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Rejection reduction of Vacuum Pump type Alternator Assembly

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ABSTRACT: *Conventional manufacturing thought limits the rejection reduction plans to rejections which needs to be scrapped and implies direct loss. But present scenario in manufacturing industries, which is facing a very competitive environment, needs to consider not only rejections leading to scrap but also rejections which can be reworked or reused. Rejections which leads to rework results in man-hour losses which in turn affects the productivity of the organization. This paper focuses on assembly rejections of vacuum pump type alternators. Top of the Pareto is a rejection called "Pump rotation tight" which accounts to 50% of total assembly line rejection of vacuum pump type alternators. In order to reduce the rejection & rework, a study is conducted to analyze the rejection using appropriate statistical tools, Shainin technique for assembly process which indicated that two of the sub assembly components were the root cause for the rejection and subsequently optimize the subassembly shaft spline runout which is manufactured by cold rolling process using Taguchi Orthogonal array. Application of these tools helped in improving the knowledge base of the manufacturing and assembly process and also helped narrowing down to the root cause or a number of root causes in quick span of time.*

Keywords*: Alternator, Pareto, Shainin Technique, Taguchi orthogonal array, Cold rolling, Spline runout*

I. INTRODUCTION

Automobiles have an alternator [Fig1.1] to generate electrical energy for supplying power to electrical items such as starter motor, ignition, fuel injection systems, and electronic control units, cabin electrical, etc. The alternator also charges the battery when it generates more current than the consumers need. Apart from functioning as an alternator, an automotive alternator also generates vacuum by an eccentric vane pump attached at its rear end. The vacuum pump uses alternator shaft as its prime mover.

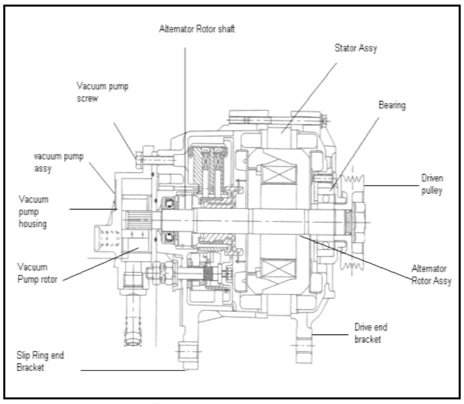

Fig 1.1 Alternator Section View

Vacuum Pumps are used for Diesel passenger cars and Heavy commercial applications for creating vacuum to the brake booster. Vacuum pumps are very critical to safe operation of a vehicle because failure of the pump results in a brake failure or hard braking condition which is fatal. This explains the importance of vacuum pump in the alternator. An alternator assembly process starts from rear bracket assembly and goes through 12 more operations and comes to final electrical and vacuum performance testing. In these various assembly operations rejections occur which affect the free flow of the assembly operation. This adversely affects the productivity of the line and also creates quality issues. During the past, rejections which creates scrap material alone was considered to be a loss, but in current market conditions where profits have thinned out, it is

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necessary to avoid rejections in any form even it is not creating scrap. These rejections do not necessarily produce scrap but creates loss in terms of loss of man hour or output which affects the productivity. Among all the rejections, 'Vacuum pump rotation tight' is the rejection at top of the Pareto [Fig 1.2]. This rejection contributes to 50% of total assembly line rejection. Eliminating or reducing this one failure will reduce the total assembly line rejection by nearly 50%.

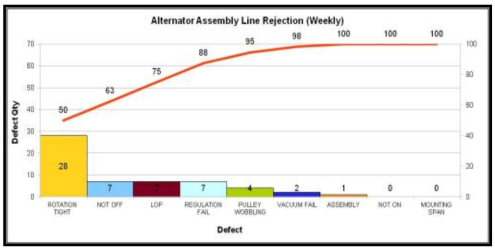

Fig 1.2 Pareto of Assembly

II. PROBLEM ANALYSIS:

The pump tight problem may be due to either the assembly process or the constituent sub assemblies. Since both the alternator and vacuum pump as individual parts are having free rotation before assembly with each other and becomes tight only after assembly this could be a rejection due to interaction of components or process. All the possible causes and suspects are analyzed, which is shown in the cause and
Effect diagram [Fig 2.1].

