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Investigation of Fracture Surface of Different Metals Welded by Resistance Spot Welding

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In this study, dissimilar resistance spot weldability of DP steel and 1xxx series aluminium metal which is used extensively in automotive industry was investigated. For this purpose, DP 450 Steel and Al1050 alloy were selected. DP steel is galvanized. The aim of this study is to investigate the weldability of these two different types of metals and to detect elemental changes in the weld metal formed. For this purpose, fracture surface SEM and EDS analysis were performed.

Keywords; DP steel, Aluminium, Resistance spot weld, SEM, EDS.

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1. Introduction

The huge technological development demands and competition seen in the world in recent years have made it important for customers to meet the increasing security and environmental demands. For this reason, steel companies force and even oblige them to produce with the latest technology. The automotive industry is a leader in this regard. Fuel saving in vehicles can be possible by increasing engine efficiency and / or reducing vehicle weight. [1,2].

Dual phase steels (DP) with ferrite and martensite structures in its microstructure have high strength and formability and are frequently used in the automotive industry. DP steels, which were used in the early 1980s and occupy a large place in automobile manufacturing, have come to this day thanks to their ductility and strength. [3-5].

Aluminum is one of the most common elements in nature and it is the metal used most in engineering structures after steels. It is often used in applications where lightness is desired. In corrosive environments, it provides resistance due to its oxide layer on the surface of aluminum alloys. Aluminum alloys have good hot and cold forming capabilities [6,7].

Welding is an important manufacturing method. Welding is one of the most effective manufacturing processes employed in wide range of industrial application for joining of materials. One of the most common joining methods in the automotive industry is the electrical resistance spot welding method. The contact surface of the parts to be welded is heated with a low voltage and high current applied for a short time and converted into a molten welding core. When the electric current is cut, the molten metal cools rapidly and solidifies, so that the welding is finished [8,9]. In this study, 2 different metal resistance spot welds were carried out. Farcture surfaces were examined and SEM and EDS analysis were done.

2. Experimental Procedure

In the study, 1xxx aluminum alloy and zinc coated DP450 dual phase steel were used (Table 1).

Table 1. Chemical compositions (wt%).

Materials	C	Si	Mn	Fe	Cu	Cr	Zn	Al
DP450	0,05	0,13	1,32	Kalan	0,14	0,51	-	0.032

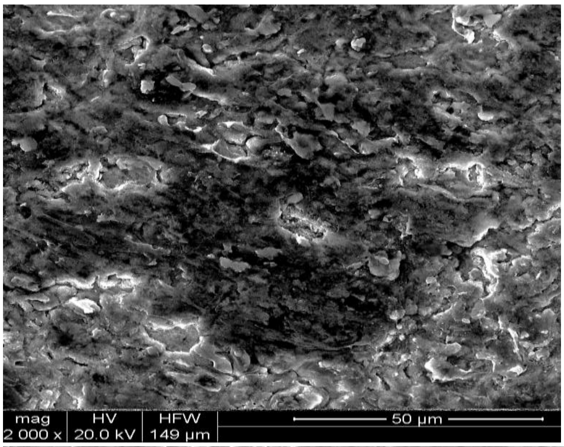
AA1050	-	0,25	0,05	0,4	0,05	-	0.05 % max	Kalan

