TAGUCHI APPROACH TO OPTIMIZE THE BAD FUSION DEFECT OF WHEEL RIM INDUSTRY: A CASE STUDY

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ABSTRACT:

Variation is the cause of defects that lead to shift the processes beyond control. Defects that reach the customers create significant problems that can result in customer dissatisfaction, resulting loss in customers and demise of an organization or business. Design of experimental technique of standard Taguchi method is used to analyze the experiments successfully. The objective of using Taguchi techniques in this research is to identify the key factors that make the greatest contribution to the variation in response parameters of interest and to ascertain those settings or values in wheel rim manufacturing. The main components manufactured by this firm are the wheel rims of automobiles. The range of diameter of wheel rims ranges from 10 inches to 30 inches and width may vary from 2.25"– 13" (inches). Through the Taguchi parametric design approach, the optimum levels of process parameters are determined. The percentage of contribution of each process parameter is determined by Analysis of variance (ANOVA) technique. Taguchi's experimental design yields optimized control factors, resulting in superior product quality and stability. It is concluded that for the bad fusion defect, the most significant factor is current (factor A) out of three factors.

KEYWORDS: bad fusion defects; wheel rim manufacturing industry; Taguchi approach; ANOVA technique

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1.0 Introduction

Taguchi (1990) suggested three stages: system design, parameter (measure) design and the tolerance design. Proper experimental designs can significantly contribute towards the accurate characterization and optimization of experimentation. There are different types of experimental approaches such as 'best guess approach', 'one factor at a time approach' and 'many factors at a time approach', used to study the effect of parameters on their performance. Best guess approach has disadvantages because hit and trail method is used, till the desired results are achieved. Then the experimentation is stopped. One factor "at a time approach" is the simplest experimental approach, but it fails to consider possible interaction between different factors. To overcome all these difficulties, a multifactor approach is considered as the most efficient approach to study the effect of factors on outputs. Several factors are considered to conduct a factorial experiment for green sand casting process. 'Multifactor experimental approach' is capable of estimating the effect of parameters and their relation with output. There are two different experimental approaches to handle multifactor design approach such as full factorial and fractional factorial design approach. Full factorial designs are used when experimentation is easy or when the numbers of factor under study are less than 4. Fractional factorial design is used when number of factor under the study are more than 4. These types of design consist of only a small number of combinations of factors setting out of all possible combinations. These are the most useful designs as they provide a valid and cost effective way of studying many factors in a single experiment.

Taguchi derived assumptions from engineering knowledge and used them to reduce the size of experiments, thereby speeding up the experimental process. Orthogonal design arrays (OAs) are significant parts of Taguchi methods. Instead of full factorial design or one factor-at-a-time variation, all factors are varied simultaneously as per design array and the response values are observed. The design of experiments helps to form a matrix consisting of different levels of controllable factors. With this technique, the settings of the different levels of controllable factors help to reduce the number of experiments. Prior to using design of experiments, Fish Bone diagram (one of the Six Sigma problem solving tools) is used to determine key variables in this case study. Sixteen controllable parameters are identified and are divided into two projects. Then eight parameters of each project are arranged in a specially design array, as recommended by Taguchi design technique. During the experimentation, it is observed that some uncontrollable factors or noise factors are also present. These factors are sources of process variation and reduce process performance. These factors are impossible or difficult to control during experimentation. Taguchi has classified the noise or uncontrollable factors into two groups, i.e. inner and outer noise factors. The outer noise factors depend upon operating and environmental conditions, while the inner noise factors depend upon manufacturing imperfections and deterioration of the process.

Pareto analysis is a statistical technique in decision making used for selection of a limited number of tasks that produce significant overall effect. It uses the Pareto Principle –Few causes account for most of effects.

