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Analysis and Optimization of Process Parameters of Resistance Spot Welding Process Using Response Surface Method-A Review

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Abstract: ***Resistance Spot welding is low cost and adequate which has made it highly popular in the making of sheet joints. Various types of resistance welding are developed for producing continuous and pressure tight joints on overlapped materials. Controlling the welding parameters plays an important role in the quality of the weld. This paper reviews on various effects of process parameters on response variables. Input parameters such as welding current, weld time, electrode force and electrode geometry effects on the response variables such as tensile strength, hardness, nugget size. In any automobile, there are 3000-6000 spot welds which demonstrate the level significance of the resistance spot welding. Controlling the welding parameters assumes an imperative part on the nature of the weld.Quality and strength of the welds and therefore body mainly are defined by quality of the weld nuggets. Resistance Spot Welding (RSW) is widely used for its low cost, high speed; simple mechanism and applicability for automation. There are various process parameters (weld current, weld time, pressure) which affect the weld nugget and its strength. So it is necessary to optimize the process parameters of resistance spot welding process. Therefore it is very important to understand the behaviour of spot welds and their failure characteristics.***

Keywords: ***Resistance Spot Welding (RSW), Response Surface Method (RSM), Tensile Strength, Nugget Diameter.***

I. INTRODUCTION

Resistance spot welding method has high efficiency in terms of production method. This is importance to the industries, which can fulfil the needs of automation lines and mass production in industries. Because of the RSW method is flexible, their process is easy to control and not mention their equipment is simple, it efficiently fits for small batch production RSW is process, which generate heat through the resistance and to the flow of the electric current in parts being welded. By increasing the contact resistance, the RSW can work properly. The RSW equipment is included with pairs of water-cooled electrodes. This electrodes usually made from copper alloyed, because to increase erosion resistance. This electrode also helps in the process by allow current to the joint and apply pressure to the work piece. This process has since then been used as a joining process in the manufacturing industries, particularly in the automobile and aircraft industry Spot welding is a joining process in which coalescence of sheet metals is produced between the surfaces of two or more metal parts by the application of heat and pressure in a localized area.

A. Introduction to Process

In electric resistance spot welding the overlapping work is positioned between the water-cooled electrodes, and then the heat is obtained by passing a large electrical current for a short period of time. There are three stages in making spot weld first the electrodes are brought together against the metal and pressure applied before the current is turned on. Next the current is turned on momentarily. This is followed by the third, or hold time in which the current is turned off but the pressure continued. The hold time forges the metal while it is cooling there are various factors involves resistance spot welding process which are responsible for the quality of weld. Depending on the thickness and type of the metal, welding conditions such as weld current, weld time, electrode type and electrode force should be adjusted. Generally, a weld cycle can be divided into a number of stages in figure 1

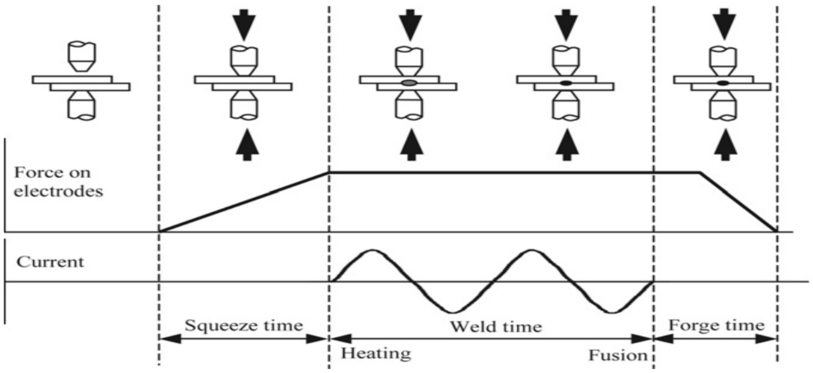

Figure1: Welding Cycle of RSW process

The major advantages of the resistance welding processes over any other welding process is the feature that heat necessary for weld formation is generated at the exact location where the joints needs to appear. The possibility to highly reduce the time to complete a weld resulting in cycle times being competitive over other welding process. The another advantage is the absence of a molten weld pool penetrating from one side through a work piece, resulting in less aesthetical damage to the work piece surfaces.

