Evaluate the Residual Stress Formation of DP600 During RSW

Abeer Mami[1], Nezar Mokthar Almahmodey[2], Abdulkarim R. Alzahougi[3]

[1-3]Manufacturing Engineering Karabuk University Turkey

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Abstract - *In this study, resistance spot welding (RSW) system utilized to industrial DP600 automobile sheet metal pairs had been examined experimentally, at specific pressure (3.5, 4.5 and 5.5 bar) under 4, 6 & 8 kA welding current. Microstructure, hardness and residual stress have been examined to consider the impact of welding pressure. Results exhibit that michardness values had been greater in welding vicinity than different parts. There used to be now not appreciably alternate hardness behaviour versus utilized welding strain for the samples. When clamping load modified from 3.5 bar to 5.5 bar, hardness was once improved. Residual stress exhibits that compression stress used to be discovered in specimens and 5 kA-6 bar specimens exhibited the very best residual stress.*

Key Words: Resistance spot Welding, Dual-Phase Steel, microstructure, Hardness and Residual Stress.

1. INTRODUCTION

Resistance spot welding has turn out to be most frequent welding approach in the automobile enterprise in current years. The RSW tactics are fast, automated, and don't want to greater wire to be blanketed from the dangerous outcomes of the surroundings by using the truth that the welding place is closed relying on the welding parameters. High power steels which are the most essential and frequent of the physique development steels of modern day vehicles. Their residences and the susceptibility of the metallurgical constructions to warmth are very touchy which impact the RSW approaches and its optimization. Detailed exploration of RSW effects, houses and performances for every situation is additionally very essential in phrases of growing the provider lifestyles and fantastic stage of manufacturing strategies [1,2]. As a outcome of the excessive RSW cooling rates, the core microstructure is converted into a totally martensitic shape by using the impact of alloying factors in RSW techniques of excessive electricity steels. For DP 600; Throughout the weld, the pre-existing martensite section tempering softens the fabric and its impact can be found with additionally lower-strength DP steels [3]. All these segment transformations for the duration of RSW of DP 600 metal accompanying to extent growth in addition to warmness switch behave as a supply of the residual stress formation in weld vicinity of the material. Residual stress formation and its degree need to be properly grasp to outline properly estimation of overall performance of the RSW junctions. In this study, to the satisfactory of our knowledge, impact of welding modern and stress on residual stress formation and degree on welding vicinity of DP600 metal sheets at the first time.

The expand in the stage of manufacturing opposition of course has greater and greater superior quality; advanced, lighter, safer, greater environmentally friendly, and eventually extra affordable, less expensive substances for the improvement of modern-day vehicles that enhance the environment, safety and automobile performance, high-strength low-alloy (HSLA) metal is now extra than ever, and due to the fact of the higher combination of ductility and strength. It is even being increasingly more changed via superior high-strength metal (AHSS). It has now been cited and identified that the improved energy of steel substances technically leads to decrease the formability [4]. RSW has been used notably in order to joint sheet metallic due to the fact of its ease of operation, excessive manufacturing effectivity and excessive velocity and low cost. A cutting-edge white physique typically has heaps of spots. Advanced High-Strength Steels (AHSS) have been considered as a Dual segment metal (DP) is regarded a new answer for gasoline proficiency, automobile security and value financial savings in the car enterprise [5]

