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OPTIMIZATION OF FUNCTIONAL PARAMETERS OF COMMUTATOR FUSING PROCESS

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ABSTRACT
Poor quality of commutator fusing process often causes quality issues like Resistance variation, Heat discoloration and Wire pressing enamel melting in armature. The quality measure of commutator fusing joint is estimated from variation in the resistance. Furthermore, four important process parameter, welding current (WC), spring load (SL) and cooler temperature (T) are considered as the factors influencing the quality of the joints. In order to develop an accurate relationship between the process inputs (4-component) and the response output (resistance variation), a linear regression model is deve1oped. ANOVA analysis is done by optimization software (MINITAB) to identify the significance of individual functional parameters and the developed model can be effectively used to predict the factors which affect the Quality.

KEYWORDS: Optimization – ANOVA – Commutator – Fusing.

INTRODUCTION
Today, fusing-machine technology allows reliable consistent fusing of commutators using low energy. In particular, this is required to process modem high-speed motors having asbestos-free commutators. Since the fusing process is also significantly affected by the commutator and wire-insulation characteristics, it should be carefully considered in new motor design.
Commutator fusing was developed in the early l950's as a method of manufacturing small Universal or DC motors. The early process of attaching wires to the commutator required dipping the commutator into a solder bath, and hand soldering the connections. This two step process was not only difficult, time consuming and therefore, expensive, but also emitted dangerous lead pollutants into the Atmosphere.
Furthermore, if a soldered armature's motor stalled or overloaded, there was a chance might remelt and "spit out" contaminating commutator and damaging the armature's coil. If enough solder left the joint, the wires could become free from the commutator and destroy the connection. As production increased, cost reductions, along with process quality improvements, needed. Thus, the process changed from soldering to fusing, a method of joining low resistance metals through the use of mechanical actions and resistance welding control.

Literature Review
The aim of this study is to find out from which process parameters (factors) electrode wear is affected and to which factor interactions it is related. This is usually done by means of analysis of variance (ANOVA). Furthermore, regression analysis is used to establish the correlation between factors and response (tool wear). The appropriate degree of the polynomial regression equation is found which is thought to be useful assessment of the predictive equation [1, 2]. Finally, the optimal factor levels are obtained.
Ugur Esme [3] has studied optimization of RSW process parameters for SAE 1010 steel using Taguchi method. He investigated that increasing welding current and electrode force are prime factors controlling the weld strength. He concluded that Taguchi method can be effectively used for optimization of spot welding parameters.
Degarmo [4] has explained Resistance spot welding (RSW) has an important place in manufacturing and it is the simplest and most widely used form of the electric resistance welding process in which faying surfaces are joined in one or more spots. Coalescence is produced in a relatively small area by the heat obtained from the

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resistance to the flow of electric current through the work pieces held together under pressure by electrodes. The amount of heat produced is a function of current, time, and resistance between the work pieces.

J. Lantz [5] has investigated that it is desirable to have the maximum temperature at the interface of the parts to be joined. Therefore, the resistance of the work pieces and the contact resistance between the electrodes and work should be kept as low as possible with respect to the resistance between the faying surfaces. This could be achieved by controlling the contact area, electrode materials, and dimensions, applied pressure, and surface quality of the work pieces.

M. Jou [6] Literature reports that work has been done on various aspects of modelling, simulation, and process optimization in the resistance spot welding process. Detailed analysis has been made to establish relationships between welding parameters weld strength, weld quality, and productivity to select welding parameters leading to an optimal process.

Martin et al. [7] proposed Artificial Neural Network (ANN) for quality control by ultrasonic testing in resistance spot welding.

Yoon et al. [8] investigated optimal welding conditions in resistance spot welding of 7075-T6 aluminium alloy sheets by the tensile-shear strength tests and the Taguchi method.

In recent years, the Taguchi method has become a powerful tool for improving productivity during research and development so that high quality products can be produced quickly and at low cost [9].

An advantage of the Taguchi method is that it emphasizes a mean performance characteristic value close to the target value rather than a value within certain specification limits, thus improving the product quality. Additionally, Taguchi's method for experimental design is straight forward and easy to apply to many engineering situations, making it a powerful yet simple tool. It can be used to quickly narrow the scope of a research project or to identify problems in a manufacturing process from data already in existence [10].

Min Jou [11] in his research explored how a change in controllable parameter (i.e., percentage heat input) affects a measurable output signal indicative of strength and weld quality (i.e., electrode displacement) for various steel sheets used in automotive industry.

P.J. Ross [12] in this book author explains orthogonal arrays, ANOVA, S/N ratio analysis and F-test are the essential tools for parameter design. The optimum condition is selected so that the influence of uncontrollable factors (noise factors) causes minimum variation to system performance.

M. Durairaj used grey relational analysis in his research. Grey theory has been widely used in engineering analysis, and it reveals the potential to solve the setting of optimal machining parameters associated with a process with multiple output parameters [13].