B. RSW Defects

Most common problem that has faced the manufacturer is the control of the process input parameters to obtain a good welded joint with the required bead geometry and weld quality with minimal detrimental residual stresses and distortion. To do so, requires a time-consuming trial and error development effort, with weld input parameters chosen by the skill of the engineer or machine operator. Then welds are examined to determine whether they meet the specification or not. Finally the weld parameters can be chosen to produce a welded joint that closely meets the joint requirements. The qualities of the spot welded joints are defined by the mechanical properties and size of the heat affected zone. Some common RSW defects are as given below:

1) Improper nugget diameter
2) Interfacial separation
3) Expulsion
4) Inadequate penetration
5) Excessive penetration
6) Poor weld shape
7) Sheet metal distortion
8) Cracks
9) Inclusions
10) Porosity
11) Burning
12) Excessive indentation
13) Brittle weld

C. Evaluation criteria of resistance spot welding

To determine weld quality a number of parameters can be used as indicators. The following geometrical features are most commonly examined.

1) Nugget/button size
2) Nugget penetration
3) Electrode indentation
4) Cracks (surface and internal)
5) Porosity / voids
6) Surface appearance
7) Location accuracy

Many of the parameters are illustrated in the cross-section of Figure 2

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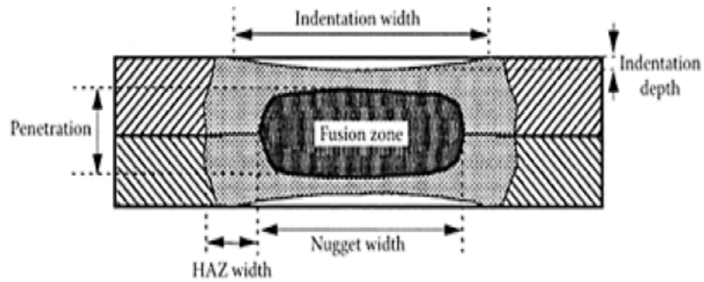

Figure: 2 Weld attributes

D. Flow Chart of Work and Methodology

Methodology employed for the successful conduction of experiments is explained by the flow diagram as

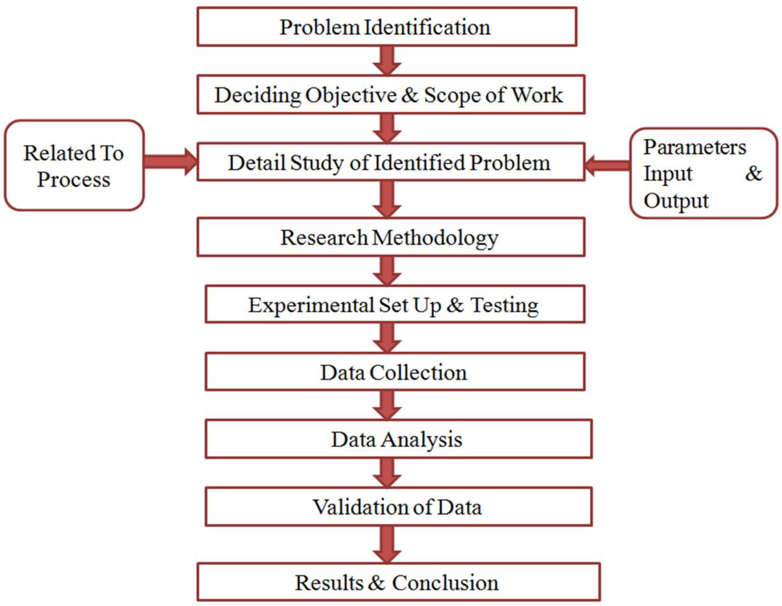

Figure 3**:** Flow Chart of Work

II. LITERATURE REVIEW

The present paper review research work related to optimization of process parameter of Resistance Spot Welding Machine. The review presented in this section is on different techniques proposed and investigated by researchers resulting in the improvement in Nugget diameter and Weld Strength. Scrutiny of the published research work emphasized the need for such a review reporting all the available literature and suggesting the future direction for research. The present survey explores different methodologies and processes regarding the enhancement of responses like Nugget diameter and Tensile Strength. The Survey is given as:

Nizamettin Kahraman [1] has carried out outcome of experimental investigations to assess the performance of commercially pure (CP) titanium sheets (ASTM Grade 2) were welded by resistance spot welding at different welding parameters and under different welding environments. The results showed that increasing current time and electrode force increased the tensile shearing strength and the joints obtained under the argon atmosphere gave better tensile-shearing strength. Hardness measurement results indicated that welding nugget gave the highest hardness and the heat affected zone (HAZ) and the base metal followed this. The argon gas used during the welding process was seen to have no influence on the hardness values. Micro structural examination showed that deformation during the welding process was in the form of twinning rather than shearing in the welding zone. It was also observed that high pressure and welding time increased the twinning.