2.0 LITERATURE REVIEW

Barua et al. (1997) used the Taguchi's method to optimize the mechanical properties of the Vacuum (V) casting process. Their prime focus was on minimizing the casting defects, developed in components manufactured by the green sand casting process. The gradient search method, the Finite element method (FEM), neural network method and the Taguchi method are some prominent methods, generally used for casting system design. Shaji and Radhakrishnan (2002) performed an analysis of the process parameters in surface grinding with graphite as the lubricant, using Taguchi method. Authors analyzed the process parameters such as speed, feed and mode of dressing as influential factors on the force components and surface finish developed, using Taguchi's experimental design methods. Jang et al. (2003) studied the Taguchi method, a robust experimental design and used it to optimize manufacturing parameters of a brake lining. In their work, a brake lining containing 15 ingredients is employed to find the best manufacturing parameters for wear resistance and friction stability of a brake lining. According to the parameter design, brake linings produced from 16 different manufacturing conditions are examined for physical properties (surface hardness and porosity), tribological properties (friction coefficient and wear), and the relationship between these two properties. From the signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) of the test results, the effective parameters to control physical properties of a brake lining are obtained and manufacturing conditions for improved tribological behavior are suggested. Results of their work show no apparent relationship between the physical properties and tribological performance of a brake lining.

Casalino et al. (2005) studied Ti6Al4V which presently is one of the most widely used titanium alloys, accounting for more than 50% of all titanium tonnage in the world, and to date no other titanium alloy has been a threat to its dominant position. Laser welding of Ti6Al4V is a major issue in the automotive and aerospace industries. In their study, both CO_2 and diode laser welding processes were investigated for Ti6Al4V alloy sheet joining using either lap or butt configurations. Artificial neural networks (ANN) processed the data coming from the experimental trials. The aim was to interpolate the database in order to form a suitable database for the analysis of the variance (ANOVA) and the Taguchi analysis of the means. Olabi et al. (2006) suggested that nowadays several numerical methods are widely used for either modeling or optimizing the performance of the manufacturing technologies. That has been advanced due to the large diffusion of the personal computer and the numerical algorithms. The knowledge of those methods and the ability in integrating their functions can make both the manufacturing engineer and the researcher ace their duties. Two of those methods have been employed, the back propagation artificial neural network and the Taguchi approach to the design of the experiment. They were applied to find out the optimum levels of the welding speed, the laser power and the focal position for CO_2 keyhole laser welding of medium carbon steel butt weld. The optimal solution is valid in the ranges of the welding parameters that were used for training the neural networks. Extrapolation over those limits would restrict the applicability of the found solution. The proposed approach would be extendable to other keyhole laser welding processes for different materials and joint geometries. Benyounis and Olabi (2008) studied welding input parameters playing very significant role in determining the quality of a weld joint. The joint quality can be defined in terms of properties such as weld-bead geometry, mechanical properties, and distortion. Generally, all welding processes are used with the aim of obtaining a welded joint with the desired weld-bead parameters, excellent mechanical properties with minimum distortion. Nowadays, application of design of experiment (DOE), evolutionary algorithms and computational network are widely used to develop a mathematical relationship between the welding process input parameters and the output variables of the weld joint in order to determine the welding input parameters that lead to the desired weld quality. A comprehensive literature review of the application of these methods in the area of welding has been introduced herein. This review was classified according to the output features of the weld, i.e. bead geometry and mechanical properties of the welds.

Ghosh et al. (2009) applied Taguchi methods to find optimum process parameters for end milling while hard machining of hardened steel. A L_{18} array, signal-to-noise ratio and analysis of variance (ANOVA) are applied to study performance characteristics of machining parameters (cutting speed, feed, depth of cut and width of cut) with consideration of surface finish and tool life. Chipping and adhesion are observed to be main causes of wear. Results obtained by Taguchi method match closely with ANOVA and cutting speed is most influencing parameter. Multiple regression equations are formulated for estimating predicted values of surface roughness and tool wear. Huang (2010) studied the effect of each welding parameter on the weld bead geometry, and then sets out to determine the optimal process parameters using the Taguchi method to determine the parameters. Three kinds of oxides, Fe_2O_3, SiO_2, and $MgCO_3$, were used to investigate the effect of activating flux aided gas metal arc welding (GMAW) on weld bead geometry, angular distortion and mechanical properties in AISI 1020 carbon steel. During welding a charge coupled device (CCD) camera system was used to observe and record images of the welding arc and analyze the relationship between penetration increase and arc profile. The experimental results showed that activating flux aided GMAW increased the weld area and penetration and tended to reduce the angular distortion of the weldment. The $MgCO_3$ flux produced the most noticeable effect. Furthermore, the welded joint presented better tensile strength and hardness. Selvaraj and Chandramohan (2010) studied the influence of cutting parameters like cutting speed, feed rate and depth of cut on the surface roughness of austenitic stainless steel during dry turning. A plan of experiments based on Taguchi's technique has been used to acquire the data. An orthogonal array, the signal to noise (S/N) ratio and the analysis of variance (ANOVA) are employed to investigate the cutting characteristics of AISI 304 austenitic stainless steel bars using TiC and TiCN coated tungsten carbide cutting tool. Finally the confirmation tests that have been carried out to compare the predicted values with the experimental values confirm its effectiveness in the analysis of surface roughness.