2. MATERIALS AND METHODS

The commercial DP600 automobile sheet metal which has 1 mm thickness and 250x250 mm sizes used to be purchased. Samples have been organized as 100x30x1 mm dimensions for resistance spot welding (RSW) in accordance to the EN ISO 14273 standard. RSW used to be utilized to the specimens the usage of eight mm flat conical copper electrodes at 4kA to eight kA welding currents with increment 2kA. The utilized electrode pressures have been decided with increment of 1 bar from 3.5, to 5.5 bar respectively. Three samples have been taken for every electrode urgent force. Welding, Squeezing, maintain and separation instances had been set as 25, 30, 15, and 20 cycle respectively (1 cycle = 0.02 sec). Transverse-transition place views of RSW samples have been organized by means of following the general metallographic process (grinding and polishing). Polished samples had been uncovered to brief time etching with 2% nital answer (2% nitric acid + 98% methanol). Microstructure evaluation used to be carried out the use of a Nikon optical microscope. Microhardness measurements have been carried out parallel to the axis alongside the weld steel and ITAB the use of a Qness Vickers hardness tester with a load of 0.2 kg for 10 seconds. Residual stress dimension was once performed via reducing method. In this technique, pressure gauge which is an electrical equipment used to be used. Firstly, weld vicinity of specimens used to be cleaned the use of degreaser, conditioner (acid) and neutralizer (base) respectively. Then strain gauge was glued on the middle of the weld part of specimens. Cutting process was applied to obtain strain values during the cutting via software (System 7000). At the end, Hooke law was applied utilizing elastic modulus (190 GPa) of samples. So, residual stress used to be calculated for every sample. Figure 1 indicates the pressure gauge and guidance substances for residual stress measurement.

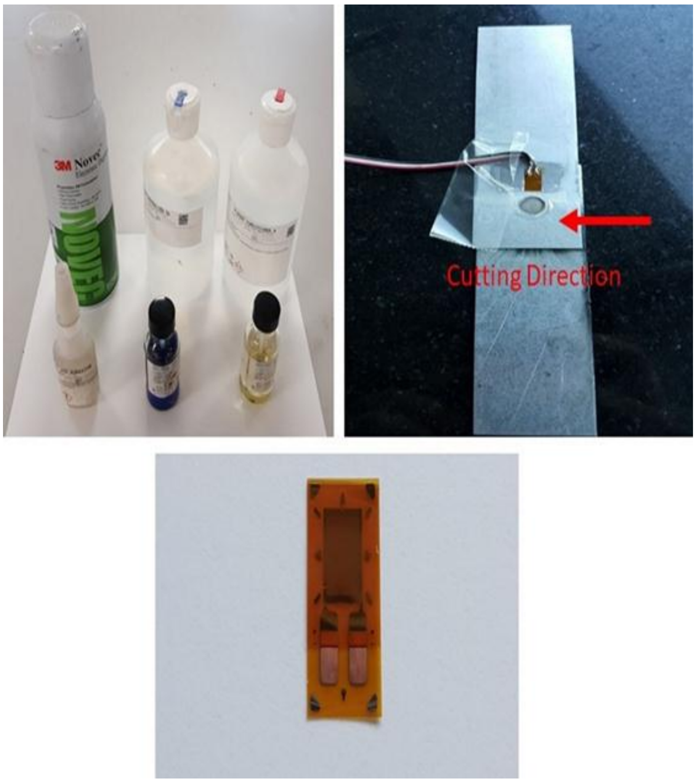


Fig -1: Equipment for Measurement of Residual Stress

3. RESULTS AND DISCUSSIONS

3.1. Microstructure

Figures 2, 3 and 4 illustrates the microstructure pix displaying the modifications in Head Affected Zone (HAZ) and welding metallic at 4, 6 and eight kA welding currents and specific electrode pressures. After the RSW process, the microstructure of all electrode compressive forces seems to be composed of low quantities of bainite and predominantly ferrite and martensite phases [3,6,7]. The used specimens consist of low portions of bainite and predominantly martensite segment in the weld metallic and HAZ considering the cooling charge of the weld region is very excessive due to the fact RSW electrodes are water-cooled and there is no longer sufficient time for carbon diffusion [8,9]. In general, the martensite extent ratios at all electrode compression forces expand alongside the base metal, HAZ and weld metal. This is due to the fact the price of ferrite dissolved in the austenite in the direction of the welding location is multiplied and speedy cooling happens after welding technique which will increase the martensite extent ratio [10].