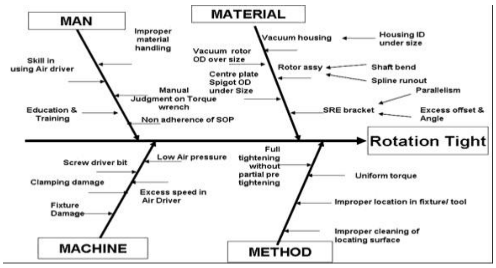

Fig 2.1 Cause and Effect

2.1 SHAININ COMPONENT SEARCH:

This method is suitable for an assembled product to find out whether the defect in the product is due to the assembly process or one of its constituent parts. Initially one pair of Best of Best (BOB) and Worst of Worst (WOW) products is chosen for analysis. They are disassembled and reassembled twice to find out whether good remains good and bad remains bad consistently, through D/d Test. It is preferable to have a measurable response to do this D/d test. If the D/d ratio is greater than 1.25, it means the assembly process is consistent and the defect in the product is due to one of its constituent parts.

2.2 BALL PARK STAGE:

Ball park stage is the stage to verify whether the Red X (Cause of Defect) is present among the causes considered. It also checks whether the cause is contributing components or the process of assembly.The best of best condition is the alternator with free rotation – 0.1 to 0.3 Nm torque

Best of Best (BOB) & Worst of Worst alternator assembly were selected for analysis. The units were disassembled and reassembled twice to check whether the bad remained bad and good remained good as shown in table 2.1. The ratio between difference between the median and average range should be greater than 1.25 to get 95% confidence that the process is not the cause.

Table 2.1 Component Re Assembly readings

	BOB (Nm)	WOW (Nm)
Initial	0.10	6.00
First Re Assembly	0.10	5.80
Second Re Assembly	0.20	6.00
Median	**0.15**	**5.9**
Range	**0.10**	**0.20**

Table 2.2 D/d Calculations

Difference between medians	D	5.75
Average Range	d	0.15
Ratio	D/d	38.3

Using the torque values in table 2.1, median and range are calculated for both BOB and WOW. The ratio between the difference of median and range average is calculated as shown in table 2.2. Here the ratio is greater than 1.25, which indicates that assembly process is stable and not the cause and only the contributing components are the cause.

2.3 ELIMINATION STAGE:

Components are ranked in the descending order of perceived importance to the problem. a) Pump rotor engagement with shaft spline, b) Vacuum Pump, c) SRE Bracket Assembly, d) DE rotor Assembly

The above were interchanged and after interchange returned to original. The experiment can be stopped when total reversal occurs or continued to find the effect of other components. BOB and WOW is taken and the components are interchanged in the required sequence and it is re assembled and each time the torque values are noted. The torque values are shown in table 2.3

Table 2.3 Component Interchange

	BOB (Nm)	WOW (B) (Nm)
Initial	0.2	6.0
First Assembly	0.1	5.7
Second Assembly	0.1	5.8
Spline 180 rotate	0.10	5.80
Re Assembly	0.10	5.70
Swap Pump	0.10	5.70
Re Assembly	0.10	6.00
swap SRE	2.00	5.90
Re Assembly	0.10	6.00
Swap Rotor	5.90	0.50
Re Assembly	0.10	5.90

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Table 2.4 Control limits for BOB & WOW

		Max	Min
BOB limits	=median of bob+/-(2.776/1.81)*d	0.5	-0.2
WOW limits	=median of wow+/-(2.776/1.81)*d	6.2	5.5

In order to analyze the interchange data graphically [Fig 2.2] and to identify reversals, control limits are calculated as shown in table 2.4.

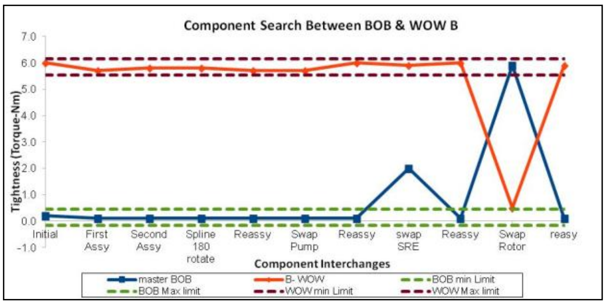

Fig 2.2 Component search between BOB & WOW

From the graph it is found that Rotor is the Red X in this case which has a complete reversal and also SRE bracket has some effect. The Red X components are to be analyzed and determine which dimension or tolerance or feature of the SRE bracket and Rotor are affecting the assembly result and making them as the Red X.

It was found that, from the dimensional reports by comparing the good and bad - among various components, dimensions and tolerances, the SRE Brackets' Parallelism and Rotors' Spline Runout caused the Pump Rotation tight rejection. In order to confirm this, the incoming component was inspected 100% for these two dimensions. Only components which fell inside the specification were used in assembly line. The experiment confirmed the causes, and all the assembled components found to be good.

