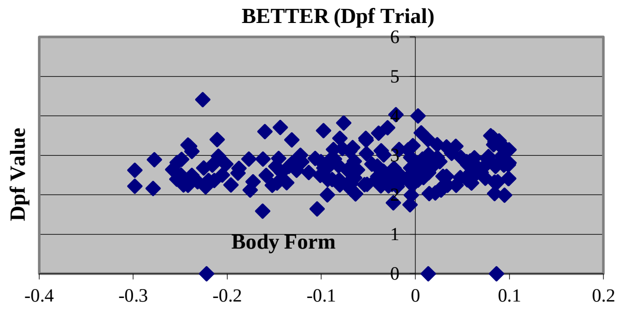

Chart- 9: Dpf Values versus body form (BOB)

Chart. 9 shows, all parts produced were within the specification i.e. 0% rejection. It implies that body form max value should be 0.1.

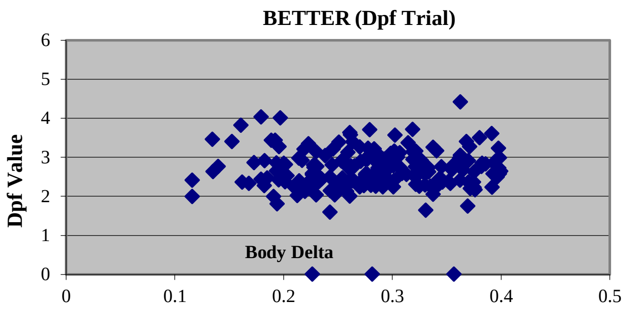

Chart- 10: Dpf Values versus body delta (BOB)

Chart10 shows, all parts produced were within the specification i.e. 0% rejection. It implies body delta max value should be 0.4.

When this control limit is put as trial for long run production, the rejection percentage was less than 0.7%.

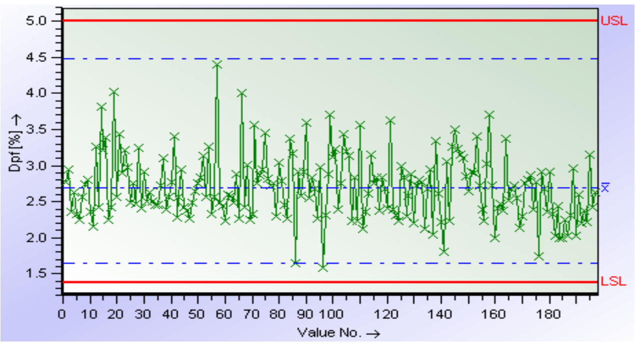

Chart- 11: Dpf Value run chart for better conditions

Chart. 11shows all parts with controlled product tolerances as referred in table 5,for best of best range of each SSV's, when passed through test bench.

Thus trials confirmed the causes highlighted in the previous stage and made it certain that the mentioned parameters and their corresponding values stated are the major contributing factors for rejection on test bench.

6. CONCLUSION

Paired comparison and Full factorial tools were successfully used to find the contributing factors for rejection of nozzles on test bench. Seat FSP i.e. clearance between the body inner diameter near the collar and the outer diameter of the needle in the same portion (FSP Seat) is a key parameter having a great effect on the final rejections but can be controlled to a certain extent. A control can be achieved on the guide clearance by directly establishing control limits on the values of body form and delta which are too significant contributors to the guide leakage phenomenon.

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