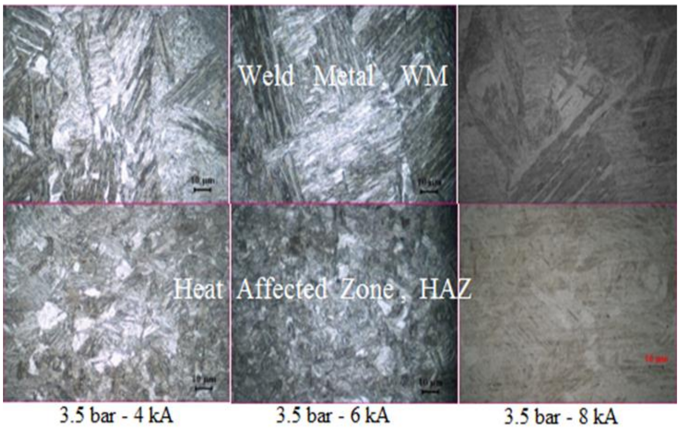


Fig-2: Light Optic Microscope (LOM) images at 4, 6 ve 8 kA welding currents and fixed pressure 3.5 bar.

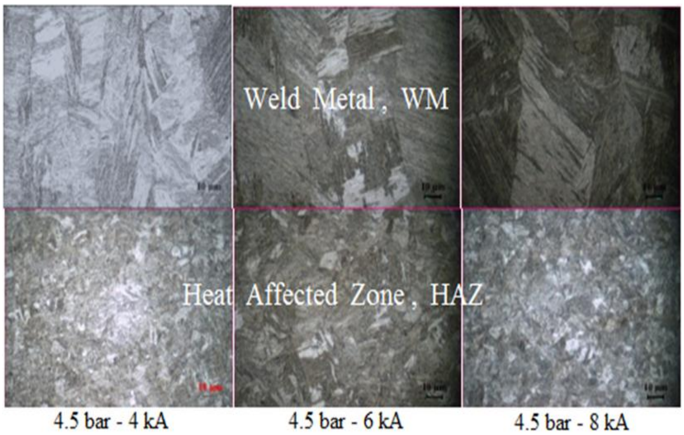


Fig-3: Light Optic Microscope (LOM) images at4,6 ve 8 kA welding currents and fixed pressure 4.5 bar.

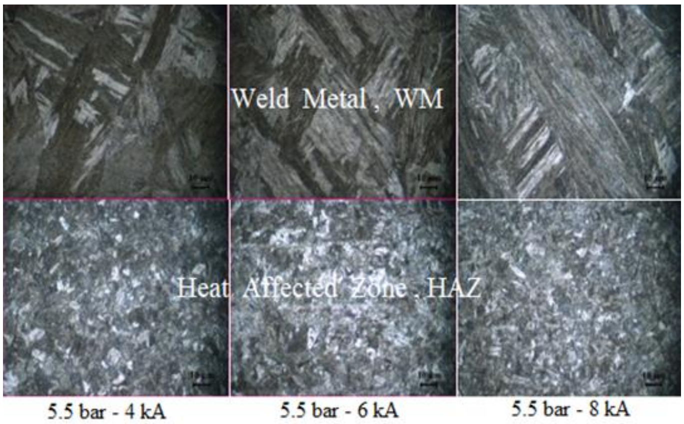


Fig-4: Optic Microscope (LOM) images at 4, 6 ve 7 kA welding currents and fixed pressure 5.5 bar.

3.2. Hardness

The hardness effects of welded samples are introduced in Figures 5, 6 and 7. As can be considered from these results, the stiffness in the weld region after weld is extensively accelerated in commonly excessive power steels and double section steels. This make bigger in hardness can be abrupt and is about two times. Hardness is truly crossed on the joint surface. While the FZ zone's hardness values are greater than 400-450 and for the HAZ which is 300-350 HV it can be linked to the martensite and the bridal ranks, hence, and the hardness of the Bas bass are estimated to be much less than 300 HV per HV and then it can be attributed to the ferrite section . The chemical composition and preliminary microstructure of the BM decide the hardness profile of spot welds of carbon steels that might also exhibit hardening in FZ and HAZ in addition to softening in the HAZ.

