A Review On Mechanical Characterization and Optimization of Parameters For Spot Welded Multigrade AHSS Joints

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Abstract

Research and development activities in improved high-strength steels have been motivated by expanding sectors including the automobile industry. As customers have sought for goods that better satisfy their demands in terms of fuel economy, vehicle performance, and vehicle safety, competition between the steel and low-density metal industries has heated up in recent decades. Development of ultra-high strength steel to address these issues has quickened in recent years . Sheet metal joints are often welded using resistance spot welding in the aerospace, automotive, and shipbuilding sectors. The welding process is very sensitive to factors like welding current, welding time, electrode force, etc. The topic of this paper is the influence of various factors on mechanical qualities. We look at how different welding settings affect the final joint strength. Characteristics of stainless steel joints welded with the same grade of stainless steel are analyzed, as are the findings from the vast majority of research that have investigated spot welding techniques. We also talk about how welding conditions affect the final product's quality..

Keywords—Resistance Spot Welding, AHSS, Mechanical Characterization.

1. Introduction

Modern materials, such as ultra-high strength steels, have received fresh attention as businesses have grown. The steel and low-density metal industries have been engaged in a heated battle over the last decade to keep up with the increasing demand for passenger safety, vehicle performance, and fuel efficiency. Advanced High Strength Steels (AHSS) are being quickly developed by the steel industry as a response to rising concerns [1]. These steels have improved formability and crashworthiness above typical steel grades. Dual phase steels (DP), transformation-induced plasticity (TRIP), and mixed-phase steels make up a subset of advanced high-strength steels (AHSS). These steel types maintain strict safety standards while facilitating the production of lighter vehicles with more economy, less emissions, and greater range in the case of electric vehicles. To facilitate stamping and stamping procedures, the thickness must be lowered while the material's malleability is maintained. This results in a cheaper end product. These characteristics may be attained by striking a balance between rigidity and adaptability. AHSS, including duplex, multiphase, transformation-induced plasticity, and martensite steels, may now be used in industry because to improvements in both method and standard apparatus. It is important to stress the advantages of the RSW process, which have made it ubiquitous in the automobile industry due to its low cost and quick turnaround time.

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Resistance spot welding (RSW) is widely used in the automotive sector, electronics, aviation, and space exploration to connect thin metal sheets. Spot welding is an efficient method for attaching sheet metal components, and it plays a critical role in the production of every vehicle, with an average of 3,000 to 6,000 spot welds each unit. RSW's low price, rapid production rates, and amenability to automation have made it a popular material for usage in a variety of industries, including the automotive, transportation, and consumer electronics industries. Resistance spot welding (RSW) is a few of the oldest electric welding processes, yet it is still frequently employed in the electronics industry for metal-metal composites and cables connections. The integrity of the weld is determined by factors like the spot weld diameter and is the result of a combination of heat, tension, and time during the welding process. RSW creates localised warming at the interfaces by exploiting the material's resistance to the flow of electric current. Weld quality must be easily controlled and modified, therefore familiarity with the mechanical dynamics of the procedure is essential. Joining both butt surfaces at one or more spots, RSW is the most common kind of electric welding processes. The RSW process consists of four distinct phases: the pinch cycle, the weld cycle, the hold cycle, and the power down cycle.

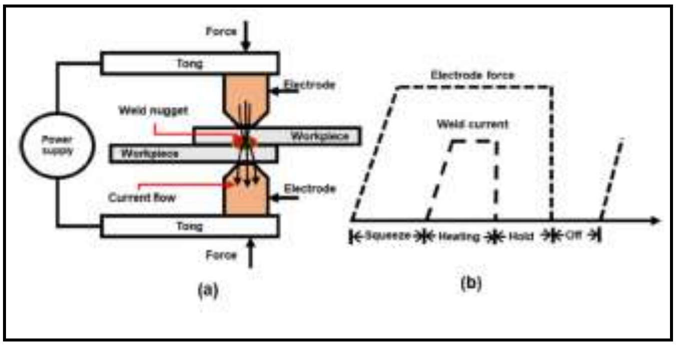

Figure 1 (a) representation of RSW & (b) stage of classic RSW cycle

2. Literature Review

Paweł Kustron [2021] Compared and contrasted three types of resistance Procedures for spot welding DP600 steel and metal-plastic composites were devised and evaluated to determine their efficacy in joining these materials. A current shunt, induction heating, or high-intensity ultrasonic waves were used to preheat the polymer core before the RSW join technique. The findings indicated that the MPC material may potentially overheat, but that measures could be taken to prevent this. Inadequately optimized process parameters might still lead to joint failures such spattering or cracking of the external metal sheet and significant polymer leakage. This approach cannot be readily automated because of the need for a shunt current element..

