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REDUCTION OF FOULING NOISE IN AN AUTOMOBILE ALTERNATOR BY QUALITATIVE ANALYSIS USING SHAININ DOE TECHNIQUE TO ELIMINATE WEDGE PAPER PROTRUSION

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Abstract. This article proposes qualitative research to reduce fouling noise created by a specific component in an alternator. The three major problematic stages in the manufacturing process of an alternator such as forming, winding, and varnishing are monitored and necessary corrective action has been implemented. The different characteristics of these stages namely top tool diameter, preheating, rpm, etc were examined. "Shainin Design Of Experiments" (DOE) technique was used to deeply analyze the alternator. The traditional method of analyzing quality issues was the Taguchi DOE methodology. The rejection ratio was formulated to identify the reason for noise occurring in a component. A wedge paper protrusion was found to be present in the stator of an alternator. The issue is rectified by placing a nominal gap between the stator and the opposite surface. The efficiency of the alternator was found to be increased to a greater extent and also the number of rejections in an alternator due to fouling noise has been reduced.
Keywords: Forming, Fouling noise, Shainin DOE, Stator, Varnishing, Wedge paper, Winding.

1. Introduction

The efficiency of an alternator depends on various factors such as load cycle, external magnetic field, etc. Quality improvement in automobile alternators also plays a major role in improving their efficiency. [1] Andrey Puzakov developed the load cycle of an automobile alternator. The change in output voltage and the current strength of an alternator leads to a decrease in the energy generated in an alternator. To improve the efficiency of the vehicle, the load cycle of an alternator has been developed for testing. The numerical value of the load cycle is used to determine the most characteristic faults.

[2] examines the rectifier faults in the car alternator in light of the output voltage spectrum. The failure of diodes in the rectifier assembly is one of the primary causes of alternator breakdowns in automobiles. The failure of an alternator rectifier is analyzed based on the output voltage spectrum. The output voltage spectrum analysis is used to improve the reliability of an alternator. [3] made a spectral analysis of the output voltage of an automotive alternator. Electrical failure is one of the causes of automobile alternator breakdown. To rectify the electrical failure, the output voltage parameters are identified. The output voltage spectrum's biggest drawback is voltage excursion. The qualitative examination of an

alternator's output spectrum served as the foundation for the development of the failure recognition algorithm. [4] diagnosed the faults in the automobile alternators or using the parameters of the external magnetic field. Electrical faults of an alternator can be evaluated by the external magnetic field parameters. An electrical fault-recognizing algorithm was developed based on the external magnetic field. Hall sensor is used to measure the axial component of the external magnetic field which is sensitive to the technical condition of the generator.

One of the key factors affecting an automobile's occupant's comfort is the sound quality. Airborne and structure-borne noise are two broad categories of vehicle noise. Any anomaly in an alternator's operation that produces a hissing sound is referred to as a fouling noise. [5] According to M.P. Jolicoeur‘s theory, the vibration that travels through a car's suspension is the primary cause of structurally generated interior noise at low frequencies. To lessen cabin noise, a feedback controller with an active vibration control has been designed. An key aspect of the electrical architecture of a car and a significant generator of noise among other parts of the vehicle is the alternator.By using component search method, the major trouble causing element that constitutes fouling noise is identified as stator. When the stator component comes in contact with the opposite surface, an abnormal noise occurs due to wedge paper protrusion. A wedge paper is defined as the accumulation of foreign particles such as “dust“, “excess varnish“ etc, that protrude on the surface of the stator.

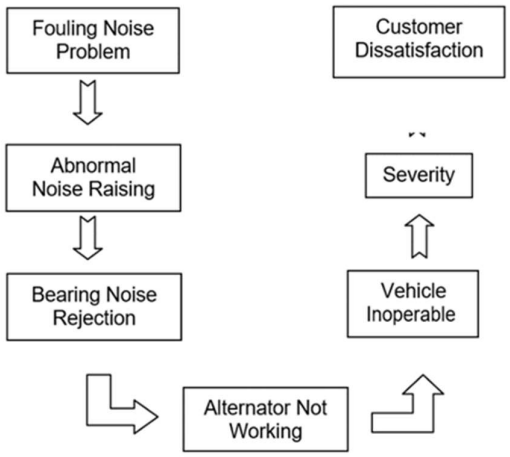

Fig. 1: The block diagram represents the severity of fouling noise problem in an alternator.