$$\text{Hardening ratio} = \frac{\text{HFZ}}{\text{HBM}} = \frac{410.13}{200.4} = 2.05 \qquad (3.1)$$

$$\text{Softening ratio} = \frac{\text{Hmin}}{\text{HBM}} = \frac{200}{200.4} = 1.0\ HV \quad \text{, For welding time 25 Cycles}$$

Where HBM, HFZ and Hmin are BM hardness, FZ hardness and minimum hardness in HAZ.

$$\text{Hardening ratio} = \frac{\text{HFZ}}{\text{HBM}} = \frac{400}{190} = 2.1\ HV \qquad (3.2)$$

$$\text{Softening ratio} = \frac{\text{Hmin}}{\text{HBM}} = \frac{281}{190} = 1.48\ HV \quad \text{, For welding time 15 Cycles.}$$

Figures 5, 6 and 7 indicates that Nugget hardness is 2.05 instances higher than the hardness of the base metal, and about 1.9 instances the HAZ is valued at about 410.13 HV and valued at about 200.4 HV and 213.68 HV for base steel and affected warmness sector respectively for weld time 25 Cycles. Nugget weld electricity is 2.05 instances greater than base metal, which is steady with the outcomes For welding time 15 Cycles, nugget hardness is 2.1 HV instances increased than the hardness of the base metal and about 1.2 HV extra than HAZ hardness. Nugget expresses extra hardness and electricity to the martensite formation. Figure 5 indicates that the hardness at clamping load of 3.5 bar is larger than the hardness with clamping load of 4.5 bar and 5.5 bar.

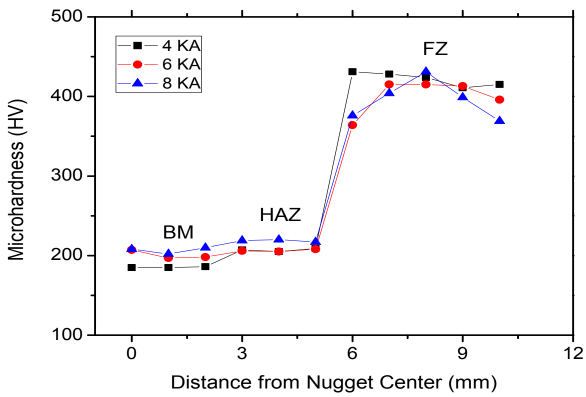


Fig-5: microhardness Profile with Force 3.5 Bar at different current.

It is proven in Figure 6 that the hardness at FZ is extra than HAZ and BM. We can conclude from this end result that hardness at spot welding is constantly better. Also, when make bigger the welding contemporary the hardness will be increased.

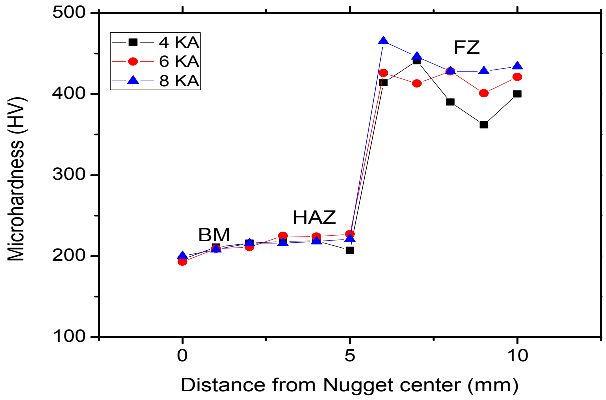


Fig-6: microhardness Profile with Force 4.5 Bar at different current.

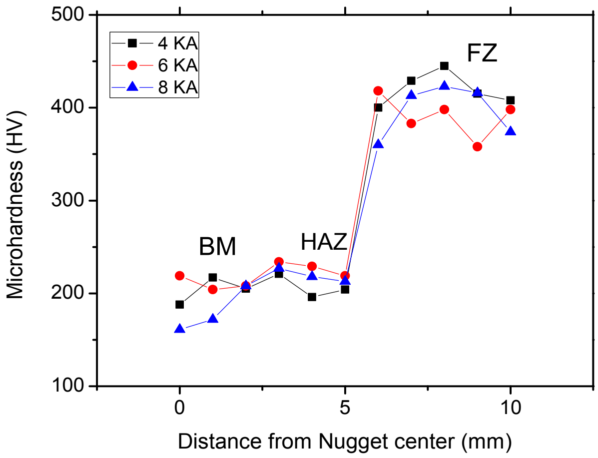


Fig-7: microhardness Profile with Force 5.5 Bar at different current.

