Electric Resistance Spot Welding: A State of Art

Pravin Arjun Dhawale
Research Scholar
College of Engineering and Research
Gopalpur, Pandharpur- 413304, India

M. L. Kulkarni
Professor
Rajeshri Shahu School of Engineering & Research
Narhe, Pune- 411041, India

***Abstract*— Resistance spot welding processes are widely used in the vehicle manufacturing and in other appliance industries. It is different from other welding processes, as filler material is not required. It is the most suitable for steel & steel alloy but recent researches made it suitable for aluminium and titanium. Computer numeric spot welding machines are able to give high production rate with low cost and reduced manpower. Mathematical model developed by using Finite element modeling method, regression analysis and ANOVA were used to investigate the effects of various welding process parameters (Electrode pressure, Weld current, Weld time etc.) on weld strength, excellent mechanical properties with minimum distortion. Optimum welding parameters are determined by different optimization techniques.**

Keywords*— *Electrode pressure, Weld current, Weld time, Modeling and Optimization

I. INTRODUCTION

An electric resistance spot welding (ERSW) is a process in which laying surfaces are joined in one or more overlapping spots by the heat generated due to resistance to the flow of electric current through the work pieces that are held together under force between the electrodes. The contacting surfaces in the region of current concentration are heated by a short-time pulse of low-voltage, high-amperage current to form a fused nugget of weld metal in between the plates being joined. When the flow of current ceases, the electrode force is still retained while the weld metal rapidly cools and solidifies. Resistance spot welding (RSW) is a noteworthy sheet metal joining process in numerous businesses, for example, the car, household apparatuses, air art and space create manufactures. It is a proficient joining process broadly utilized for the creation of sheet metal congregations. There are 3000-6000 spot welds in any auto, which demonstrates the level significance of the resistance spot welding. RSW has astounding techno-monetary advantages, for example, ease, high creation rate and flexibility for mechanization which settle on it an appealing decision for auto-body gatherings, truck lodges, rail vehicles and home machines. [1] It is one of the most seasoned of the electric welding forms being used by industry today. Practically speaking, in any case, the procedure can altogether veer off from the ostensible condition, and in this way bargain the nature of the weld.

II. LITERATURE REVIEW

A. Process Parameters in ERSW Process

S. Aslanlaret. al.[1] explored the impacts of welding time on the malleable peel quality and ductile shear quality of resistance spot welding joints of chromate miniaturized scale alloyed steel sheets. Elastic peel quality and malleable shear quality was investigated by utilizing related period charts as a part of request to get ideal weld times.

Doo-Hwan Kim et. al. [2] investigated the effect of welding time and current on the tensile strength and fatigue life on cross-tension type specimens of cold rolled mild steel sheet. Tensile and fatigue tests were conducted on cross-tension type specimens with different sized nuggets produced under various spot welding currents and times. It was observed that, the J-integral parameter can properly predict the fatigue life, including data with different specimen geometries as compared to notch stress and equivalent stress intensity.

A.M.Pereira et.al. [3] concentrated on the impact of the weld parameters on the microstructure and pliable shear quality of resistance spot welds on an aluminium composite 6082-T6. With a specific end goal to decide the impact of welding parameters on the nature of the welds, microstructural examinations and hardness assessments were done. With a specific end goal to get weld quality and disappointment mode, the welded joints were subjected to static tractable shear tests. A huge increment in the disappointment stack in static shear lap tests was seen in welds finished with expanding weld current and time.

M. Pouranvari et.al. [4] explored the impact of welding time, welding current and terminal compel on disappointment modes and mechanical execution of different resistance spot welding amongst DP600 and DQSK low carbon steel under the semi static elastic shear test. Interfacial, pullout and halfway thickness–partial pullout disappointment modes were seen amid the pliable shear trial of disparate double stage and low carbon steel. Move of disappointment mode from interfacial to pullout was seen with expanding welding time, welding present and diminishing terminal drive. Removal and extreme terminal space ought to be maintained a strategic distance from keeping in mind the end goal to get PF disappointment mode which advances prepare parameters.