COMMUTATOR FUSING MACHINE

Universal or DC electric motor armatures are manually loaded and unloaded into the Commutator Fusing Machine, as shown in Figure 1 [14]. The armature is held by its shaft in a collet, and indexed with a precision electronic indexing mechanism. The armature can be automatically or manually aligned. The collet type index mechanism is used because it is extremely fast and accurate, and does not damage the armature's iron laminations in any way.

This System requires three phase electrical input, cooling water input and compressed air [no less than 60 PSI or 4 Atmospheres]. A refrigerated circulating water cooler can be optional.

This machine is controlled by an industry standard programmable machine controller, incorporating machine diagnostics, which can have a computer act as an interface between the setup personnel and the machine. Human interface controls can be either hard wired, through a video touch screen, or a combination of the two. All safety switching and devices are hard wired. The machine's control system can interface with a communication system for central control, central data capture of SPC data and machine diagnostics.

Commutator Fusing Process

Commutator Fusing is the process of joining low resistance metals with resistance welding machine, but without appreciable distortion of the joining parts. The parts are heated and pushed together until all the air between them is eliminated and the high points of one part are pushed into the low points of the other, and vice versa.

A surface adhesion contact then will hold the parts together, and it is not a weld. It is a compression joint which affects only about 0.0002 inches (0.005 mm) of surface depth without amalgamation of metals. As the strength of the joint is moderately strong, it must be used only with parts specifically designed to be fused, such as a slot or tang in a commutator as shown in Figure 2.

Figure1: Commutator Fusing Machine

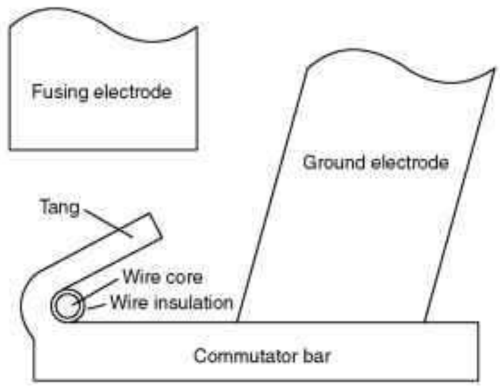

Figure 2: Commutator Fusing Process

EXPERIMENTAL WORK

The process flow for producing the motor's commutator is shown in Figure 3. The basic component is the core shaft of the motor, upon which a brass collar is pushed. After pushing, it is send to epoxy coating machine for coating, then it is visually inspected for proper coating. After coating, the commutator is pressed and copper wires are wounded using winding machine. After winding the component is sent for fusing process. After fusion, some parts were found to be defective. The quality is determined by the resistance variation in each lug. The variation is observed in EP armature testing machine. Armature is tested after applying gel and varnish which will resist corrosion.

Taguchi method is followed and three significant functional input parameters were identified and are given below. The measurable output parameter of resistance is directly related to the quality of fusing based on the literature review.

1. Welding current.
2. Spring load.
3. Cooler temperature.

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Mechanical calibrations were made to avoid major defects in fusing process. The following mechanical calibrations were carried out before conducting the experiments:

1. Hook distance of tungsten steel bar and commutator is kept at 1 – 2 mm.
2. Cathode bar is kept at 0.5 – 1 mm below the tungsten steel bar.
3. Rotor shaft is kept at the centre of chuck and the bearing touches the commutator.
4. Stroke of pressure cylinder is adjusted.
5. Position of the tungsten steel bar is adjusted.
6. Cathode copper bar angle is adjusted.
7. Semi-automatic loading and unloading is manually done.

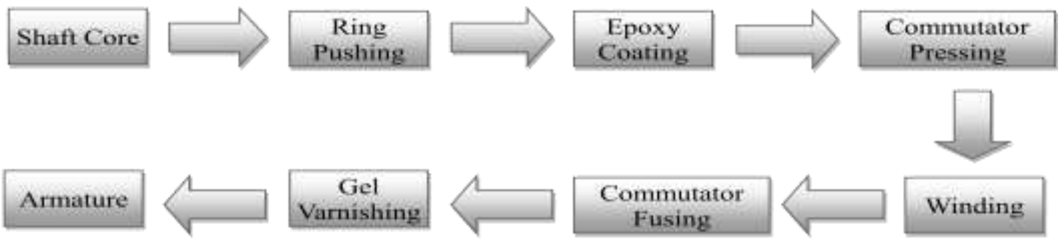

Figure 3: Process Flow

RESULTS AND DISCUSSION

The input parameters (welding current, spring load, and cooler temperature) that affect the quality of the component were varied and the values of corresponding resistance were measured as shown in Table 1.

The regression equation: Resistance = 1.18 + 1.05 Current + 0.0811 load + 0.0105 Temperature.