Chan and Man (2011) studied two L27 Taguchi experiments, which were carried out to study the effect of fiber laser welding parameters and their interactions upon the weld bead aspect ratio of nickel–titanium thin foil. The optimum parameters to produce full penetrated weld with the largest aspect ratio and desirable microstructure were successfully obtained by the Taguchi experimental design. The corrosion property of the optimized NiTi weld in Hank's solution at 37.5 °C was studied and compared with the as-received NiTi. To improve the corrosion properties of the weld, the effect of post-weld-heat-treatments ranging from 573 to 1173 K was investigated. Saatchi et al. (2011) studied a design of experiment (DOE) technique, The Taguchi method, has been used to optimize the pulsed current gas tungsten arc welding (PCGTAW) parameters for the corrosion resistance of super duplex stainless steel (UNS S32760) welds. A $L_9(3^4)$ orthogonal array (OA) of Taguchi design which involves nine experiments for four parameters (pulse current, background current, % on time, pulse frequency) with three levels was used. Corrosion resistance in 3.5%NaCl solution was evaluated by anodic polarization tests at room temperature. Analysis of variance (ANOVA) is performed on the measured data and S/N (signal to noise) ratios. The higher is better response category was selected to obtain optimum conditions. The optimum conditions providing the highest pitting potential were estimated. The optimum conditions were found as the second level of pulse current (120 A), second level of background current (60 A), third level of % on time (80) and third level of pulse frequency (5 Hz).

Koilraj et al. (2012) studied the joining of dissimilar Al-Cu alloy AA2219-T87 and Al-Mg alloy AA5083-H321 plates using friction stir welding (FSW) technique and the process parameters were optimized using Taguchi L_{16} orthogonal design of experiments. The rotational speed, transverse speed, tool geometry and ratio between tool shoulder diameter and pin diameter were the parameters taken into consideration. The optimum process parameters were determined with reference to tensile strength of the joint. The predicted optimal value of tensile strength was confirmed by conducting the confirmation run using optimum parameters. This study shows that defect free, high efficiency welded joints can be produced using a wide range of process parameters and recommends parameters for producing best joint tensile properties. Analysis of variance showed that the ratio between tool shoulder diameter and pin diameter is the most dominant factor in deciding the joint soundness while pin geometry and welding speed also played significant roles. Paventhan et al. (2012) described friction welding as a solid state joining process used extensively currently owing to its advantages such as low heat input, high production efficiency, ease of manufacture, and environment friendliness. Materials difficult to be welded by fusion welding processes can be successfully welded by friction welding. An attempt was made to develop an empirical relationship to predict the tensile strength of friction welded AISI 1040 grade medium carbon steel and AISI 304 austenitic stainless steel, incorporating the process parameters such as friction pressure, forging pressure, friction time and forging time, which have great influence on strength of the joints. Response surface methodology was applied to optimize the friction welding process parameters to attain maximum tensile strength of the joint. The maximum tensile strength of 543 MPa could be obtained for the joints fabricated under the welding conditions of friction pressure of 90 MPa, forging pressure of 90 MPa, friction time of 6 s and forging time of 6 s.

3.0 Introduction of industry

This industry was established in 1985 and its commercial production started in 1991, with a vision to innovate – to continually reinvent the wheel into the driving force behind comfortable motion. The plant is situated in northern part of India with a capacity of 5 lakhs wheel rims per month. The company has technical collaboration with one company of Japan. This company is ISO-9000, QS-9000, TS-16949 9000 and ISO 14001 certified company.

3.1 Products manufactured by the company

The main components manufactured by this firm are the wheel rims of automobiles. The range of diameter of wheel rims ranges from 10 inches to 30 inches and width may vary from 2.25"– 13" (inches). The wheel rim of 10" is mainly being used in scooters, three wheelers etc. The wheel rims of diameter range of 13"-16" are mainly used in cars. The wheels of larger diameters are mainly used for tractors, harvesting combines & HCVs etc.

