Influence of Process Parameters on Tensile Strength and Hardness of AHSS Spot Welded Joints

Dhiraj D. Balsaraf[1], Rupesh R. Gawande[2]
[1]Research Scholar (Ph. D), Mechanical Engineering Department, Bapurao Deshumukh College of Engineering, Sevagram, Wardha (M.S.), India. Email: dhirajbalsaraf1988@gmail.com
[2]Associate Professor, Mechanical Engineering Department, Bapurao Deshumukh College of Engineering, Sevagram, Wardha (M.S.), India. Email: wsbdcoe@rediffmail.com

ABSTRACT
One of the newest and popular steel types is Advanced High Strength Steels (AHSS) which is more strong-weight-ratio and crashing worthiness in comparison with other types of steels. The most commonly used joining method to use on the sheets of AHSS is Resistance Spot Welding (RSW). Nevertheless, the mechanical performance of spot-welded joints is extremely sensitive to the process parameters of authors research the effect of main process parameters on tensile strength and hardness of spot-welded joints in AHSS. The test was done under various combinations of parameters and the obtained joints tested on tensile shear tests and microhardness. The findings suggest that current and time of welding have a major impact on nugget formation hence strength and hardness are influenced. The best parameter choice has the effect of giving better joint efficiency.

Keywords: AHSS, Resistance Spot Welding, Tensile Strength, Hardness, Welding Parameters, Nugget Formation
How to cite this article: Balsaraf DD, Gawande RR. Influence of Process Parameters on Tensile Strength and Hardness of AHSS Spot Welded Joints. Int J Drug Deliv Technol. 2026;16(22s): 249-253. DOI: 10.25258/ijddt.16.22s.27
Source of support: Nil.
Conflict of interest: None

Introduction:
The hot topic of engineering materials especially in the automotive and structural engineering sectors where there has been a high demand in materials which are light in weight, high in strength, and capable of absorbing energy. During the last several decades, the world has concerned the fuel efficiency, emission minimization, and safety of the passengers, where AHSS is at the core of fulfilling those demands.

Historical Process and Development.
This history of inventing steel materials that can be utilized in industrial activities early 20th century where the traditional low-carbon steels were mostly the ones that were utilized because they are relatively simple to manufacture and inexpensive. Nevertheless, the materials were not very strong nor resistant to crashing and this limited their use in high performance buildings.
The first generation of High Strength Steels (HSS) was invented in the 1970s and it was aimed at enhancing yield strength by using processes. Such steels were better in terms of mechanical properties than that of conventional steels yet they were yet to be balanced in terms of strength and ductility.
During the 1980s and 1990s, it evolved to the owing to the improved metallurgical processes. These materials had enhanced formability and tensile properties with increased tensile strength hence they are applicable in the automotive body structures. It was the era of transition between the traditional steels to the currently known first generation of AHSS.
By the early 2000s, the automotive business started gaining wide usage of AHSS as the stricter safety regulations and the policy of environmental protection were introduced. The offered superior ductility and strength albeit at an expensive production cost as this prevented their use at large scale.
Recently especially in the years since 2010, the design of the third generation AHSS has been on the way towards striking the right ratio in terms of strength, ductile efficiency and cost-effectiveness. These steels have enhanced microstructures, such as martensite, bainite, and retained austenite, and thus is able to be used in enhanced mechanical performance. Currently, automotive components (crash structures, reinforcements, and parts of a safety-critical nature) are widely made out of AHSS materials.
Welding required on AHSS Structures.

Since the main utilization of the AHSS materials is in the form of sheets, the process of joining in the manufacturing process of complex assemblies is important. Among all the welding methods has been the best adopted technique particularly in the automotive sector because it can be automatized and also is cost effective.

Resistance welding has its roots in the end of the 19 th century, and its spread to industry not only grew in the mid-20 th century as the mass production sectors were expanding, but also contributed to the rise of those industries. By 1990s, the vast majority of car makers in the US had adopted the RSW as their preferred method of joining cars, which involved making thousands of welds in one automotive body.

Problems with Spot Welding AHSS.