Both the components are made in-house and the data showed that more than 60% of spline runout is out of specification and 40% of bracket parallelism is out of specification. In order to reduce the rejection due to these tolerances, both the process were studied

III. COUNTERMEASURES:

3.1 BRACKET MACHINING PROCESS STUDY:

The bracket machining process was studied for any deviations that could cause the parallelism go out of spec. The causes are analysed using the cause and effect diagram.

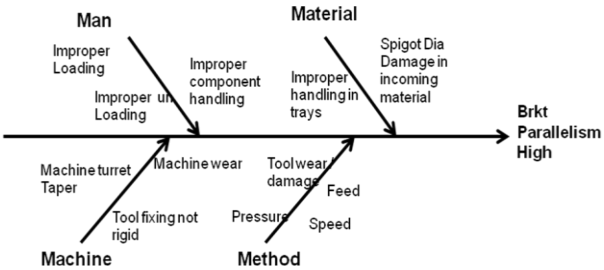

Fig 3.1 Cause and Effect diagram – bracket Machining

Fig 3.2 Bracket Machining and Parallelism Measurement

Bracket Parallelism		
S.No	In machine Clamped Condition (mm)	Outside machine - Declamped Condition (mm)
1	0.024	0.042
2	0.028	0.044
3	0.02	0.038
4	0.022	0.04
5	0.026	0.042
6	0.028	0.044
7	0.01	0.02
8	0.012	0.024
9	0.026	0.042
10	0.024	0.042
11	0.018	0.036
12	0.02	0.036
13	0.028	0.042
14	0.014	0.026
15	0.018	0.034

From the data it is found that the clamping pressure is causing the change in parallelism in clamped and de clamped condition. In order to eliminate this effect, the clamping pressure is reduced from 15 bar to 7.5 to 8 bar.

The change in clamping pressure has resulted in elimination of variation in parallelism in clamped and un clamped condition.

3.2 ROTOR MANUFACTURING PROCESS STUDY:

When the rotor manufacturing process was studied, Spline runout was high at first process – rolling stage.

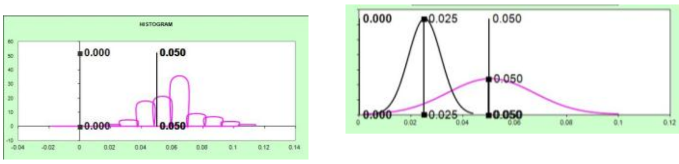

Fig 3.3 Spline Runout

The fig 3.3 shows the histogram and normal curve of spline runout, whose maximum runout allowed, is 50 microns. But data show that most of the shafts are out of specification, taking the process capability index to

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negative, Further data were collected shift wise to check the effect of shift changes using multi vari chart, effect of input shaft runout on the output runout are also studied. They are shown in graphical form in fig 3.4 and 3.5.

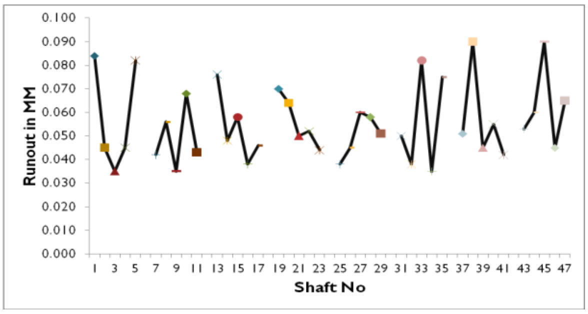

Fig 3.4 Spline Runout Shift wise –Multi Vari Chart

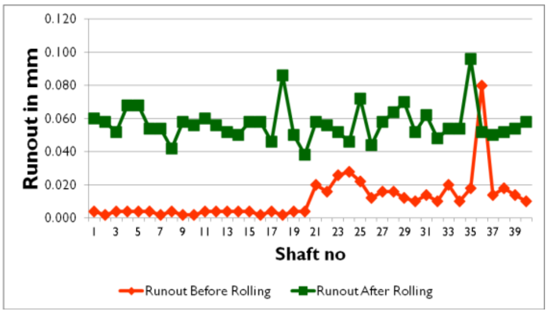

Fig 3.5 Spline Rolling Input and output Relation

It is inferred that both the shift and input condition is not the case and only the rolling process is creating the runout. So it was decide to run an experiment with the following 4 process parameters at 3 levels.