3.2 Customers of the company

1. Maruti Suzuki, India 2. Tata Motors 3. Honda Siel Cars India 4. Mahindra & Mahindra 5. General Motors India 6. Punjab Tractors Ltd. 7. New Holland Tractors 8. Escort Ltd. 9. Eicher Tractors

3.3 Manufacturing Process

A brief manufacturing process is shown with the help of flow diagram, as shown in Fig. 1.

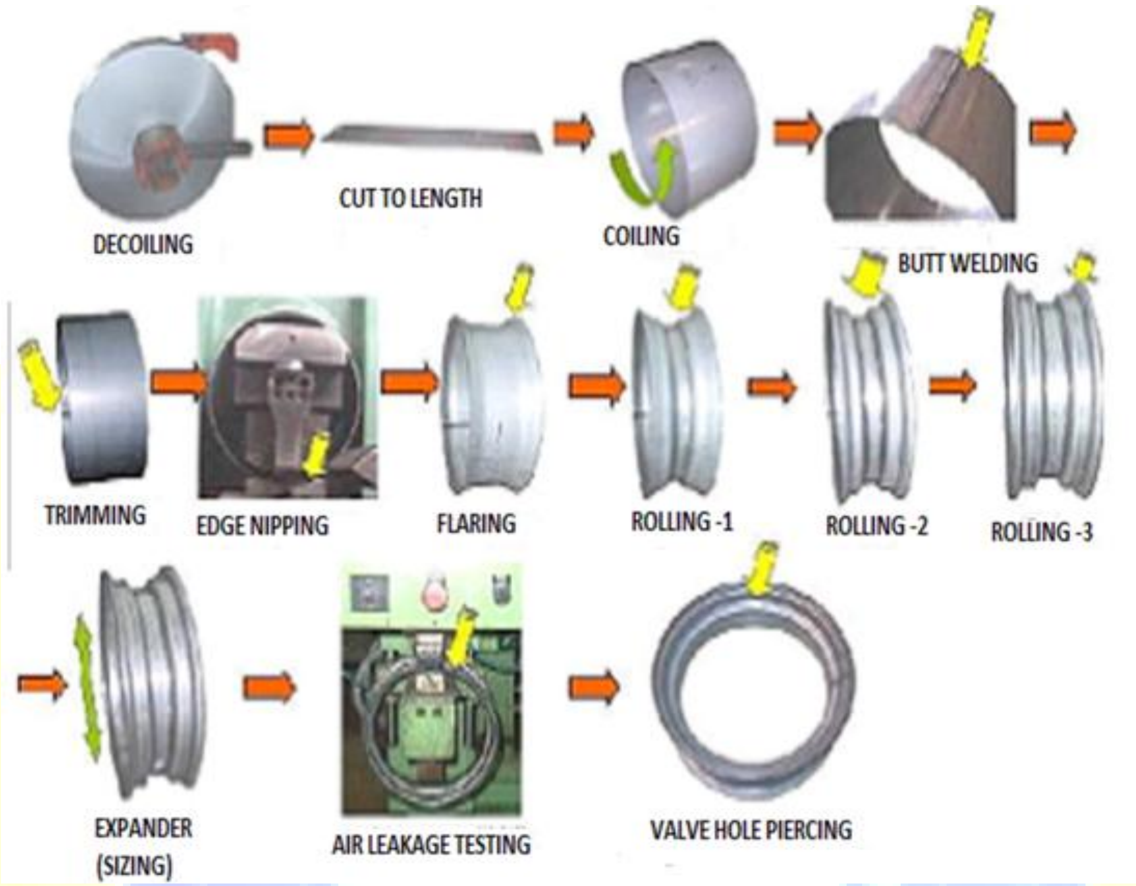

Fig.

Fig. 1 Manufacturing process of wheel rims

3.4 Output and rejection details

The average percentage of rejection of defectives along with their causes in assembly line of the wheel rim industry for the year 2011-12 for all the four quarters is shown in Table 1.