Irrespective of the strengths, welding AHSS is characterized by a number of difficulties connected to its complex structure and great strength. The process of welding has the localized heating and heat rapid cooling, which hugely transforms the microstructure in the weld area. It commonly leads to development of hard and brittle martensitic phases in the nugget of weld and heat-affected zone (HAZ).

Process parameters are very important in determining some of the defects that may occur due to improper choice of parameters include expulsion, electrode degradation, insufficient fusion and less strength of the joint.

Since the beginning of 2000s, a great amount of research work has been performed to comprehend the connection between welding parameters and mechanical properties of AHSS joints. Research has revealed that the amount of current in welding is the most determining factor in the generation of heat and size of nugget and the length of time in welding regulates the length of the heat input. Contact resistance is influenced by the electrode force that also plays a major part in stabilizing the welding process.

Mechanical Characterization is of Value.

Spot-welded joints require mechanical characterization, which would guarantee their stability and their competency in real-life situations. The tensile strength is one of the essential parameters which define the load bearing behavior of the joint whereas hardness offers a hint on microstructural changes and behavior of the material in the weld area.

The use of AHSS in parts with critical applications as far as safety is concerned has necessitated the use of the optimum welding parameters to ensure the required balance in strength, hardness, and ductility is reached. During the past few years (since 2015), researchers have paid attention to the combinational work of experimental methods with numerical simulation and optimization approaches to improve the quality of welds and their performance.

Related Works:

It has received a lot of attention with respect to wide usage in automotive and manufacturing industries. Several scholars have studied microstructural development as well as mechanical performance of welded joints.

The article of Loulou and Kchaou (2018) studied resistance spot welding impact. Their experiment indicated that current and time of welding are the most vital factors to impact tensile properties and welding nuggets. They noted that current increases heat input thus making joint stronger to an optimal point, when this increases further, joints might get defects like expulsions. Other information brought out in the study is that appropriate choice of parameters is a key to attaining a desirable mechanical performance.

The study by Sun et al. (2007) was concerned with the correlation between failure behavior and size of fusion zone in AHSS spot welds. Their results showed that the size of the weld nuggets used leads to the increase better the energy absorption power. Furthermore, they determined various like which highly relies on weld geometry and the process conditions. This work gave a more insight on the weld size and its effects on the structural performance.

Pouranvari and Marashi (2013) conducted an advanced review of the use of spot welding in steels in the automobile sector and explained how the process parameters relate to microstructure and mechanical properties. They pointed out in their study that AHSS materials are exposed to significant microstructural changes when welded including the development of martensite in the weld nugget. They also stressed on the need to restrict heat input in order to prevent brittleness and assure of optimum quality weld.

In their basic research on resistance welding, Zhang and Senkara (2011) described how the heat generation, current flow, and electrode behavior was presented in the process of spot welding. The book presents a theoretical basis of explaining how parameters of welding can affect the formation of nuggets and performance of a joint. It also relates the significance of the electrode force and contact resistance in ensuring that the welds are stable.

Khan and Kuntz (2008) examined the difficulties involved with welding of AHSS. According to them, AHSS has high strength and alloying content and, therefore, the zone of welding is commonly harder and less ductile. Among the problems outlined in their study, electrode wear, expulsion and non-uniform quality of the weld, it is implied that carefully of the process to ensure reliable joints.

Kou (2003) gave extensive information about the welding metallurgy especially in relation to the phase transformation and the microstructural alterations during the welding process. It gave an explanation of the effect of the high heat and cooling-down temperatures in RSW which causes the hard martensitic structures in AHSS. The piece is a key to the relationship between the Thermal cycles and distribution of the hardness in the welded joints.

The article by Bhadeshia (2015) covered the creation and use of advanced steel in the car industry. The paper has stressed the role of AHSS in the attainment of lightweight and high-strength constructions. It also emphasized the way in which welding operations should be optimally streamlined to retain the appropriate qualities of such high-quality materials.

Gould (2012) paid attention to the methods of joining of AHSS and pinpointed the essential issues with resistance spot welding. The research indicated that it is important to control the weld parameters in order to avoid defects and establish integrity of the joints. It also talked of the effect of electrode design and cooling conditions on the quality of the weld.