M. Vuralet. Al. [5] concentrated on the weariness quality of resistance spot welded stirred steel sheets and austenitic stainless steel sheets as a lap joint. Test parameters were chosen as material blend and piece distance across. The high cycle weariness tests were performed and S–N bends were acquired for every example. The outcomes

demonstrate that aroused steel sheet mix has the most noteworthy weariness confine. For these spot welded joints C and m coefficients of Paris–Erdogan condition were likewise acquired.

G. Mukhopadhyay et.al. [6] has been concentrated on the quality of spot-welds of pre-strained ductile shear tests of additional interstitial free and steels. With expanded greatness of pre-strain on base metals, the quality of spot-welds increments. The area of disappointment is regularly at the interface of warmth influenced zone and base metal. For the spot-welds on as-got high quality interstitial free steel, disappointment happens at the base metal. It was watched that with expanding pre-strain the leftover separation thickness around the spot-weld increments. Microstructure and hardness profile along the weldment were broke down to decide the area of disappointment.

B. Modelling of ERSW Process

Lardeur et.al [7] watched that a few decades prior, spot welds were not demonstrated as limited components to make a spot weld association between two sections. One would just give various hubs in the two sections a chance to concur, accordingly shaping the association [6]. This is an exceptionally clear approach, however with a hindrance for the displaying procedure that the two welded parts must be coincided all the while. In addition, the approach neglects to consider the real spot weld measurements, firmness and compel spreading properties, which offers ascend to (huge) forecast blunders.

S. Xu, X. Deng et.al [8] concentrated that the spot welds must be spoken to by FE models also. As it is not possible to demonstrate every spot-welded joint in detail, the same disentangled model ought to be utilized to speak to every spot weld association, in such way that precise forecasts are gotten for the utilitarian execution of intrigue.

M. Palmonella et.al [9] decided Stiffness and NVH expectations can be gotten with a coarse spot weld show, while a much better work ought to be utilized for spot weld exhaustion examination, for which point by point neighbourhood stresses must be assessed [1]. In both cases there's a trade-off between the fancied exactness and the accessible calculation time; for precise framework level weakness life expectations a higher neighbourhood forecast precision is wanted, so the adjust is moved more to nitty gritty spot weld models (and in this way to an expansion in calculation time). From a vehicle improvement point of view, the disentangled spot weld models ought to not just yield exact execution forecasts in a constrained measure of time. It ought to likewise be conceivable to helpfully and consequently incorporate the spot weld models in the vehicle model, to supplant parts and to produce new spot weld associations.

S. Donders et.al. [10] exhibited an approach in view of FE models, which are broadly utilized as a part of the car business to evaluate the vehicle conduct in the low and medium recurrence extend. Exact expectations must be gotten when sensible spot weld associations are incorporated into the vehicle limited component demonstrate. The detail of FE models is an exchange off amongst precision and calculation time. An adjust ought to be looked for with the end goal that meeting is accomplished: the expectation of practical execution traits ought to not fundamentally change when the work is further refined.

H. Zhigang et.al [11] has been produced A 2D axisymmetric Finite Element Method model to examine the transient warm practices of Resistance Spot Welding process. In this model, the temperature subordinate material properties, stage change and convectional limit conditions were considered for the change of the ascertained exactness, yet the assurance of the contact resistance at the surface is decently improved so as to lessen the figuring time through the examination. The created show has been utilized for the warm history of the entire procedure (counting cooling) and temperature disseminations for any position in the weldment.

Xin Yang et. al [12] built up an improved model to mimic the haul out disappointment conduct of spot welds in full vehicle crash reproductions. The disappointment is just considered in the base steel which is described with the Gurson display. The parameters of the Gurson model are advanced from displaying a few diverse test sorts of base steel. The weld locale is spoken to by a solitary strong component, and its properties are improved from demonstrating the mentor peel and lap-shear joints. The disentangled model is approved by displaying the spot-welded coupon tests. It is demonstrated that an adequate time step estimate for full vehicle crash re-enactments can be accomplished with the model.