Due to bearing noise rejection, an abnormal hissing noise occurs leading to malfunctioning of the alternator. The vehicle becomes inoperable thereby increasing the severity of the problem which leads to Customer dissatisfaction.

The objective is to improve the quality of an automobile alternator by reducing the fouling noise. This noise occurs due to a defect in a particular component in the alternator. The main focus is that fouling noise can be reduced in the forthcoming alternators by providing awareness that a gap should be maintained between the stator and the opposite surface. This results in increased efficiency and reliability.

2. Existing Method:

[6] proves that for testing real-world systems and deterministic or random simulation models, the design of experiments (DOE) is required. Experimental design in conventional DOE is sequential and compared to other DOEs, it has a low confidence level.

Earlier, the Taguchi DOE method was formulated for solving chronic quality problems. The results of this procedure were just approximate and did not pinpoint the parameter that has the greatest influence on the performance characteristic value. Although there was no progressive growth in its characteristics, it was regarded as an exponential power system.

[7] According to A.K. Verma, Shainin methods are a group of guiding concepts that serve as the foundation for an ongoing effort to improve quality.

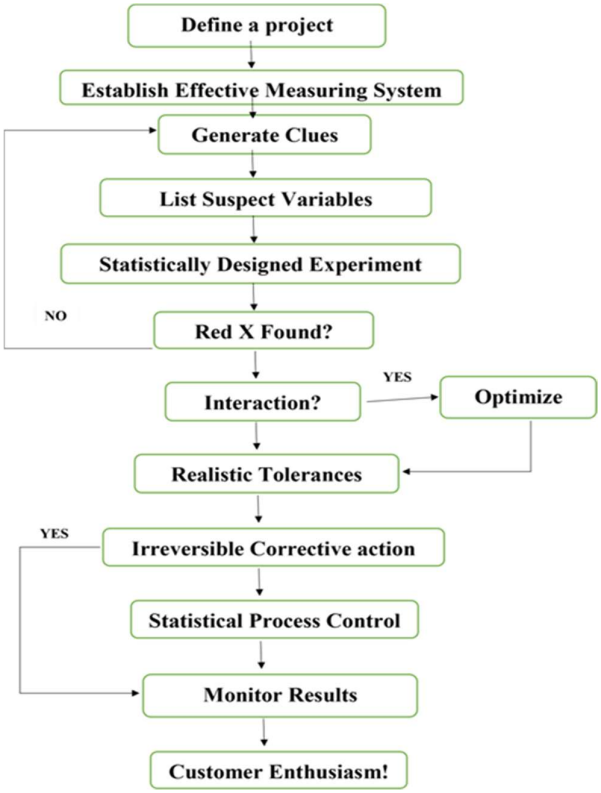

Fig. 2: The flowchart shows an easy way of providing better results by solving problems efficiently.

The project is defined in the first step followed by establishing effective measuring systems to generate clues. If Red X is found, further interactions are carried out by SPC (Statistical Process Control) approach. If Red X is not found, the steps are repeated back to generate clues. The realistic tolerances are optimized and results are monitored. Corrective action can be taken to solve any type of problem which is found during monitoring. This enhanced approach leads to customer satisfaction.

In the Shainin DOE method, there are many terminologies in which some of the most widely used terms are described below.

Green Y: Green Y is used to define the problem in an alternator assembly line

Red X: Red X is the most widely used Shainin term in an alternator assembly line. It is used to describe the dominant cause that has a large effect(70%)

Pink X: It is the second contributing factor that accounts for 20- 30% of the effect

Pale Pink X: It is the third contributing factor.

3. Proposed Method

Table 1 : Data Analysis in Assembly Line Rejection

Rejection Parameters	No. of Rejections	Cumulative Quantity
Fouling noise	121	121
Bearing noise	98	219
Slip ring damage	77	296
Fan bend	65	361
Double Varnish	55	416
Pole gap	45	461
Rotor coil damage	23	484
Total	484	

Table 1 shows the number of rejections that occurred in an alternator line due to different parameters in one month. A cumulative value is calculated to estimate the Pareto chart.