Table 1 Percentage of defects and their causes for all the quarters

S No.	Name of defects	Average Percentage of defectives	Causes
1	Weld crack expansion	33.48	Material composition may not be correct. Burrs remain during cutting of length operation Spiral Problem: In this faces which are to be joined during welding are not properly aligned to each other so welding doesn't properly take place. Faces remain

			unaligned to each other. Fusion problem due to improper current. Clamping Force – It is the force with which both the faces to be joined are held together. Cylinder pressure & leakage in cylinder account for it. Other welding parameters like voltage and upsetting pressure etc. may affect
2	Trim line	16.445	Improper coiling. Spiral problem- Faces are not properly aligned Flattening may not be properly done. Wear out of trimmer tool. Electrode height might not be adjusted. Improper setting of trimmer angle. Improper gap between tool & slag to be removed.
3	Bad fusion	8.9875	Improper material composition. Burrs on faces, to be welded. Spiral Problem: misalignment of faces to be welded is not aligned to each other. Improper fusion due to insufficient supply of current. Improper clamping pressure. Improper voltage.
4	Dimensioning problem	6.6775	Improper setting of side spacer guides
5	Bad rolling	5.46	Improper setting of loader
6	Bad coiling	4.5125	Incoming material not properly checked
7	Material crack expansion	3.825	Grain size of not proper grade
8	Material scratch	3.4475	Improper setting of loader, Improper setting of side spacer guides
9	Stamp problem due to CTL	3.2075	Stamp offset due to less hydraulic pressure.
10	Wrong expansion	2.9	Improper expansion force
11	Stamp opposite on ref-1	2.5225	Unskilled labor.
12	Material pitting	2.1725	Slag not properly removed before upsetting.
13	Bad flaring	2.065	Due to unskilled labor as manual machines are used.
14	Tilted welding on B/W	1.4975	Clamping pressure not proper.

15	Air leakage machine	0.8875	Improper butt welding of joint
16	Joint pitting	0.735	Due to improper cleaning of electrode.
17	Over bead	0.47	Improper welding speed
18	Undercut	0.3275	Improper settings of depth of cutting tool.
19	Scuffing problem	0.2675	Excessive usage of die and Coolant not properly cleaned.
20	Bead seat diameter more	0.059	Due to increase in outer diameter after flaring.
21	Vent hole opposite mark	0.0575	Due to improper indexing in vent hole die

Table 1 shows the percentage rejection of products for all the quarters (year 2011-12) manufactured in one of the assembly line. Study has been performed on the assembly line to reduce the rejection of products by applying Taguchi and ANOVA methods. The various types of defects are responsible for rejection of product but bad fusion defect is one of the main defects that need anylysis. So Taguchi methodology is applied for analyzing the bad fusion defect, which has been further studied and presented in this paper.

3.5 Bad fusion defect

Bad fusion defect occurs due to poor welding of incoming material after "cut to length operation". The incoming material is joined together by electric arc butt welding method. "Cut to length" material is made into coiled shape and joined by butt welding process. Coiled material is held by four electrodes with the help of clamping pressure. Out of four electrodes, two electrodes are used to hold one side of material and other two for second side of material. Two electrodes on left side are fixed and others two on right side are movable. Movable electrodes are used to align both the faces of coiled material.

3.5.1 Factors responsible for bad fusion defect

- Improper material composition.
- Burrs on faces to be welded.
- Spiral problem- misalignments of faces to be welded.
- Improper fusion due to insufficient supply of current.
- Improper clamping pressure.
- Improper voltage.

3.5.2 Application of Taguchi approach for bad fusion defect

The Taguchi approach is implemented in the above industry to find the optimal solution regarding causes for rejection due to weld crack expansion defect. Table 2 shows the important process parameters and their levels.

Table 2 Process designations and process parameters

Process designation	Process parameters	level 1	level 2
A	Current (ampere)	400	500
B	Clamping pressure (bar)	70	90
C	Voltage (volts)	16000	18000

3.5.3 Selection of Orthogonal Array (OA)

Once the parameters are assigned to a particular column of the selected orthogonal array, the factors at different levels are assigned for each trial. An orthogonal array is a type of experiment where the columns for the independent variables are “orthogonal” to one another. Ensure that the degree of freedom of orthogonal array is greater than degree of freedom of factors and interactions. For this case study, the Orthogonal Array of $(OA)_8\ (2)^3$ has been selected.

Where,

8 = number of trials are used.