S. Aslanlar [2] has experimentally study effect of nucleus size on mechanical properties in electrical resistance spot welding of sheets used in automotive industry. When the high tensile-shear and tensile-peel strengths are desired 7 and 8.5 kA welding currents for 15 cycle periods are advised. The 20% sheet thickness limit is exceeded in this condition. In these values, deep electrode indentations, excessive deformations, colour changes in welding zone and over-melting due to excessive heat input may be occurred.

When the high surface quality prior to strength,5 kA welding current for 15 cycles welding time, 4.5kA welding current for 20 cycle welding time and 6 kA welding current for 10 cycle welding time are enough. The depth of electrode indentation into material is 6%, 10% and 14%, respectively. It is obvious that these values are below the acceptable limit 20%.

M. Vural et.al. [3], have aimed to analyze the Effect of welding nugget diameter on the fatigue strength of the resistance spot welded joints of different steel sheets. This paper presents an experimental study on the fatigue strength of resistance spot welded galvanized steel sheets and austenitic stainless steel (AISI 304) sheets. Material combination and nugget diameter were selected as experimental parameters. The high cycle fatigue tests were performed and *S–N* curves were obtained for each specimen. The results show that galvanized steel sheet combination has the highest fatigue limit. The sheet combination which has the minimum fatigue limit is galvanized–AISI 304 sheet combination. For austenitic stainless steel–galvanized steel sheet joint, the measurements of the nugget diameter and crack length were performed after fatigue tests. Crack growth rate of the spot welded galvanized–AISI 304 joining type is slower than that of base metals.

L. Han et.al. [4], concluded experimental Correlation Study of Mechanical Strength of Resistance Spot Welding of AA5754 Aluminium Alloy. In this paper AA5754 aluminium alloy was resistance spot welded (RSW) to produce 27 different joint stack-ups with differing process parameters and corresponding weld quality. Quasi-static joint strength was evaluated for three test geometries; lap-shear, coach-peel and cross-tension. The results derived from over 1000 samples demonstrate various fundamental relationships. For lap-shear strength, a strong relationship with weld nugget diameter was observed; whilst discrete strength levels were found for coach-peel test geometry, depending on the governing metal thickness of the parent sheet for the various stack-ups. For cross-tension strength; there is a relationship with nugget diameter; but data are sensitive to nugget periphery defects. These fundamental relationships provide a set of generalized design guidelines for RSW of aluminium that will have significant relevance to manufacturing communities. For cross-tension test geometry, a relationship between plug diameter and breaking load is suggested as data is distributed linearly in discrete bands according to the GMT. The load carrying capacity of a spot weld in cross-tension is at least twice that for an equivalent spot weld tested in coach-peel geometry due to the load being distributed around the entire periphery of the weld.

S.M. Hamidinejad et.al. [5], carried out the modeling and process analysis of resistance spot welding on galvanized steel sheets used in car body manufacturing. the resistance spot welding (RSW) process of the galvanized interstitial free (IF) steel sheets and galvanized bake hardenable (BH) steel sheets, used in the manufacturing of car bodies, has been modeled and optimized. A back propagation neural network model was developed to analyze RSW process and the interaction effects of the parameters. In the second phase of this research, Genetic Algorithm with the fitness function based on an ANN model was employed as an optimization procedure for determining a set of process parameters; as a result, the maximum joint strength was obtained. Optimization results showed high compatibility with the actual experimental data. The regression analysis reveals that there is a non-linear relationship between the welding parameters and the tensile–shear strength of the RSW joints. The effects of welding parameters and their interactions on the tensile–shear strength were analyzed on the basis of the ANN model. This can provide a beneficial reference for the RSW process of galvanized interstitial free (IF) steel sheets and galvanized bake hardenable (BH) steel sheets. The combined ANN / GA optimization procedure proposed in this paper provides reasonable results for the optimization of the RSW process. The optimized results, obtained by GA, were successfully verified against the actual experimental data.