It is clear from Figure 7 that when make bigger the clamping load up to 5.5 bar, the hardness at welding modern eight kA is much less than the hardness with welding modern-day four kA. The martensitic shape emerged in the steels is excessive challenging due to the fact it prevents the dislocation of the slip through some motives which are motionless dislocation structure, volumetric growth and shear-consolidation, twinning, etc. In the non-critical HAZ place which is shut to the important metal, there are softening zones due to martensitic tempering [11]. In literature, Callister W. D. stated that [12] martensite hardness is anticipated to be above 350 HV for carbon content material exceeding 0.05% mass percentage. In this study, weld steel hardness values got at all electrode urgent forces at 4, 6 and eight kA welding currents are inside the referred to rule line and in the martensite hardness range. Another idea estimation method on hardness additionally was once utilized in this study. To decide the impact of the electrode pressure, the carbon equal of the DP600 sheet metal used in the experiments used to be calculated the usage of this equation (3.3) which used to be developed by way of Yurioka et al [13]. They have tried to estimate the hardness values of excessive electricity steels relying on the chemical content material after welding.

$$CE_Y = C + A(C) \times \left\{5B + \frac{Si}{24} + \frac{Mn}{6} + \frac{Cu}{15} + \frac{Ni}{20} + \frac{Cr + Mo + Nb + V}{5}\right\} \quad (3.3)$$

$$A(C) = 0.75 - 0.25\tanh\{20(C - 0.12)\}$$

According to Equation 1, the hardness of the weld area will increase as the chemical substances are enriched due to the fact of inflicting greater carbon equal values. CEY indicates a linear relationship between the hardness of the weld sector and the chemistry of the base metal.

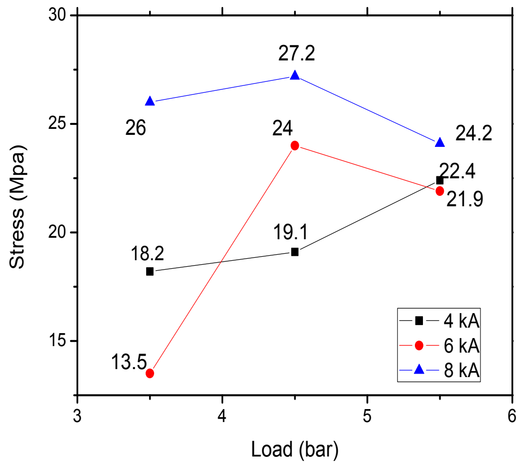
3.3. Residual Stress Results

The Figure under exhibit the residual stress values of specimens. Cutting technique with stress gauge was once commonly used to apprehend stress kind and content material in specimens as a negative technique. Stress values have been calculated by way of Hooke's regulation after pressure values got by way of software program in the course of cutting. The following components used to be used to calculate stress dimension results.

$$\sigma_{longitudinal} = -E.\varepsilon \quad 3.4$$

Where σ_longitudinal is the residual stress, E is the elastic modulus of steel sheet and ε is the strain value. Results clearly show that compression stress which play important role to enhance the mechanical performance of materials. The value of 6 kA welded samples, 5.5Bar possess highest stress, which can exhibit better hardness and strength. When welding current changed, compressive residual stress increases.

At clamping load 3.5, 4.5 and 5.5Bar with 6 kA welded pattern has 19.1, 24 and 27.2 MPa stress fee as proven in Figure 8, So, it can be deduced that the clamping load may be extra tremendous than welding modern to decide the residual stress overall performance these effects at welding time of 25 Cycles. However, at 15 weld time of 15 cycles, additionally the fee of 6kA welded samples however with4.5 Bar possess absolute best stress, which can show off higher hardness and strength, rather of 5.5Bar. When welding modern-day changed, compressive residual stress increases. The cost was once 34.2 MPa as proven in Figure 9.



