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Effect of welding time on tensile-shear load in resistance spot welded TRIP 800 and microalloyed steels

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In recent years, some topics in Automotive industry has become important such as energy saving, carbon emission and automotive safety issues. The main motivation to meet these requirements is employing high strength and low weight materials for vehicles. Therefore, the conventional materials have been substituted with Advanced High Strength Steels (AHSS) and High Strength Low Alloy (HSLA) steels that have high strength-to-weight ratios. However, in addition to material investigation, the joining and welding of these materials is of high importance cannot be underestimated. In this work, weldability of TRIP 800 (transformation induced plasticity), a AHSS steel, and microalloyed steels, a HSLA steel, with resistance spot welding has been investigated. The effect of welding time parameter on tensile-shear properties was analyzed. The optimum parameters for tensile-shear strengths and the encountered separation modes have been examined. The highest tensile-shear loads was obtained using 15 periods.

Keywords: Resistance Spot Welding, Welded Joint, Automotive steels, Tensile–Shear Test

In recent years, due to increasing requirement about reducing automotive gas emissions, increasing fuel saving and decreasing weight of automobiles and raising automotive safety, new materials for car bodies has been investigated by automotive industries and steel companies[1,2]. Then, Advanced high strength steels (AHSS) has been developed to meet these requirements. Transformation Induced Plasticity (TRIP) steels are one of members of AHSS family.

TRIP steels can be regarded as composite steels, Because microstructure of a typical TRIP steel consists of bainite, martensite inclusions, and retained austenite, which are embedded in a ferrite matrix[3-5]. Retained austenite in low alloy steels which result in deformation hardening stem from strain-induced martensitic transformation, provides to TRIP steel a good combination of high strength and fracture toughness[5].

Microalloyed or high strength low alloy (HSLA) steels are the reason for preference because of high mechanical properties and better corrosion resistance[4]. Microalloyed steels have been already used in automotive body parts.

Resistance spot welding executed with two electrodes which positioned on the surfaces of overlapped specimens and the welding heat generated by high electrical resistance to current flowing through work with a brief time period[6-8]. Resistance spot welding is the most practiced joining technique in automotive body parts because it has a short process time, suitable for mass production and can be easily welded with/on assembly[9]. However, spot welding parameters such as welding time and current highly affects strength of weld joints. In a typical car body, there are 3000 or more spot welds[10-12]. This substantial quantity illustrates the importance of suitable parameters.

In this work, effect of welding time and welding current on tensile-shear load of TRIP 800 and microalloyed steel joints has been investigated. Also, tensile-shear loads and failure modes of welded materials have been determined for various welding times.

Finally, an optimum welding time and three failure modes were investigated.

Exprimental Section

Resistance spot weld tests carried out with an industrial RSW machine having 120 KVA current capacity and pneumatically controlled press mechanism. Water cooled Cu-Cr electrodes with 6 mm contact surface diameter were employed. The TRIP 800 and microalloyed steels were supplied from local automotive companies. TRIP 800 steel sheets having 1.5 mm thickness and microalloyed steel sheets having 1 mm thickness were sliced to 30 mm. the specimens were cleaned ultrasonically, and overlapped with 30 mm for tensile shear tests. The detailed dimensions are illustrated in Fig. 1.

During all experiments, electrode force adjusted 6 kN. Electrode squeeze time and hold time adjusted to 25 period and 30 period respectively. Applied welding currents ranging between 8.5-16.5 kA with 0.5 kA increments, and welding periods varying from 5 cycles to 25 cycles with 5 period increments. The detailed welding scheme is shown in Fig. 2.

Chemical compositions of TRIP 800 and microalloyed Steels are presented in Table 1 and Table 2. After tensile tests, 480 MPa and 184 MPa have been found yield strengths of TRIP 800 and microalloyed steels respectively. Tensile strengths and total elongations of these materials have been obtained as 785.8 MPa, %25.1 for TRIP 800, and 357 MPa, %39 for microalloyed steels.

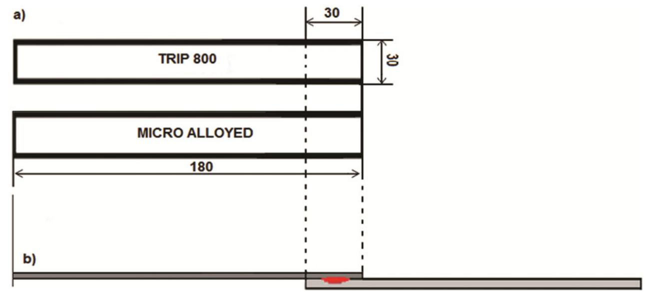

Fig. 1 — Dimensions of the (a) materials of specimens (b) welding specimens for tensile-shear test