From ANOVA table it is found that current and load factors are significant. Analysis of variance as shown in Table 2, Regression equation main effects plot as shown in Figure 4, Interaction plot as shown in Figure 5, and Counter plot as shown in Figure 6 for resistance variation were analyzed.

Table 1: Design Matrix

Current (kA)	Load (kgf)	Temperature (°C)	Resistance
0.6	4	23	1.905
0.6	6	24	2.065
0.6	8	25	2.190
0.9	4	24	2.225
0.9	6	25	2.345
0.9	8	23	2.453
1.2	4	25	2.450
1.2	6	23	2.690
1.2	8	24	2.910

Table 2: Analysis of Variance

Source	D F	Seq SS	Adj SS	Adj MS	F	P
Current	2	0.5968	0.5968	0.29842	91.5	0.011
Load	2	0.1580	0.1580	0.07902	24.2	0.040
Temperature	2	0.0081	0.0081	0.00407	1.25	0.445
Error	2	0.0065	0.0650	0.00326		
Total	8	0.7695				

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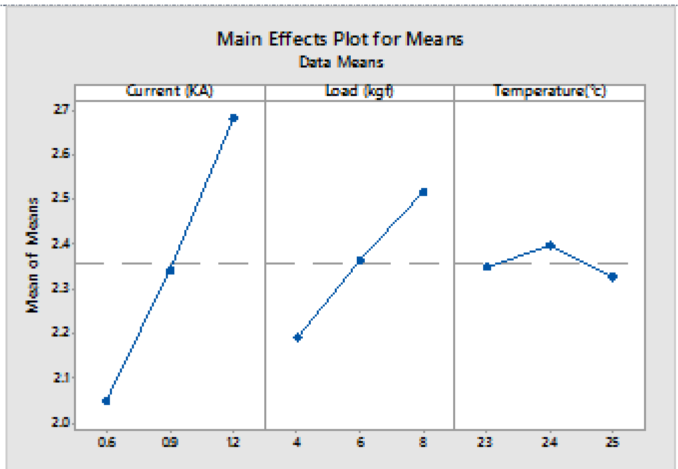

Figure 4: Main Effects Plots

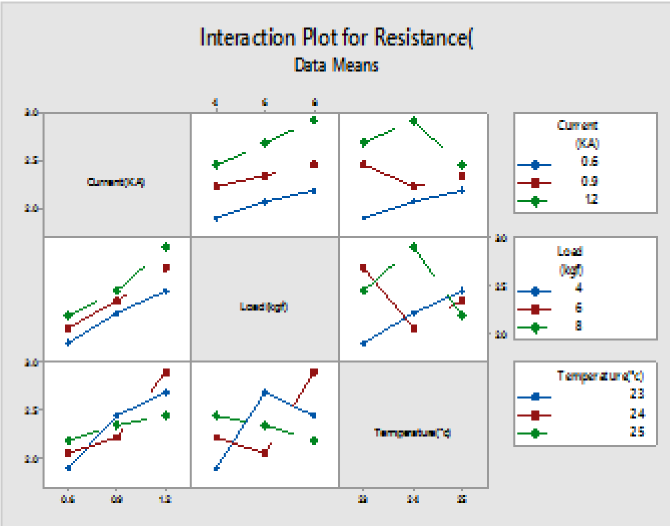

Figure 5: Interaction Plots

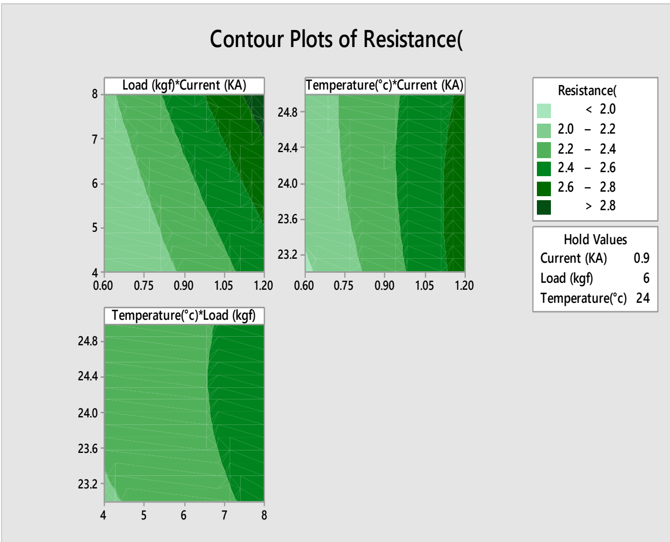

Figure 6: Contour Plots

CONCLUSION

Experiments were conducted according to Taguchi method on commutator fusing machine, the control parameters like welding current, spring load and cooler temperature were varied to conduct 9 different experiments and the result were observed for resistance. A regression model was designed comparing the three functional parameters welding current, spring load and cooler temperature. The interaction plots, contour plots and main effects plots shows optimal functional parameters. The functional parameters like welding current and spring load were causes significant defects using analysis of variance.

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