Factors
A: Dwell Time – in Divisions (1 div = 0.2 sec)
B: Roller RPM
C: Roll Pressure - Psi
D: Feed rate – mm/s

A L9 orthogonal array was selected for the experimentation and the experiment data is shown below in table 3.2.

Table 3.2: Experiment Design and Response

Dwell time	Roller rpm	Roll pressure	Approach speed	R/O at output	R/O at output	Sum	Avg
A	B	C	D				
4	19	750	2.5	0.022	0.042	0.064	0.032
4	24	500	1.8	0.03	0.018	0.048	0.024
4	29	700	3	0.022	0.026	0.048	0.024
2	19	500	3	0.04	0.06	0.1	0.05
2	24	700	2.5	0.016	0.052	0.068	0.034
2	29	750	1.8	0.03	0.04	0.07	0.035

Table 3.3: ANOVA

Source	SS	DOF	MS	F	F Table
Dwell Time	0.00054	2	0.00027	1.98495	4.1028
Roller RPM	0.00018	2	0.00009	0.65947	4.1028
Roll Pressure	0.00031	2	0.00016	1.14548	4.1028
Approach	0.00016	2	0.00008	0.59074	4.1028
Error	0.00136	10	0.00014	1.00000	
Total	0.002548				

From the analysis of runout data received from experimentation and the f ratio in ANOVA table 3.3, it shows that none of the parameter individually affects the cause. So the mean of each factor at each level were analyzed and the process parameter levels with lowest runout mean were selected. The mean values are shown in fig 3.6 & 3.7

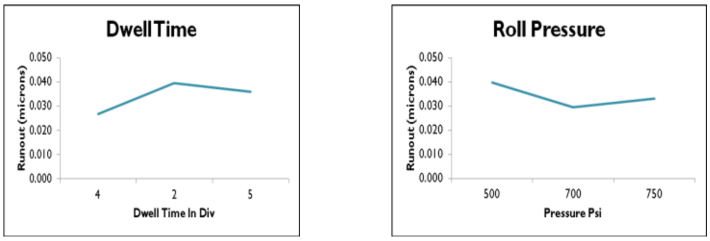

Fig 3.6 Mean Analysis – Dwell time and Roll Pressure

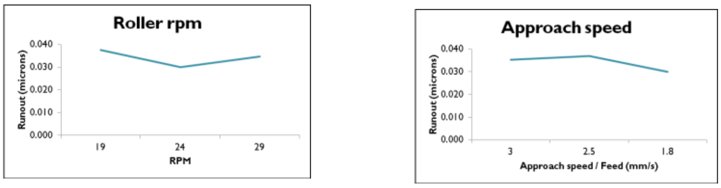

Fig 3.7 Mean Analysis – RPM and Approach Speed

A confirmation run with the parameters as Dwell – 4 Div, RPM – 24, Roll Pressure – 700 Psi, Feed 1.8mm/s done.

The runout data with the optimized process parameters have improved much to produce a cpk of 0.81, which was negative earlier. The mean also shifted to 35 microns.

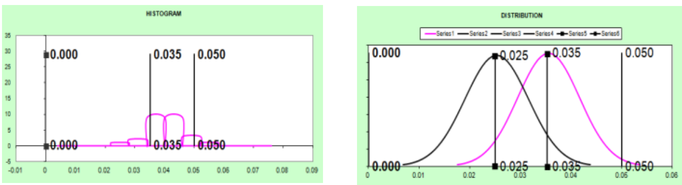

Fig 3.8 Spline Runout after Optimization.

This shows that the rejection level is brought down to a considerable level.

IV. CONCLUSION

Thus the two major root causes SRE bracket parallelism and spline runout is reduced to a considerable level to reduce the vacuum pump rotation tight assembly rejection. The present rejection details are shown in the figure. The rejections have reduced by almost 50%. The results are being monitored for long term effectiveness.

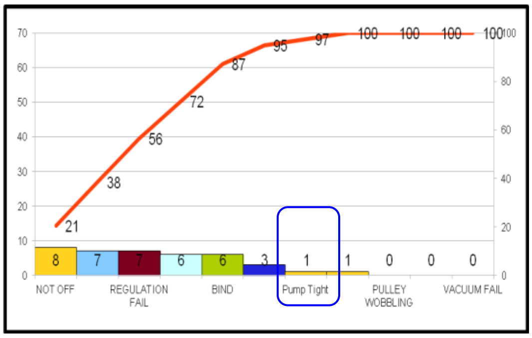

Fig 4.1 Rejection Pareto.

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