(2) = number of levels of each factor and $(\ )^3$ = number of factors

3.5.4 Orthogonal array – $OA_8\ (2)^3$ for bad fusion defect

Table 3 shows Taguchi’s recommended orthogonal array design for our experimental run. The first column shows trial number, second column shows factor A i.e. current for welding in ampere, third column shows factor B i.e. clamping pressure in bar and fourth column shows factor C i.e. voltage in volts.

Table 3 Taguchi’s recommended orthogonal array design

TRIAL NUMBER	A	B	C
	CURRENT (Ampere)	CLAMPING PRESSURE (Bar)	VOLTAGE (Volts)

1	1	1	1
2	1	1	2
3	1	2	1
4	1	2	2
5	2	1	1
6	2	1	2
7	2	2	1
8	2	2	2

3.5.5 Experimental Array- OA_{16} $(2)^3$ for bad fusion defect

Table 4 shows the experimental orthogonal array design for the experiments of this case study. The first column shows trial number whereas second column shows the values of factor A i.e. current (40 and 500 amperes) for welding. Third column shows factor B i.e. clamping pressure (70 and 90 bar) whereas fourth column shows factor C i.e. voltage (1600 and 1800 volts).

Table 4 Experimental orthogonal array

TRIAL NUMBER	A	B	C
	CURRENT (Ampere)	CLAMPING PRESSURE (Bar)	VOLTAGE (Volts)
1	400	70	16000
2	400	70	18000
3	400	90	16000
4	400	90	18000
5	500	70	16000
6	500	70	18000
7	500	90	16000
8	500	90	18000

3.5.6 Using Signal to Noise ratio (S/N ratio) for the case study

Taguchi's emphasis on minimizing deviation from target led him to develop measures of the process output that incorporate both the location of the output as well as the variation. These measures are called signal to noise ratios.

The signal to noise ratio provides a measure of the impact of noise factors on performance. The larger the S/N, the more robust the product is against noise.

3.5.6.1 Calculation of S/N ratio

Calculation of the S/N ratio depends on the experimental objective:

- Bigger-the-Better

$$\frac{S}{N}_{(Bigger)} = -10 \log\left(\frac{\Sigma\left(\frac{1}{y_i^2}\right)}{n}\right)$$

------------------ **Eqn. (1)**

- Smaller-the-Better

$$\frac{S}{N}_{(Smaller)} = -10 \log\left(\frac{\Sigma y_i^2}{n}\right)$$

------------------ **Eqn. (2)**

Nominal-is-Best -

$$\frac{S}{N}_{(Nominal)} = 10 \log\left(\frac{\bar{Y}^2}{s^2}\right)$$

----------------**Eqn. (3)**

The response table is prepared on the basis of above equations and presented in the following section.

3.5.6.2 RESPONSE TABLE FOR ORTHOGONAL ARRAY- OA_8 $(2)^3$ FOR WELD CRACK EXPANSION DEFECT

Table 5 shows response table and calculated S/N ratios for experimental orthogonal array.

Table 5 Response (R1, R2, R3) and S/N Ratios

TRIAL NUMBER	A	B	C	R1	R2	R3	S/N RATIO
1	1	1	1	7	7	7	-16.9
2	1	1	2	7	8	7	-17.32
3	1	2	1	8	7	7	-17.32
4	1	2	2	6	6	6	-15.56
5	2	1	1	6	6	6	-15.56
6	2	1	2	4	4	5	-11.35

7	2	2	1	6	5	5	-14.57
8	2	2	2	6	7	6	-16.09

S/N ratio (lower is better) = $-10\log_{10} (1/n \sum y^2)$

Where, R1, R2 and R3 are rejected parts from our sample size of 1000.

3.5.7 Sample calculations for S/N ratios

S/N ratio (lower is better) = $-10\log_{10} (1/n \sum y^2)$

For first trial, $-10 \log_{10}\{1/3(7+7+7)^2 = -16.9$

Similarly, the S/N ratios for remaining seven trials are given in S/N ratio column of Table 5.