Dawei Zhao et.al [6] demonstrated Process analysis and optimization for failure energy of spot welded titanium alloy. Seventeen tests were designed according to the three-level three-factor Box–Behnken experimental design and the mathematical model correlating the process parameters and the failure energy was established on the basis of response surface methodology (RSM) technique. Sensitivity analysis was also carried out to explore the impact of each process parameter on the quality of welding joint. The optimal combination of process parameters for maximum failure energy of the welded joint was obtained using the model based on artificial fish swarm algorithm (AFSA). Though all the three input variables affected the failure energy, ANOVA indicates that welding current contributed more on the failure energy, followed by welding time and electrode force. The optimum process parameters maximizing the failure energy of the welded joints developed from the mathematical model using AFSA were respectively welding time of 9.54 ms, welding current of 2.4 kA, and electrode force of 127 N.

Norasiah Muhammad et al. [7] aimed to Optimize and modelled spot welding parameters with simultaneous multiple response consideration using multi-objective Taguchi method and RSM. In this paper an alternative method to optimize process parameters of resistance spot welding (RSW) towards weld zone development. The optimization approach attempts to consider simultaneously the multiple quality characteristics, namely weld nugget and heat affected zone (HAZ), using multi-objective Taguchi method (MTM). The experimental study was conducted for plate thickness of 1.5 mm under different welding current, weld time and hold time. The optimum welding parameters were investigated using the Taguchi method with L9 orthogonal array. The optimum value was analyzed by means of MTM, which involved the calculation of total normalized quality loss (TNQL) and multi signal to noise ratio (MSNR). A significant level of the welding parameters was further obtained by using analysis of variance (ANOVA). Furthermore, the first order model for predicting the weld zone development is derived by using response surface methodology (RSM). The contribution of different control factors is welding current (73.91%), weld time (16.72%) and hold time (7.14%).The highly effective parameter for the development of radius weld nugget and width of HAZ is the welding current.

Haiqiang Long et al. [8] aimed to investigate the effect of holding time on microstructure, hardness and mechanical properties of unequal thickness weld joints between low carbon steel and advanced high strength steel. The microstructures in the regions of weld nugget, heat affect zone and base metal are obviously different. The increase of holding time reduces the welding efficiency, thus, a suggestion based on the test result is proposed that the holding time should be less than 15 cycles to ensure the manufacturing efficiency. A nonlinear finite element analysis is applied to simulate the tensile test procedure. The increase of holding time increases the max shear resistance force of weld nugget by means of enhancing the hardness of fusion zone. The peak load of the weld joint increases corresponding to the increasing of holding time before the failure mode turns from IF to PF. If the failure turns to the type of button pull-out, the increasing of holding time does not notably affect the peak load of the weld joint. Meanwhile, the increasing of holding time reduces the productive efficiency. A suggestion based the hardness and failure test is proposed that the holding time should be less than 15 cycles to ensure the manufacturing efficiency in thin sheets metal welding process.

Min Jou [9] performed real time monitoring weld quality of resistance spot welding for the fabrication of sheet metal assemblies. He concluded that RSW suffers from a major problem of inconsistent quality from weld to weld. This problem results from both the Complexity of the basic process as well as from numerous sources of variability, noise, and errors. The approach of this research is to create a relationship between a key process input variable and the key process output of a quality weld. The input parameter chosen is the percentage heat input, as this directly affects the size and strength of the resulting weld. The output chosen is electrode displacement, as this has been shown to accurately reflect the formation and growth of a weld nugget. A series of experiments will be conducted to explore how changes of the percentage heat input affect the electrode displacement curve for various sheet steels used in the automotive industry. These experiments explored the phenomenon of how changes of percentage heat input affect the electrode displacement curve. These provide important information for process representation and the development of a control method by compensation for the process variations and errors arising from these sources.

R.S Florea et al. [10] explored welding parameters influence on fatigue life and microstructure in resistance spot welding of 6061-T6 aluminum alloy. The fatigue behaviour of resistance spot welding (RSW) in aluminum 6061-T6 alloy (AlMg1SiCu per International Standard Office nomenclature) was experimentally investigated Load control cyclic tests were then conducted on single weld lap-shear joint coupons to study the microstructure and fatigue life properties. From successive iterations and ‘‘witness samples’’ collected, the optimum current, force and welding time were determined. Process sensitivity was studied and summarized. The MIL-W-6858D Military Specification was met or exceeded for ‘‘nominal’’ and ‘‘high’’ welding conditions. The welding current had a large influence on welding nugget dimensions and lap joint mechanical behaviour. On ‘‘low’’ welding condition the fatigue life was decreased by an order of magnitude, which is a dramatic change in mechanical properties under cycling loading. The number of cycles to failure ranged from approximate 6000 to 2,000,000 cycles.