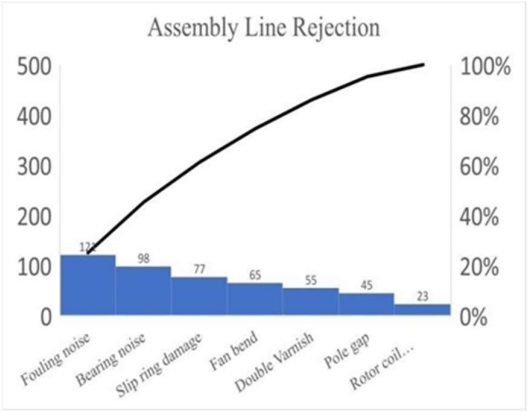

Fig. 3: shows the pareto chart used to highlight the major problems among a set of problems.

Using Pareto analysis, the issues can be evaluated and prioritized by comparing each problem which decreases the efficiency of an alternator. Fouling noise is identified as the major problem which makes an alternator fail.

A strong and efficient experimental design strategy is provided by the Shainin DOE method for addressing persistent quality issues. It is a method that is systematic and effective for examining the link between various input variables and important output variables. It is a methodical process for gathering information and developing discoveries.

This method involves a twelve-step approach to solving chronic quality issues. A novel work has been performed in automobile alternators to increase the efficiency of the vehicle.

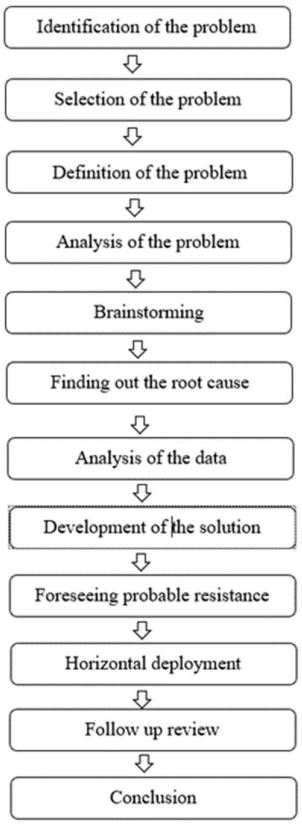

Fig. 4: depicts the twelve-step approach of Shainin DOE.

The first step involves the identification of the problem. In the alternator assembly line, nearly 50 problems that affected the efficiency of the alternator are identified. Some of the problems include bearing noise, pulley friction not ok, fouling noise, slip ring damage, etc. The next step involves Pareto analysis in which the problems can be evaluated and prioritized by comparing the benefits of each problem.

In the alternator assembly line, there is a set of assembly line rejections (ALR) that are to be identified. Out of these rejections, the major root cause is identified by means of a Red X method. Out of the possible causes, the most probable cause is analyzed and evaluated.

Using the product process search approach, the process factors that affect a product's quality are enumerated and quantified. The component search approach is used to swap parts and sub-assemblies between a good and a bad product until the problem's source is found. By using the paired comparison method, the qualities or criteria that differentiate the best from the poorest examples of products are compared.

The root cause defines the main reason for the problem occurring in the component. A wedge paper protrusion is identified as the major root cause.

Fig. 5: depicts the Wedge paper protrusion occurred in an automobile alternator which decreases the efficiency of an alternator.

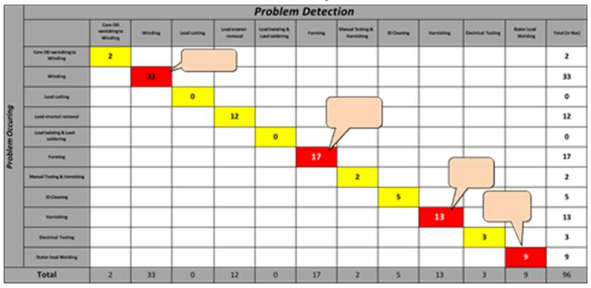

Fig. 6: shows the diagonal matrix in which all the stages were monitored for the wedge paper protrusion and observed that the final forming, Winding & Varnishing stages were major problematic stages.