3.5.8 Analysis of variance (ANOVA)

Sample calculations for various parameters have been done and presented as follows:

Mean Sum of Squares for each factor A (MSS_A) = ratio SS_A / Dof_A

- Correction factor (CF) = (sum total of all observations)^2 / Total number of all observations

  Correction factor (CF) = $\dfrac{(21+22+22+18+18+13+16+19)^2}{24}$

  CF = 925.04

- Total sum of square $SS_{total} = \Sigma\ Yj^2 - CF$

  $(SS_{total}) = (7^2 + 7^2 + 7^2 + 7^2 + 8^2 + 7^2 + 8^2 +7^2 + 7^2 + 6^2 + 6^2 + 6^2 + 6^2 + 6^2 + 6^2 + 4^2 + 4^2 + 5^2 + 6^2 + 5^2 + 5^2 + 6^2 + 7^2 + 6^2) - 925.04$

  $(SS_{total}) = 991 - 925.04$

  $(SS_{total}) = 65.96$

- Total Degree of Freedom=Total number of observations – 1

  Total Degree of freedom= 24-1 = 23

- SS_a (Sum of squares for factor A) = $(A_1)^2 +\ldots\ldots\ldots+ (A_k)^2 / m - CF$

  Where, m- number of observations for each level.

- Sum of square of Factor A (SS_a)=

  $$\frac{(7+7+7+7+8+7+8+7+7+6+6+6)^2 + (6+6+6+4+4+5+6+5+5+7+6+6)^2}{12} - 925.04$$

$$(SS_a) = \frac{(83)^2 + (66)^2}{12} - 925.04$$

$$(SS_a) = \frac{6889 + 4356}{12} - 925.04$$

$SS_a = 937.08 - 925.04$

$\mathbf{SS_a = 12.04}$

- Sum of square for factor B (SS_b)=

$$\frac{(7+7+7+7+8+7+6+6+6+4+4+5)^2 + (8+7+7+6+6+6+6+5+5+6+7+6)^2}{12} - 925.04$$

$$(SS_b) = \frac{(74)^2 + (75)^2}{12} - 925.04$$

$$SS_b = \frac{5476 + 5625}{12} - 925.04$$

$SS_b = 925.08 - 925.04$

$\mathbf{SS_b = 0.04}$

- Sum of square for factor C (SS_c)=

$$\frac{(7+7+7+8+7+7+6+6+6+6+5+5)^2 + (7+8+7+6+6+6+4+4+5+6+7+6)^2}{12} - 925.04$$

$$(SS_c) = \frac{(77)^2 + (72)^2}{12} - 925.04$$

$SS_c = 926.08 - 925.04$

$\mathbf{SS_c = 1.04}$

Residual sum of square by subtraction $SS_e = SS_{total} - SS_a - SS_b - SS_c$

$SS_e = 65.96 - 12.04 - 0.04 - 1.04$

$SS_e = 52.84$

- Residual degree of freedom= total degree of freedom – (sum of degree of freedom of each factor) = 23 – (1+1+1) = 20

Table 6 shows ANOVA table for bad fusion defect.

Table 5.6 ANOVA for bad fusion defect

SOURCE	Degree of Freedom	Sum of Square	Mean Sum of Square	F- ratio	Significance
A	1	12.04	12.04	4.55	**Significant at 95%**
B	1	0.04	0.04	0.015	Insignificant
C	1	1.04	1.04	0.39	Insignificant
RESIDUAL	20	52.84	2.642		
TOTAL	23	65.96			

3.5.8.1 ANOVA graph for bad fusion using Minitab software

ANOVA graphs for bad fusion shows the variation in number of defects for various changes in factor's values. For factor A i.e. Current the number of rejected pieces due to it keeps on decreasing with increase in the value of current from 400 amperes to 500 amperes. For factor B i.e. clamping pressure, the number of rejected pieces keeps on increasing for increase in the clamping pressure from 70 bar to 90 bar. For factor C i.e. voltage, the number of rejected pieces keep on decreasing on increasing the voltage from 16000 volts to 18000 volts. Figure 2 shows ANOVA graph for bad fusion.