A.G.Thakur, V.M.Nandedkar [11] presented the use of Taguchi method for Resistance Spot Welding of Galvanized Steel. The experimental studies were conducted under varying welding current, welding time, electrode diameter and electrode force. Based on the ANOVA method, the highly effective parameters on tensile shear strength were found as welding current and welding time, whereas electrode force and electrode diameter were less effective factors. The results showed that welding current was about two times more important than the second factor weld time for controlling the tensile shear strength.

D.S.Sahota et.al [12] aimed to study the effect of parameters on resistance spot weld of ASS316 material. It is clear from the results that parameters significantly affect both the mean and the variation in the percentage improvement in Hardness values of the ASS316 material. An increase in weld current, weld time and electrode force results in an increase in weld nugget diameter and width. An increase in weld current, weld time and electrode force results in an increase in electrode indentation.

J.B. Shamsul and M.M. Hisyam [13] concluded experimental study of austenitic stainless steel type 304 was welded by resistance spot welding. They used Austenitic SS304 of 3mm thickness. The experimental results to shows, that the changes of the current, the nugget diameter were changed. So it is proven that the weld nugget increases with the increasing of welding current. The results show that increasing welding current increased the nugget size. The nugget size does not influence the hardness distribution. In addition, increasing welding current does not increase the hardness distribution.

Darwish et al. [14] created a mathematical model to study the influence of spot welding parameters (welding current, welding time, electrode force and sheet thickness) on the strength of spot welded Stainless steel sheets with commercial purity. Experiments were planned on the basis of Response Surface Methodology (RSM) technique. The mathematical models (failure load and nugget area) co-relating process parameters and their interactions with the response parameters have been established. These models have been used in selecting the optimum process parameters for obtaining the desired spot welding quality at the least possible consumed power.

M. Hamedi et al. [15] aimed to numerical study of nugget formation in resistance spot welding. They concluded that as the welding process continues temperature of sheets interface rises quickly until this area melts and nugget forms. After the formation of nugget, rate of temperature rise is reduces. At the end of welding time, as current switches off, the weldment starts to cool dawn. And at low electrode forces and high welding currents, the formed fusion zone is large.

N.S.Payaghan et al. [16] performed optimization of machining parameters in EDM process of Cu-W metal matrix composite using response surface methodology. In this investigation, mathematical model of Ra was evaluated to correlate dominant machining parameters including the discharge current, voltage, and pulse on time and duty factor to minimize Ra. The optimum value of Ra=3.62µm is observed at current of 42A, voltage 100V, and pulse on time 1000µs and at duty factor of 6 within experimental domain. The two main significant factors affecting the value of the Ra are the discharge current and pulse on time, whereas voltage has least statistical significance on values of Ra during experimentation. Experimental values of Ra can satisfactorily be predicted from experimental diagrams of response surface and contour plots. In the analysis, it was observed that predicted and experimental results were in good agreement and the coefficient of determination was found to be 0.952 implies adequacy of derived model. Also average prediction error was calculated as 1.57% reflecting that proposed model can precisely predict responses.

Majid Pouranvari [17] experimentally studied failure mode of AISI304 resistance spot welds is studied under quasi static tensile-shear test. He concluded that failure location for AISI 304 RSW in pullout failure mode is at HAZ, adjacent to the weld nugget Low fusion zone hardness to failure location hardness ratio increases the tendency of spot weld failure to occur in the interfacial failure mode during the tensile-shear test. Metallurgical characteristics of welds should be considered to predict and analyze the spot weld failure mode more precisely.

Panchakshari et al. [18] compared the Study of Responses of Resistance Spot Welding Obtained from Genetic Algorithm, Response Surface and D- Optimal Method. Low carbon steel is used as a testing material for this research work. Mathematical model developed by using regression analysis and ANOVA. Weld cycle and welding current are most effective factors for welding to obtain above mentioned values of nugget diameter and strength of weld, both these variables should be at middle values of their range at 12 cycles and 11.2 KA respectively. Hold cycle time is less significant, to obtain optimal result it should always at it mid value of range that is 20 cycle. Squeeze cycle take part in formation of nugget diameter and to maintain strength of weld it should be at its high value of range equal to 30 cycles.