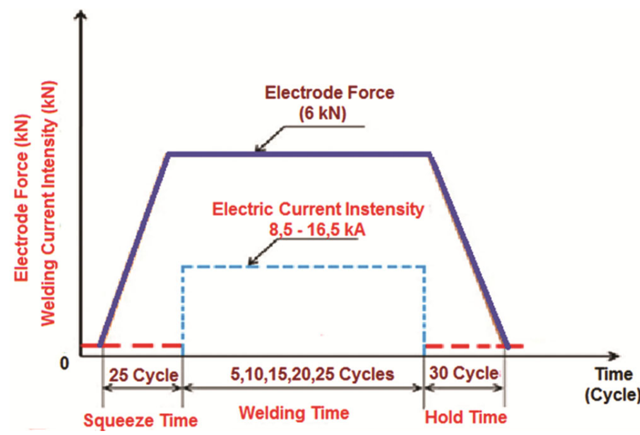

Fig. 2 — Welding cyclesfor spot welding

Results and Discussion

Tensile-Shear load values have been regarded as the maximum load during tests.According to the tensile-shear test results, as period duration raises, heat input raises which affects the weld nugget size and then, tensile-shear loads have been raised. However, in high periods causing excessive heat input give rise to expulsions and, in consequence, tensile-shear loads have been decreased. Similarly, as current increased, the lower periods have been performed the same behaviours. Tensile shear test samples are shown in Fig. 3.

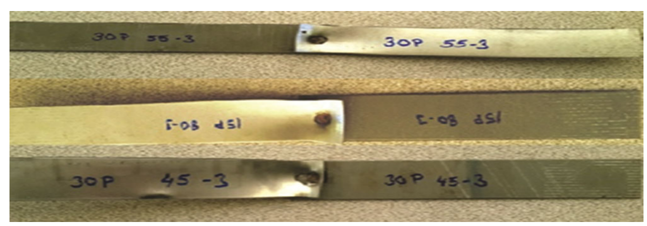
Fig. 3 — Pictures of tensile shear test samples after the tensile test

In tensile tests, there have been encountered three types of failure modes. (1) interfacial failure, (2) knotting and (3) tearing. Some of the samples that encountered different failure modes have been presented in Fig. 4.

Effect of welding time on tensile-shear load of weld joints in TRIP 800/microalloyed pairs are presented in Fig. 5. The maximum tensile-shear load value was obtained in 20 cycles at approximately 13.5 kA welding current.In 10 and 15 period welding times, tensile shear loads of specimens increase up to 15 kA where relatively the maximum point can be regarded for all periods and it decrease after 13.5 kA.

Table 1 — Chemical composition of TRIP 800 steels

C	P	Mo	Co	Ti	Sn	Si	S	Ni
0,179	0,011	0,025	0,072	0,014	0,01	1,719	0,007	0,074
Cu	V	Mg	Mn	Cr	Al	Nb	W	Fe
0,1	0,013	0,001	1,691	0,065	0,02	0,053	0,04	95,90

Table 2 — Chemical composition of microalloyedsteels

C	Si	Mn	P	S	Ti	Fe
0,12	0,50	0,60	0,10	0,45	0,30	97,93

In low welding time durations, due to low heat input, small weld nugget diameters were obtained; in return, lower tensile shear load value than that of base-metal was measured. As a result, interfacial type separation was observed. The same conditions were encountered in currents. In low welding currents,

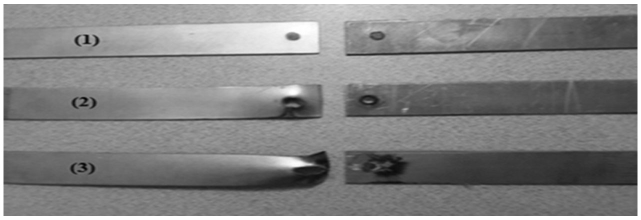

Fig. 4 — Breaking failure samples observed

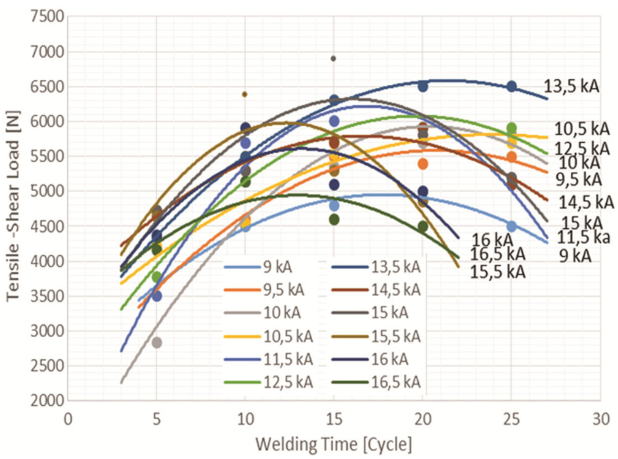

Fig. 5 — Effect of welding time on tensile-shearload of weldjoints

small weld nugget diameters were obtained and similarly, lower tensile shear load value than that of base-metal was measured due to low heat input at weld zone. As a result, the failure type was observed as interfacial separation.

Conclusion

As a result of the work performed at 6 kN electrode force, the obtained results and some suggestions are given below:

I. TRIP 800 and microalloyed steel sheets are welded successfully in RSW.

II. In the joining couple of sheets, maximum tensile shear load is obtained at 15 kA welding current in 15 period.

III. The maximum value of tensile shear load is determined as 6900 N using 15 period at 15 kA welding currents.

IV. Low welding times (5 -10 periods)is caused to interfacial separation failure mode

V. The tensile shear load is increased via increasing welding time

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