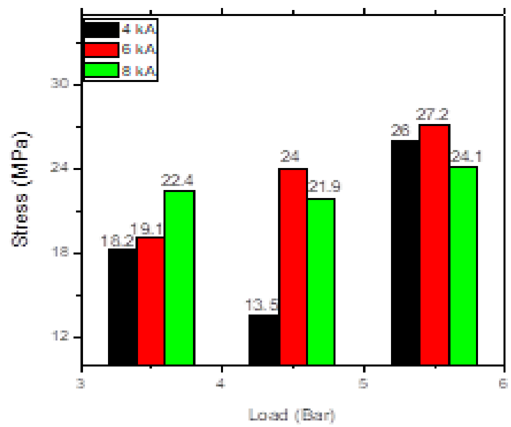
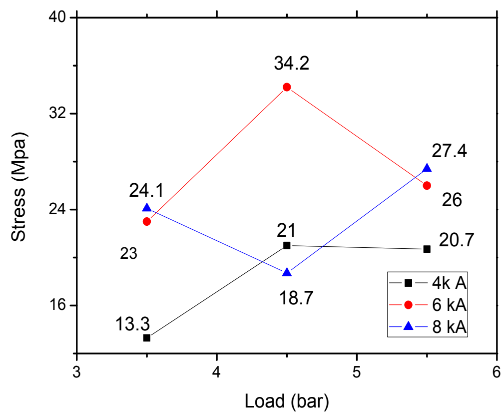


Fig-8: Residual stress at time of 25 Cycles.



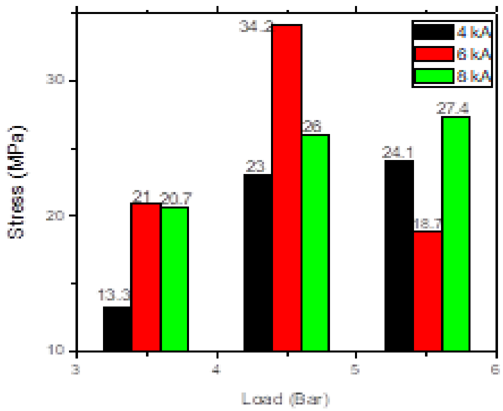


Fig-9: Residual stress at time of 15 Cycle.

Residual stress values provide records about the mechanical residences of materials. If it is known, fatigue and tensile residences of specimens can be predicted. If the compressive residual stress is higher, fabric famous higher fatigue performance. If the specimens have tensile residual stress, fatigue performance is lower. So, researchers can see the mechanical overall performance of specimens after welding procedure with the aid of residual stress dimension with stress gauge approach which is achievable and financial procedure in contrast to different techniques. We seen that when make bigger load, the stress will be increased. At the load 3.5 bar, we discovered that the stress at 8kA is greater than the stress at 4kA and 6kA. While at the load 4.5, 5.5Bar, it is discovered that stress at 6kA is greater than 4kA and 8Ka respectively. These consequences are at the time 25 cycle. Whereas at 15 cycle, we located that the best stress is at the load 4.5 bar and 6kA.

4. CONCLUSIONS

Based on the microstructure, hardness and residual stress results, following findings have been observed.

• Microstructure of the weld region all through base metallic and weld metallic consists of the growing quantity martensite (nearly utterly martensite at core of the weld), substantially lowering ferrite and little bainite.

• On Hardness of the weldment, weld modern-day is very effective. However, the impact of the weld pressures is now not clear barring for four bar at 7 kA current.

• It can be deduced that the impact of clamping load might be more effective than welding current to determine the residual stress performance. However, at 15 cycles welding time, the value of stress at 6 kA welded samples with 4.5 bar possess the highest stress of 34.2 MPa, which can exhibit better hardness and strength

• It used to be found that there is direct relationship between quantity residual stress value, and weld pressures

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