Shashi Dwivedi et al. [19] aimed to Optimize of Resistance Spot Welding Process Parameters on Shear Tensile Strength of SAE 1010 steel sheets Joint using Box-Behnken Design. The welding current, welding cycle and electrode force are the principal variables that are controlled in order to provide the necessary combination of heat and pressure to form the weld. Response surface methodology (Box-Behnken Design) is chosen to design the experiments. In the range of process parameters, the result shows that as welding current increases shear tensile strength decreases, whereas welding time (cycle) and electrode force increase shear tensile strength increase. From the ANOVA table it can be concluded that electrode force is contributing more and it is followed by welding time and welding current. Optimum values of welding current (6 kA), welding time (25 cycle) and electrode force (4.5 KN) during welding of SAE 1010 steel sheets joint to maximize the shear tensile strength (Predicted 8.214 KN) have been find out. There was approximately 6.12 % error was found between experimental and modeled result.

S.P.Tewari et al. [20] carried out welding done separately on three different stages firstly on low carbon steel, secondly on high strength low alloy steel and after that combination of these two. During experiments welding current has been changed but other parameter kept constant. Focused on to find out relation of bearing capacity, hardness and weld nugget with welding current. Outcomes from this research the weld ability of low carbon steel is more than HSLA steel followed by combination of these materials. The hardness of HSLA steel is more than low carbon steel hence electrode force doesn't get transferred properly on the weld zone and causes deeper electrode penetration in metal. The rate of increase in current with nugget diameter is proportionate in low carbon steel but sudden in HSLA steel.

H.A.Shende et al. [20] performed Optimization of Resistance Spot Welding Process Parameters of AISI 304L and AISI 1020 Welded Joints. The main affecting welding parameters such as weld current, weld time, pressure and holding time were determined as the basis for quality evaluation. The welded samples are later undergone the tensile test and metallurgical test to characterize the spot weld growth. Taguchi quality design concepts of L9 orthogonal array has been used to determine Strength to Noise (S/N ratio), Analysis of Variance (ANOVA) and F test value for determining most significant parameters affecting the spot weld performance. Optimization technique revealed that the best combination of parameters for maximum tensile strength and minimum nugget diameter is current 10 kA, pressure 4 bars, weld time 10 cycles and hold time 25 cycles. Welding current is the most significant factor for tensile strength and nugget diameter. Hold time does not have much more effect on tensile strength and nugget diameter.

A. K. Pandey et al. [21] aimed to optimize Resistance Spot Welding Parameters Using Taguchi Method. In this research they have been represents the optimization of various process parameters of resistance spot welding process. The material used is low carbon cold rolled 0.9mm mild steel sheets (AISI 1008/ASTM A366). For the experimental setup and investigation of varying process parameters (welding current, welding pressure, and welding time) to effect of the quality characteristic (tensile strength) using Taguchi Method. An experimental result shows that, S/N ratio to tensile strength indicates the welding current to be the most significant parameter that controls the weld tensile strength where the holding time and pressure are less. The contribution of Welding current, holding time and Pressure towards tensile strength is 61%, 28.7%, and 4% determined by the ANNOVA method.

Chinmoy Mondal et al. [22] performed parametric optimization of Spot welding of 17-4 Ph Stainless Steels using the Analytic Hierarchy Process. attempted optimization of spot welding of 0.6 mm thick 17-4 precipitation hardening stainless steel by using the analytic hierarchy process and obtained good weld nuggets with a current of 2.5 KA, for a welding time of 6 to 7 cycles and also with another current value of 6 to 7 KA with a welding time of 5 cycles keeping load as constant at 4 KN. Nachmni Charde et al. [20] aimed to experimentally Investigating spot weld growth on 304 austenitic stainless steel (2 mm) sheets. On investigation of spot weld growth on 304 austenitic stainless steel (2 mm) sheets, reported that the growth of a spot weld is primarily determined by its parameters such as current, weld time, electrode tip and force. This paper is intended to analyze only the effects of nuggets growth due to the current and weld time increment with constant force and unchanged electrode tips. He reported that the hardness of welded zones is greater than the hardness of the un-welded zone and also the heat affected zones.

Sreenu. S. et al [21] performed Regression Modelling and Process Analysis of Resistance Spot Welded Joints. study the effects of weld current, weld time, electrode force and combination of these on the nugget diameter, heat affected zone and tensile-strength of welding joint in electrical resistance spot welding of AISI 304 Sheets of 1mm thickness are investigated. Squeeze time is kept constant throughout the process at 40 cycles. The effect of weld current, weld time and electrode force on nugget diameter, HAZ and tensile-shear are then researched by regression modelling and by related diagrams. Optimum weld current, weld time and electrode force for various configurations are thus arrived at. An increase in weld current, weld time and electrode force resulted in increase in weld nugget diameter and thus thickness.