C. Optimization of ERSW Process

K.Y. Benyounis et.al.[13] have been produced a scientific relationship between the welding procedure input parameters and the yield factors of the weld joint with a specific end goal to decide the welding input parameters that prompt to the craved weld quality by utilization of plan of trial (DoE), transformative calculations and computational system. The advancement techniques secured were proper for demonstrating, control and upgrading the diverse welding process. The study uncovers the abnormal state of enthusiasm for the adjustment of RSM and ANNs to anticipate response(s) and enhance the welding procedure. Joining two improvement procedures, for example, GA and RSM would uncover great outcomes for discovering the ideal welding conditions.

S.M. Darwish et.al.[14] did exploratory examinations on the spot welding of business aluminum sheets. Investigations were completed to concentrate the impact of spot welding parameters (welding current, welding time, cathode drive and sheet thickness) on the quality of spot welded aluminum sheets with business immaculateness. Trials were moved toward the premise of reaction surface system (RSM) strategy. The scientific models (disappointment load and piece zone) associating process

parameters and their cooperation with reaction parameters have been set up. These models have been utilized as a part of selecting the ideal procedure parameters for acquiring the craved spot welding quality at any rate conceivable devoured control.

UgurEsme [15] has displayed an examination on the enhancement and the impact of welding parameters on the pliable shear quality of spot welded SAE 1010 steel sheets. The test studies were directed under fluctuating cathode powers, welding streams, anode measurements, and welding times. The settings of welding parameters were controlled by utilizing the Taguchi test outline strategy. The level of significance of the welding parameters on the tractable shear quality is dictated by utilizing investigation of change (ANOVA). The ideal welding parameter blend was acquired by utilizing the investigation of flag to-commotion (S/N) proportion. The exploratory outcomes affirmed the legitimacy of the utilized Taguchi strategy for upgrading the welding execution and enhancing the welding parameters in the resistance spot welding process.

M. Ouisse et.al [16] displayed a basic leadership system which permits a few parts of the strength issues to be incorporated into the spot weld configuration prepare. An effective advancement strategy in view of vitality contemplations was utilized to take out repetitive spot welds while saving quite far the ostensible auxiliary conduct. This quantitative technique gives basic leadership markers that permit the examiner to guarantee a given level of framework execution at the cost of playing out a quality control of a set number of welds falling off the sequential construction system and additionally fortifying an arrangement of basic welds to enhance the heartiness to exhaustion disappointment. Likewise, this procedure gives a device to control the expert in the following stride to enhancing heartiness while giving an estimation of the cost of the anticipated change.

Q. I. Bhatti et.al. [17] Concentrated the conduct of a spot welded structure under element loads which was unequivocally impacted by the number and areas of the resistance spot welds. A versatile advancement strategy was exhibited which iteratively adds and evacuates spot welds to locate the ideal conveyance and additionally the quantity of spot welds expected to enhance the execution attributes. The auxiliary exhibitions can be undermined by the nearness of deficient or missing spot welds because of assembling deformities or weakness. A straightforward approach was defined to break down the effect of the quantity of blemished or missing spot welds on the framework execution. This approach can give a measure of power as well as serve as a valuable instrument to give knowledge into the most compelling spot welds and in addition for choosing what number of spot welds ought to be assessed.

R.D.S.G. Campilho et.al.[18] were completed a test and a numerical review on half breed spot-welded/reinforced single-lap joints, by examination with the spot-welded and adhesively fortified counterparts, for the assessment of this procedure and the capacity of CZM for configuration purposes. The review started with an impact examination of the welding parameters on the quality of spot-welded joints and on the unmistakable cement corruption by welding-incited warming, which permitted selecting the most reasonable conditions. The Finite Element Method (FEM) and Cohesive Zone Models (CZM) for harm development were likewise tried in Abacus R to assess this system for quality expectation, demonstrating exact estimations for a wide range of joints.