Although Induction Heating Assisted RSW is the most efficient way for heating material in the weld, it is important to position the material correctly in the inductor to guarantee consistent temperature allocation and prevent damage to the MPC material from overheating. Nevertheless, if the whole region is heated at once, the polymer core may leak out, leaving a wide HAZ in the compounded joint. If the induction heating procedure takes too long, the joint's overall quality will suffer. Knowing the kind of UT vibration, which greatly affects the heating of the material in the bonding zone, is essential for the more complicated process of ultrasound-assisted RSW. For future research and practical applications, it is essential that the UT phase not lengthen the bonding cycle. Although ultrasound-assisted RSW facilitates localized material bonding, it may result in an uneven bend of the outer layer of the MPC cover sheet in the vicinity of the joint. [1]

Esmaeil Mirmahdi's 2020 The impact of flaws on spot welding in the automobile sector are the subject of this study, both on identical and mismatched panels. Spot welding is used to join metal sheets of varied thicknesses, and the welds are put through nondestructive testing using ultrasonic waves. The ideal probe location, boundary conditions, and excitation frequency are all explored. Research shows that ultrasonic detection of spot welds with flaws like porosity and fractures is achievable, and that the waveform of Scan A varies in magnitude at various sites of the weld. The value of the research lies in its ability to accurately identify mistake patterns in the automobile sector. [2].

Another study in 2019 by S. Sobhani and M. Pouranvarei examines spot welding's influence on the mechanical characteristics and phase transition of duplex stainless steel 2304 martensitic advanced high-strength steel at 1.2 GPa. When the solidification mechanism and transformation route of the fusion zone are investigated, it is discovered that the size of the FZ at the plate/sheet interface is the deciding factor in the pullout failure rate. As compared to other materials, DSS and MS sheets have a lower relative stress at the interface (RSW). [3].

In a further study by D. Manafi and D. Akbari in 2019, A combination of finite element analysis and particle swarm optimization is used to find the optimal spot weld design. After evaluating the mechanical properties of a sample spot weld, three unique spot welding techniques were simulated and validated. The stress axis and the symmetry axis were found to be at an angle of 66 degrees, with the best sample consisting of four points on a circle with a radius of 18 mm. [4].

N. Akka conducted an experimental investigation into the resistance spot welding of SPA carbon steel sheets in 2018 for use in the walls and tops of train vehicles. Resistance spot welding was used to join two pieces of carbon steel (SPA) sheet. By doubling the welding current from 6 kA to 14 kA, we were able to increase the cycle lengths to 10, 15, 20, 25, and 30 seconds. Using a light microscope, we determined the lens diameters of the fabricated weld specimens and provided users with suggestions for ideal weld conditions. [5].
Q.B. Feng further explored the metal's welding potential after production by comparing his two-ply hot dip galvanized duplex to low carbon steels of comparable metal. Welds made with all three materials were analyzed for their microhardness profiles, and it was discovered that the steel welded nugget had become much softer. Due to interface cracking, it easily fails the lap shear test despite its small size. [6].

S.H. Mousavi studied in 2018 the relationship between the lap shear strength of dissimilar connections and variables such welding time, current density, electrode force, and post-weld holding time. Minitab software enabled him to do a Taguchi-style analysis of the impacts of variables, enabling him to fine-tune the experimental setup. SEM analysis was used to investigate the optimal condition's microstructure, and tensile shear testing was used to measure the connection's durability. Electrode force, current density, welding time, and post-weld holding time were found to be the most influential parameters, with optimal values of 8 Kamps, 40 cycles, and 16 cycles, and 5 kN, respectively.. [7].