Chiragsinh Vaghela [22] aimed to analyze the process Parameters for Resistance Spot Welding on Cold Reduced Low Carbon Steel. He optimizes different parameters (weld current, weld time, cathode power) which influence the weld chunk and its quality. So it is important to upgrade the procedure parameters of resistance spot welding procedure. The setting of welding parameters was resolved utilizing Taguchi test plan technique and L9 orthogonal cluster was picked. The ideal welding parameter for multi-targets was acquired utilizing multi sign to commotion proportion (MSNR). The level of significance of the welding parameters on the ductile shear quality is dictated by utilizing examination of difference (ANOVA). The contribution percentage for Welding current is 76.49% which is very big. The contribution percentage for cycle time is 8.28% which is also very small. From this, it can be concluded that theoretical value is far from the practical value. From above table it is indicated that it was found deviation in practical and theoretical value of Tensile Strength. The p-value of Welding current is below 0.05; So Welding current is the parameter significant for obtaining tensile strength.

Hardik Hindocha [23] experimentally evaluate Heat Flow Parameters of Resistance Spot Welding for Stainless Steel SS304.He investigate on inner and outer sleeve which is used in stove manufacturing industry. Material is taken stainless steel SS304 for experiment having thickness 0.5mm. Experimental investigation based on two defects which is interfacial separation and improper nugget diameter in spot welding. For this investigation welding current and welding cycle time taken as main parameter affecting on defect. Experimental work based on design of experiment (DOE) full factorial design having L9 orthogonal array. With increase current and cycle time nugget diameter is also increase. For good tensile strength it is necessary to heat flow by electrode is slightly greater than heat required for melting nugget. Tensile strength is increase at some level and after its decreasing with respect to current and cycle time in mostly case. For better quality of weld, thermal cycle is more important. By experiment, it is investigated that thermal cycle time is slightly greater than 1sec. So, for reducing interfacial separation, the component is holding stationary for some time. Experimental results of nugget diameter are validated by software and analytical method.

Oscar Andersson [24] experimentally performed process planning of resistance spot welding. The goal of this thesis is to establish new knowledge for updated and improved process planning of RSW in industrial applications. A number of conclusions can be drawn from the studies. Firstly, variations of RSW weld sizes were statistically analyzed. The studies showed that under apparently identical conditions, weld sizes vary by a significant magnitude. The magnitude of variations was also seen to be different between controlled laboratory conditions and production conditions. The standard deviation of laboratory welds and production welds were approximately 0.3 mm and 0.9 mm, respectively. Also, the studies of weld size variations showed the distribution of weld sizes. It was seen that both in laboratory and production conditions, both normal and Weibull distributions could describe the distribution of weld sizes. Further studies analyzed numerical methods of the RSW process by both regression models and FE simulations. The numerical methods were evaluated by comparison to physical welds. Both models showed promising results by physical verification. The standard deviations of the regression models were in the order of 0.5 mm to 0.7 mm and for the regression models and in the order of 0.7 mm for the Simulations. For the FE simulations, material models for several materials were generated. The models included thermal, mechanical and electrical data for elevated temperatures. The models were generated by means of material simulation, material testing and literature studies.

III.CONCLUSIONS

The objective of the review article has been aimed to report the work of various researchers for improving Nugget diameter and Tensile Strength during Resistance Spot Welding and to bridge the gap between the untouched areas. The work presented here is an overview of recent works of Resistance Spot Welding process and future references.

material like stainless steel and aluminium. But the work has been carried out only for limited materials not for other material. The literature above reveals that the lot of efforts was taken in order to rationalize the RSW process. RSW process experimental work has been carried out by researchers for process parameters like welding current, welding time and squeezes time and hold time, Electrode Pressing force, electrode geometry, the choice of electrode material. The resistance welding process is highly dependent on its process parameters viz. welding current, electrode force, weld time, pressure. Response surface Method, Analysis of Variance (ANOVA) and Taguchi method has proved to be very efficient tools for controlling and optimizing the effect of process parameters on response variables such as tensile strength, hardness, nugget diameter. It can also be numerically modeled with the use of Finite Element Analysis (FEA), Artificial Neural Network (ANN) etc Also research has been done for product parameters like penetration, and heat affected zone, sheet thickness, and Overlapping length, strength of weld and distortion stresses. The findings of literature review is Little work has been reported on the modeling and analysis of effects of Welding parameters on the performance characteristic in RSW process of Cold rolled steel grade CR-1, CR-2, CR-3. The literature survey infers that there is a need to study the effects of all process parameters on the weld quality and weld strength in detail. At the some of the research papers concluded that current is the major factor to affect of the weld quality and weld strength by increasing or decreasing others parameters.