From one month of production, the alternator rejection percentage was observed as 2.5%, in which we have identified that Winding will cause rejection of 1.2 %, Forming rejection was observed as 0.9 % and Varnishing as 0.4%.

4. Results and Discussions

Table 2: Foreseeing Probable Resistance

Week number	Quantity produced	Quantity rejected
2	1800	0
3	1750	0
4	1885	0
5	1780	0

Table 2 shows the weekly production and rejection quantity of an alternator after implementing the corrective actions. In order to quickly generate remedies, the next issues are anticipated.

The improvements done in the upcoming steps provide tangible benefits such as improved production, high amps rejection eliminated, and first-time-through increases. The results of the monitoring are collected and a review is performed.

Winding

In this process, wedge paper lift occurs in winding after retracting by lower arm insulation paper

due to height variation during insertion. The bottom tool lower arm deviation also occurs. The root cause is identified as friction acting on the insulation paper. [8] Li Zhang works on designing stator windings for maximum efficiency. The type of stator winding has a significant impact on the stator's copper loss and stray loss.

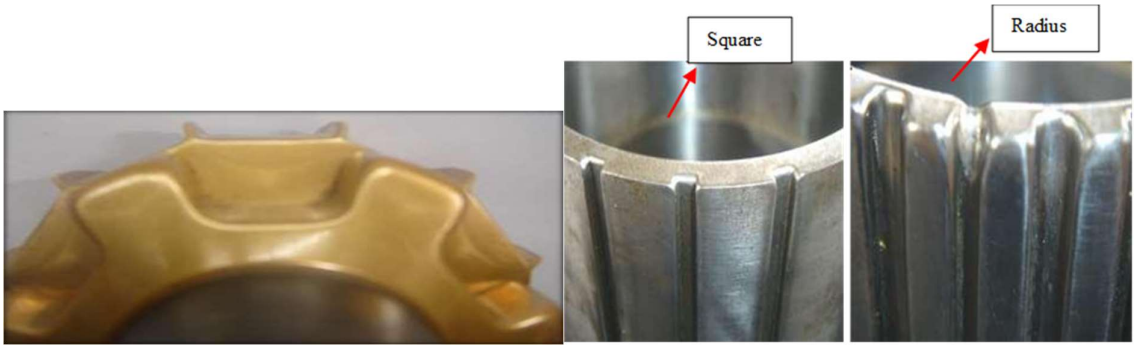

Fig. 7: shows the insulation paper inserting bottom tool diameter decreased from 102.8 to 102.0.

Forming

Using appropriate stresses like compression, shear, and tension, the materials go through plastic deformations and take on the necessary shapes and sizes. This operation refers to a mechanical process used in industries. The top tool used for shaping now has a radius instead of a square. Height of the previous part is increased. [9] According to Mirko, one method of raising the slot filling factor is to shape the relevant conductors so that their cross sections match their locations. The description of interactions in the formation of tooth coils with trapezoidal cross sections of the individual turns is the primary topic of this work.

Fig. 8: Top tool profile was modified from square to radius type so that the wedge paper protrusion can be avoided.

Varnishing

Optimized process setting level implemented to avoid excess/less varnish in a stator assembly line. [10] The findings of the best protective varnish thickness selection to reduce crosstalk in multiconductor buses are presented by Roman S. Surovtsev.

Table 3: Factors affecting varnishing

Factors	Before	After
Viscosity	60:80	100:120
RPM	15	25
Preheating	100	110

Table 3 depicts the optimized process setting level implemented to avoid excess/less varnish in stator assembly. To reduce the varnish weight gain variations viscosity,

RPM and preheating are changed. The following processes are involved in anticipating resistance: brainstorming, detecting potential obstacles before they arise, and coming up with solutions. Future issues are anticipated in order to quickly generate remedies.

5. Conclusion

The cost of one stator is Rs.850, on average 68 stators were rejected in an alternator assembly line in three months. Per year nearly Rs.2,25,000 loss had occurred due to the fouling rejection of an alternator. After implementing the check sheet, Pareto chart, cause and effect diagram, component search analysis, design of experiments (DOE), and some other techniques the fouling rejection had been solved.

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Author Contributions

All authors were major contributors in completing the work.

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