Niranjan Kumar Singh et.al. [19] exhibited an examination on the improvement and impact of welding parameters on the space of spot welded AISI 301L stainless steel. The level of significance of the welding parameters on space is controlled by ANOVA. In light of ANOVA technique, the profoundly viable parameters on space are found as weld cycle, a collaboration between weld current and weld cycle and communication between weld current, weld cycle and hold time though welding current, hold time and cool time were less successful variables. An ideal parameter blend for the ostensible space was gotten utilizing the solid shape plot. The test comes about affirmed the legitimacy of Taguchi technique for upgrading the procedure parameter in resistance spot welding.

A.S.Panchaksharietal. [20] completed the similar investigation of reactions of resistance spot welding process acquired from three philosophies of a Genetic calculation, Design of Experiments and Response surface technique. Low carbon steel is chosen as a material for an example. The numerical model created by utilizing relapse examination and ANOVA. It was watched that weld cycle and welding current were most noteworthy components to acquire high subjective estimations of chunk distance across and quality of the weld. Hold process duration is less noteworthy; press cycle participates in the development of piece distance across and to keep up the quality of the weld.

M. I. Khan et.al.[21] examined resistance spot welding forms which are broadly utilized as a part of high generation operations, particularly in the car and in other machine ventures too. It didn't require filler material which made it more financial in the generation field. It is the most appropriate for steel and steel compound however late looks into made it reasonable for aluminum and other modern metals.

D. Recent development in ERSW Process:

TABLE I
REVIEW OF RECENTLY PUBLISHED WORK OF RESEARCHER IS ILLUSTRATED AS BELOW

Authors Name	Year	Material	Methodology	Paper Work
M. JAFARI VARDANJANI et al (22)	2016	Al2219 sheets	FEA and Experimentation	Shunting impact in RSW is explored utilizing EM and the outcomes are contrasted and investigations on AA2219.
N. Baca et al (23)	2013	Cu47Ti34Zr11Ni8 (Vitreloy 101)	FEA ,Experimentation and Microscope	The outcomes show that Vitreloy 101 can be joined effectively by resistance welding. The most grounded welds were framed by quickly shaping the weld piece took after by cooling at a normal rate extraordinarily in overabundance of the basic cooling rate for this material. The shear quality of lap welds was around 25% lower than the anticipated most extreme and in dangerous peel tests disappointment happened in a district around the weld piece (pullout disappointment). The model demonstrated this area stayed liquid longer and cooled more gradually than the focal point of the weld chunk, prompting to minor measures of crystallization and embrittlement.
M. Spitz et al (24)	2015	hot dip galvanised steel	Experimentation,	Spot welding of greased up sheet brings about a more uniform and diminished alloyed material take-up that stores on the welding anode cap. Accordingly, the low testimony of material on the cathode surface improves the weldability of hot-plunge excited steel sheets.
Qiuyue Fan et al (25)	2016	stainless steel		This work uses the DR to screen the stainless steel single spot welding procedure and studies the impacts on the DR of various conditions that prompt to removal, attempting to acquire the changed run of the DR. This will help welders finely conform the welding parameters to diminish or dispose of ejection harm. The tractable shear quality is utilized as a general measure for the spot welding quality underway, so the impact of removal on the malleable shear quality has been explored.
P. Banerjee et al (26)	2016	DP590 steel sheets mm thick sheets of DualPhase (DP590) steel	FEA and Experimentaion	In this review, chunk measure, score geometry and microstructure are shifted by changing the warmth input, and the impact of piece size and indent geometry (under various warmth input conditions) on high cycle exhaustion execution have been explored.
M sun et al (27)	2016	aluminum to magnesium with Sn-coated steel interlayer	Experimentation	Sn-covered steel has been utilized as an option interlayer for the different joining of AA5052 to AZ31 by resistance spot welding. Endeavours have been made to enhance the mechanical properties by means of improving the welding procedure, for example, downslope time.
Lihu Cui et al (28)	2015	Steel and Aluminium Alloy	Experimentation	In this review, aluminum amalgam A6061 and mellow steel Q235 was welded utilizing resistance spot welding. The impacts of welding parameters on properties of the joint were broke down, and give some major data to enhancing mechanical properties of the joint between aluminum amalgam and mellow steel.
LonglongHoua et al (29)	2015	Titanium and stainless steel.	Experimentation	They have explored the interfacial microstructure and mechanical property of the joint profoundly, and give some major data to enhancing properties of the joint amongst titanium and stainless steel.
S.A. Turnage et al (30),	2016	Aluminum 6061-T6 joint	Experimentation	Audit On Finite Element Analysis utilized as a part of FEA
Euiwhan Kim et al (31)	2015	6061-T6 aluminum	Numerical model Fea and experiment	In this review, we utilize a novel test method to portray and build up a structure-property database of RSW 6061-T6 aluminum lap joints for use in limited component examinations. All the more particularly, the mechanical properties are resolved from semi-static tractable tests alongside semi-static shear punch tests through the weld locales. request to research the affectability of chunk development to changes in every parameter, a numerical model which joins the electrical, mechanical and warm contact was produced and the re-enactment results were investigated quantitatively to build up a principal comprehension of the controlling parameters all the while