Saha and Das (2016) examined behaviour of the resistance spot welded. They found that the region of the weld nugget contains an improved level of hardness than the base metal as a result of the martensitic transformation. They further noted that tensile strength has a close dependence on the size of nuggets and welding circumstances.

Kumar, Singh and Sharma (2019) used the Taguchi optimization identify the best to use on AHSS. Their experiment showed that statistical methods can properly determine increase the tensile strength and reduce defects. The findings established that optimisation strategies are useful aids in the enhancement of the quality of a weld.

On the whole, it can be observed that the currently reviewed literature suggests that the considered to be the most significant parameters that affect the mechanical properties of AHSS. Although much has been achieved in the welding behavior of AHSS, there is still a possibility of the further research to make the process parameters more optimal to provide a balance of the strength, hardness, and ductility.

Objectives of the Study:

1. To analyze the effect of welding current, welding time, and electrode force on AHSS spot welded joints.
2. To evaluate tensile strength variations under different welding conditions.
3. To study hardness distribution across the weld zone.

Material and methods:

Multigrade Advanced High Strength Steel (AHSS) sheets of thickness 1.2 mm were used to conduct the current study which is popular in automotive structural uses as a result of their high strength and hardness. The chemical composition of the material mainly consisted of carbon, manganese, silicon and other alloying components that help in increasing the hardenability and mechanical performance. Before welding, the sheets were cut into standard lap joint specimen and the surface was cleaned thoroughly to eliminate some of the surface contaminating agents like oil, rust and dust to ensure uniformity on the welding.

The Resistance Spot Welding (RSW) was done using the pedestal-type spot welding machine provided with the water-cooled copper electrodes. The welding was carried out by the insertion of pressure and electric current by use of the electrodes into the metal substances to induce heat at the joint of the sheets leading to the creation of a weld nugget. The important parameters of the process that were chosen in the study included welding current, welding manipulated systematically in terms of three variables, which were the welding current (6 kA, 8 kA and 10 kA), the welding time (10, 15 and 20 cycles) and the electrode force (2, 3 and 4 kN). An experimental design method was used to make sure that the interactions between the parameters are adequately evaluated and several samples were ready to make the results more reliable and repeatable.

The mechanical and metallurgical testing of the specimens was done after welding. The maximum load bearing capacity and the strength of the joint of the welded pieces were investigated through tensile shear tests using a Universal Testing Machine (UTM). They were tested under a constant crosshead speed and peak values of loads were measured to be analyzed. Also, microhardness tests were conducted on various parts of the weld which included using

Vickers hardness testing technique. The hardness profile gave an insight into how the microstructural changes that took place as a result of thermal cycles that took place during welding.

In addition, microscopic observation and microstructure analysis of the welds were conducted to determine the defects, expulsion, cracks, or undone fusion.

Analysis of the study:

Table 1: Tensile Strength Results

Welding Current (kA)	Welding Time (cycles)	Electrode Force (kN)	Tensile Strength (MPa)
6	10	2	320
8	15	3	420
10	20	4	390

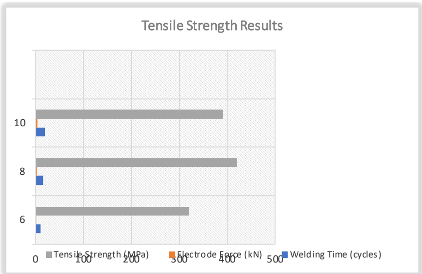
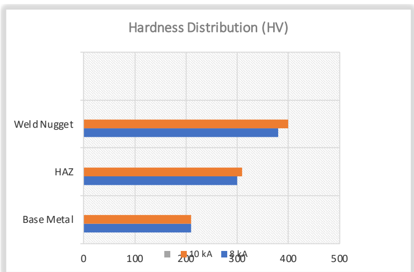


Table 2: Hardness Distribution (HV)

Region	6 kA	8 kA	10 kA
Base Metal	210	210	210
HAZ	280	300	310
Weld Nugget	350	380	400



Analysis

- With welding current, tensile strength rises to an optimum (8 kA), after which it falls off, by expulsion.
- Heat Affected Zone (HAZ) exhibits moderate hardness as a result of partial conversion.
- The overcurrent results into brittle welds of low strength.