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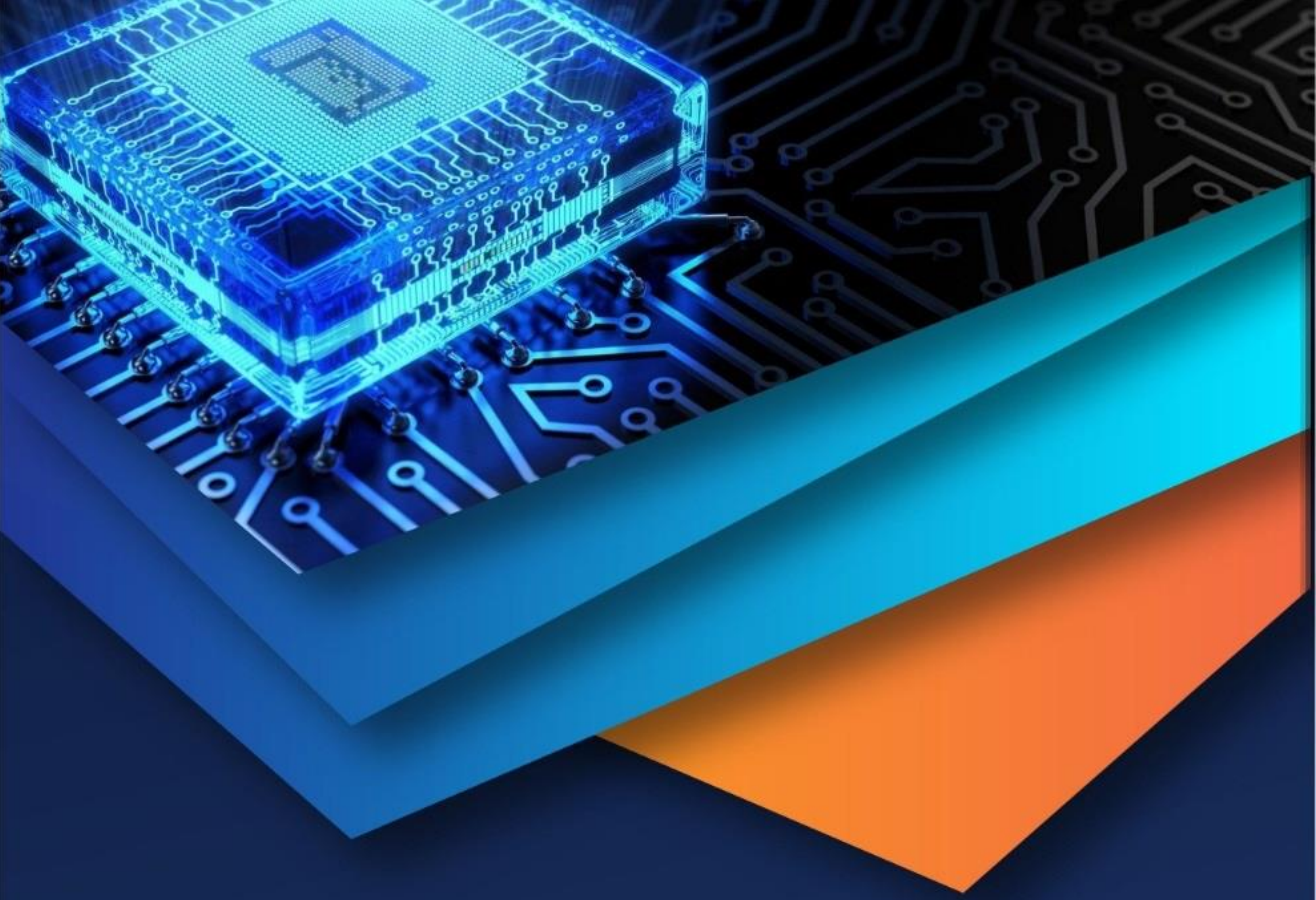

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