Liang Chen checking for flaws in the mechanical joining of dissimilar metals like steel and aluminum, but manufacturing problems arose. Element arc spot welding (EASW) is a novel approach designed to address this issue. By inserting a hollow steel component (such as a rivet) into a hole in the top aluminum sheet and depositing molten filler metal into the empty part of the component using an electric arc, electric arc welding with filler metal (EASW) successfully welds the component and lower steel plate together, firmly holding the upper aluminum alloy plate between them[9]. This technique may be utilized for closed section bars and for steel plates of any strength, with joint strengths equal to or exceeding those of mechanical joints. As EASW only requires a 1 mm tolerance, welding may be done in any position. [8].

With the aid of tensile impact testing, Emin Bayraktar's work the varying load conditions prevalent in automobile crash testing are described and investigated, together with the behavior of thin welds formed of different steel grades. This research will aid in the development of superior automotive steels and the selection of optimal welding procedures. [9].

B. Bouyousfi's study on welding resistance utilizing a spot-welding method provides concrete instances of the influence that course factors have on joint physical features. The elastic modulus is shown to be highly dependent on process factors, notably the applied load, as shown by statistical analysis of experimental data[10] .

In his paper, Murat Vural compares the resistance spot welding capabilities of lap joints manufactured from austenitic stainless steel sheets and galvanized non-gap (cold formable) steel sheets in an experimental setting. The SN curve was generated by subjecting each weld sample to a series of cycle fatigue tests, and the effect of welding parameters on microhardness distribution was analyzed. [11].

A time- and current-controlled electric resistance spot welder was used to prepare the samples for S. Aslanlar's 2006 research comparing the effectiveness of using microalloyed steel sheets with a chromium plating thickness of 0.8 mm and 1.0 mm galvanized. Several welding current durations were tested in order to evaluate the welds' core size, height, and core size ratio; the welds that resulted were then subjected to lap peel and lap shear tests. [12].

D. Osmani, referring about the year 2019, cautioned that the martensite concentration and phase variety of weld nuggets must be enhanced to prevent cracking when using dual-phase steel (DP), steel with transformation-induced plasticity (TRIP), and boron steel for body components[13].

Resistance spot welding (RSW) was utilized to create solid welds in C. Rajarajan's 2020 research, whereas EBSD methods were used by Arian Ghandi in his 2021 study to investigate the phase shifts associated with various weld sites. [14-15].

Welding current increases tensile shear strength and transverse tensile strength, according to research by Kemal Aydin in 2021[16]. Mechanical impacts of homogeneous AHSS resistance spots, including the influence of interior liquid metal embrittlement (LME) fractures on damage progression , were explored by Outhmane Siar in 2021 using a controlled degradation of welding conditions. The detection of LME internal fractures altered the stress condition at the notch [17], but had no effect on the load-carrying capacity of the weld or the failure modes. Resistance spot welding is used by Kitae Kwon (2021) to study the effects of the Type-C LME on the uniaxial tensile and high-cycle fatigue performance of TRIP steel joints. In CT mode, there is a higher local stress concentration, which increases the contribution of LME cracks. While types A and B of LMEs had no effect on the high fatigue strength of resistance spot welded treated transverse induced plasticity steels, type C LMEs did [18]. Before advanced third-generation high-strength steel (3GAHSS) can be efficiently used in automotive builds, the joining process must be thoroughly tested. Weld seam and heat-affected zone qualities in resistance spot welding, particularly cross welds, must be developed for consistent and satisfactory performance voltage charge mode because to the bigger carbon corresponding of 3GAHSS in comparison to frequently used first generation AHSS like 980 DP. After a paint bake, martensitic tempering may be used to increase the transverse tensile strength of 3GAHSS welds[19]. Recently, scientists have looked at how changing resistance spot welding (RSW) parameters affects the void size and formation procedure. Welding current, resistance welding characteristics like pinch force, and non-weld elements like plate thickness and material strength were all found to contribute to defining the void volume, which was observed and measured using computed tomography (CT) techniques. Electrode pressing force had a variable effect on cavity volume, although welding current, sheet thickness, and sheet strength all had direct effects. [20]. It has been hypothesized that the fatigue strength of DP980 spot welds may be greatly boosted by doing comprehensive post-weld cold working (PWCW) tests, about doubling from the welded condition. Precision has grown in significance as the size of instruments has reduced. Since PWCW is easily mechanized, it might be used in the manufacturing of car components [21]. The microhardness, mechanical properties, and fatigue behavior of the joint were investigated in another study that compared RSW and LSW on Q&P 1180 steel used in the command position. The secondary break and the fatigue crack both extend away from the surface of the specimen, following the path of the fatigue muscle. Welds created with the same welding technique and shape were compared for their strength and foundation metal life [22]. We also looked at the RSW of 7Mn and DP590, two medium-manganese TRIP steels. As the mechanical qualities and quality of the resultant 7Mn/DP590 spot weld were thought to be affected by both the single- and double-pulse welding parameters and starting current, research into these factors was deemed important. We observed that modifying the welding parameters greatly decreased the nugget's thickness and diameter. Joint ejection, cracking, and shrinking are brought on by excessive electrode pressure [23]. The resistance spot weldability of CP800 and highly formable DP1000HF steel joints was also studied in a separate experiment. According to the results, the lap shear strength is affected by the weakest part of the joint, which is the SCHAZ of the DP1000HF [24]. The importance of Si concentration in LME in resistance spot welding of zinc QP-980 advanced high strength steel was also studied recently. The microstructural evolution of galvanized QP980 AHSS was shown to be strongly impacted by an increase in Si content. As a result, the decarburized coating's depth or inner oxide density may increase, which might induce abnormal molten material crevice corrosion during assembly welding and reduce the material's usefulness in the automotive sector. [25].