Results and Discussion:

The experimental evidence shows that affects tensile strength. With moderately high currents (8 kA), the heat generation will become optimal, creating proper fusion and larger nuggets, the size of which will be correspondingly the greatest strength.

Time on the welding is another factor in the growth of the nuggets. The more time welding takes place, the more heat is subjected to it, however this has to be limited to avoid overheating. Contact resistance is influenced by the applied electrode force, and the moderate force gives stable welding.

Analysis of hardness has revealed that, the weld nugget has the highest hardness as it has cooled down very fast and formed the martensite. High hardness offers strength but can decrease ductile suggesting there is a trade-off between toughness and strength.

This research proves that a specific set of parameters should be used to attain the desired quality in welds which are not defective like expulsion or cracks.

Conclusion:

This paper attempted to learn more about the mechanism in which the various resistance spot welding parameters influence the mechanical behavior of Advanced High Strength Steel (AHSS) joints. Based on the experiments and the analysis, it is evident that both tensile strength and hardness of the welded joints are directly and significantly influenced by parameters of welding. among the considered parameters. Optimal current will assist in good heat production and development of a good weld nugget that enhances the tensile strength, when the current is raised to an ideal level. However, when the current is excessively large, it causes defects, including expulsion, which eventually causes the decrease in the strength of the joint. The same pattern is witnessed with the welding time as moderate time offers enough amount of heat to bond, whereas the extra time is harmful to the quality of the welding.

The results of hardness indicate that the weld nugget area is harder significantly in comparison to the base metal. This has largely been because of the formation of martensitic structure during rapid cooling. Although high hardness is a sign of more power in material, this is also a hint at high brittle nature that not necessarily helps in the real-world situations. As such there must be a compromise on the strength and ductility.

All in all, the research indicates that it is highly imperative to ensure that suitable welding parameters are used to ensure high quality welds in AHSS. With proper optimization, it is not only the mechanical properties that are improved, but also the defects and reliability of the welded structures is improved. This research can be particularly helpful in such fields of industry as automotive production since hard and light-weight materials are a necessity in safety and performance.

References:

1. Loulou, T., & Kchaou, M. (2018). Effect of resistance spot welding parameters on mechanical properties of advanced high strength steels. *Materials Today: Proceedings*, 5(9), 18234□18241.
2. Sun, X., Stephens, E. V., & Khaleel, M. A. (2007). Effects of fusion zone size and failure mode on peak load and energy absorption of advanced high strength steel spot welds. *Engineering Failure Analysis*, 14(7), 1410□1421.
3. Pouranvari, M., & Marashi, S. P. H. (2013). Critical review of automotive steels spot welding: Process, structure, and properties. *Science and Technology of Welding and Joining*, 18(5), 361□403.
4. Zhang, H., & Senkara, J. (2011). *Resistance Welding: Fundamentals and Applications* (2nd ed.). CRC Press.
5. Khan, M. I., & Kuntz, M. (2008). Resistance spot welding of advanced high strength steels. *Welding Journal*, 87(6), 145s□152s.
6. Kou, S. (2003). *Welding Metallurgy* (2nd ed.). Wiley-Interscience.
7. Bhadeshia, H. K. D. H. (2015). Steels for automotive applications. *Proceedings of the Royal Society A*, 471(2176), 20140724.
8. Gould, J. E. (2012). Joining of advanced high strength steels. *Welding Journal*, 91(11), 193s□199s.
9. Saha, D. C., & Das, S. (2016). Mechanical behavior of resistance spot welded dual-phase steels. *Journal of Materials Engineering and Performance*, 25(4), 1500□1508.
10. Kumar, R., Singh, R., & Sharma, A. (2019). Optimization of resistance spot welding parameters for AHSS using Taguchi method. *International Journal of Advanced Manufacturing Technology*, 103(5□8), 2345□2356.