M.H. Razmpoosh et al (32)	2016	Fe–31Mn–3Al–3Si TWIP steel	Experimentation and testing	In this review, comparative resistance spot weldability of a Fe–31Mn–3Al–3Si Twinning Induced Plasticity (TWIP) steel was examined. The microstructural development was considered by method for optical microscopy (OM) and filtering electron microscopy (SEM) keeping in mind the end goal to assess the impacts of test conditions on spot welded (RSW) joints. Also, tensile–shear load bearing limit of welded materials and disappointment modes were accurately assessed to decide the mechanical properties and break conduct of welded joints
.R. Arghavani et al (33)	2016	Al-5052 ,st 12,GI sheet	Experimentation and testing	To examine the part of zinc layer in RSW of aluminum to steel through correlation of microstructures and mechanical properties of the resistance spot welds amongst aluminum and low carbon and in addition aroused steels.
Jing Bi et al (34)	2016	5A06 aluminum alloys	FEA and Experimentaion	The properties of shunting in Al RSW are contemplated tentatively and broke down by utilizing the business limited component re-enactment programming ANSYS. Tests and numerical recreations of shunting in two and multi-spot welds were done. A useful and compelling strategy to reduce the shunting in Al is proposed in this work.
Jianbin Chen et al (35)	2016	A5052 aluminum alloy and DP 600 steel	Experimentation and testing	The microstructure of the welded A5052/DP 600 joint was examined by checking electron microscopy (SEM) and electron back-scattered diffraction (EBSD). Interfacial IMC framed in the welded joints were distinguished. Welding parameters were additionally advanced to accomplish greatest quality of joints

III. CONCLUSIONS

There are wide scopes of utilizations of electric resistance spot welding on which diverse creators had done their experimentations. For this procedure rather than routine machines, PC controlled machines are utilized to get control over the parameters (like terminal weight, Weld current, welding time) so as to accomplish better precision, quality with least twisting and dependability of welded structure. The numerical model can be produced with the assistance of Taguchi, Response surface displaying, direct relapse; and the critical parameter related to the assistance of ANOVA. The choice of ideal outcome is gotten by utilizing Taguchi, Genetic Algorithm (GA) and Artificial Neural Network (ANN).

In the wake of checking on the writing the writer arrives at the conclusion that parametric investigation of resistance spot welding as for pliable and shears quality of the weld
and to advance process factors for various spots regarding weld quality.

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