Conclusions

- Resistance Spot welding is a very efficient method of welding. Yet, the joint quality is affected by a variety of variables beyond only the electrode force and welding current..
- The impact of welding parameters on mechanical characteristics and failure mechanisms is investigated in this study.
- The study demonstrates the connection between welding settings and joint strength. Nugget diameter, metallurgy, stress, and microhardness were the criteria used for evaluation.
- Investigations were also done into how annealing heat treatment affected weld characteristics.
- The development of flaws in spot welds has only been the subject of a few investigations. The most common flaws, including cracks and blowholes, as well as other flaws, are displayed.
- Resistance spot welding is a popular method for combining aluminum and steel, which is a critical problem for multi-material weight reduction schemes.

Analysis of Literature Review

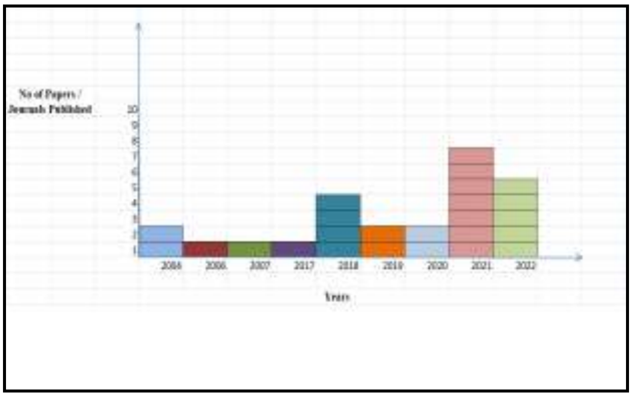

Figure 2 Numbers of papers/journals published in a year

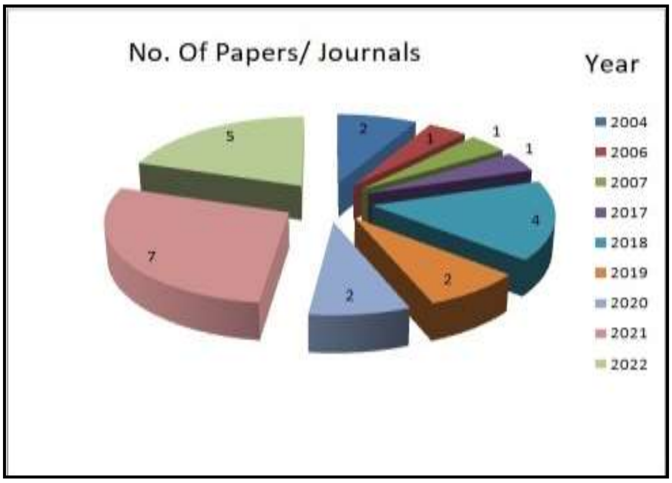

Figure 3 Number of papers/ journals published in year.

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