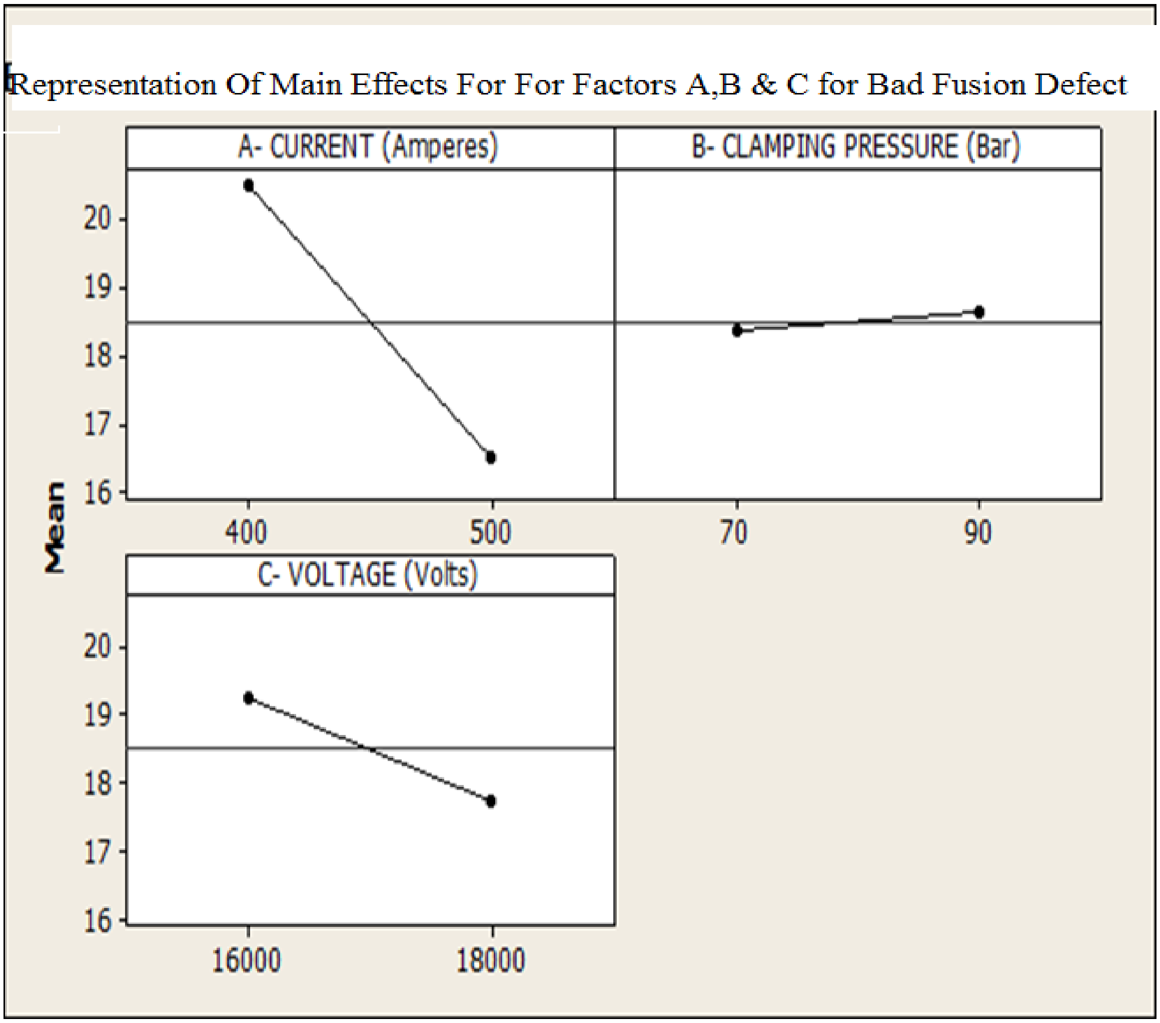

Figure 2 ANOVA graph for bad fusion of Minitab software

4.0 Conclusions

The outcome of this work is the optimized process parameters of the manufacturing process of wheel. It is concluded that for bad fusion defect, the most significant factor is the current (factor A) out of three factors.

Taguchi method is statistical method developed by G. Taguchi to improve the quality of manufactured goods. It is found that the application of Taguchi's experimental design to the manufacturing of wheel rims improves the productivity by identifying and rectifying the causes of defects. Taguchi's experimental design yields optimized control factors, resulting in superior product quality and stability. From the analysis, it is concluded that the Taguchi method of parameter design at the lowest possible cost will be useful to identify the optimum levels of signal factors, due to which the noise factors effect on the response parameters is less.

Taguchi method cannot judge and determine the effect of individual parameters on entire process while percentage contribution of individual parameters can be determined using (ANOVA) technique.

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