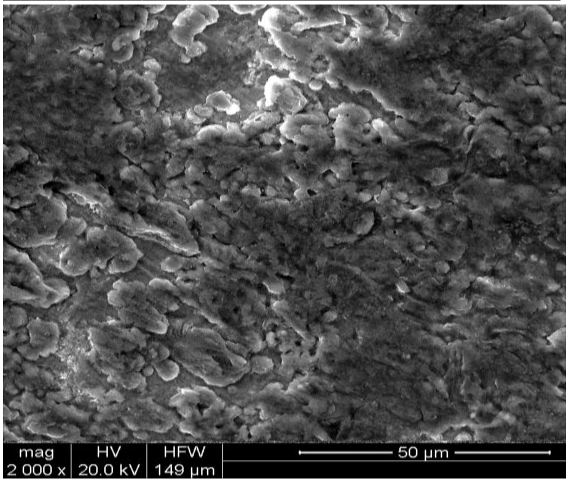
1.0 mm thick Steel and 2.0 mm thick aluminum sheet materials are cut in 30mm x 100mm dimensions. In the pneumatic and digital controlled point resistance welding machine, the materials placed overlapping 30mm were applied at 15 kA welding current for 15 cycles of welding time and 25 cycles of electrode retention. 4 x 105 Pa electrode pressing force has been adjusted. SEM analyzes and EDX analyzes were done in METU Laboratories.

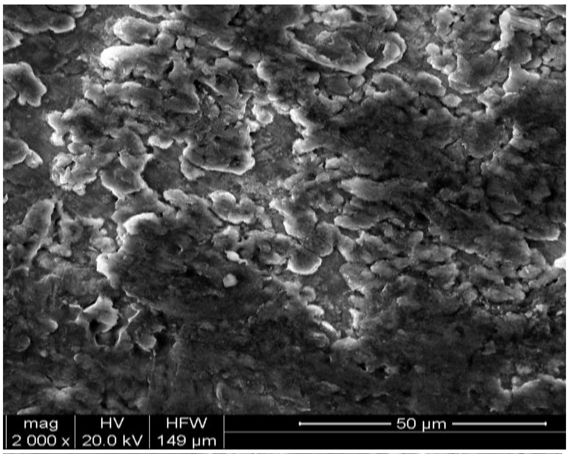
3. Results and Discussion

3.1. Fracture Surface

SEM images of welded joints of the tensile test fracture surfaces are given below.







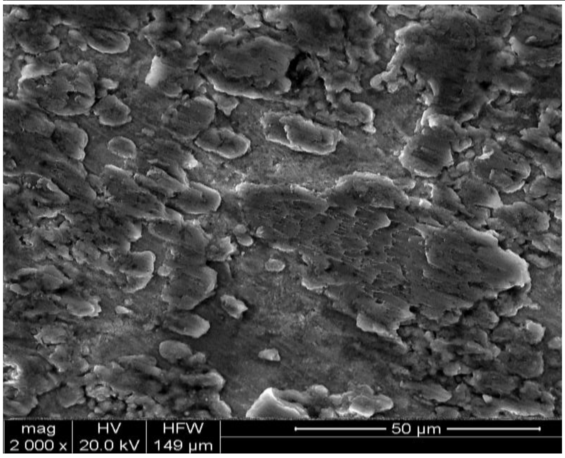
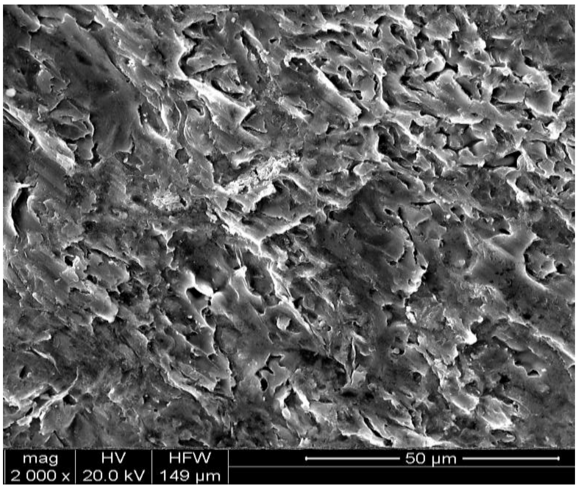


Figure 1. SEM images of steel side.

A fragmented and non-porous structure was seen in SEM photographs. Here, the surface of the severed surface of the welded joint on the steel side is given. Various brittle phases or intermetallics are thought to occur. SEM images on aluminum side are given in Figure 2.



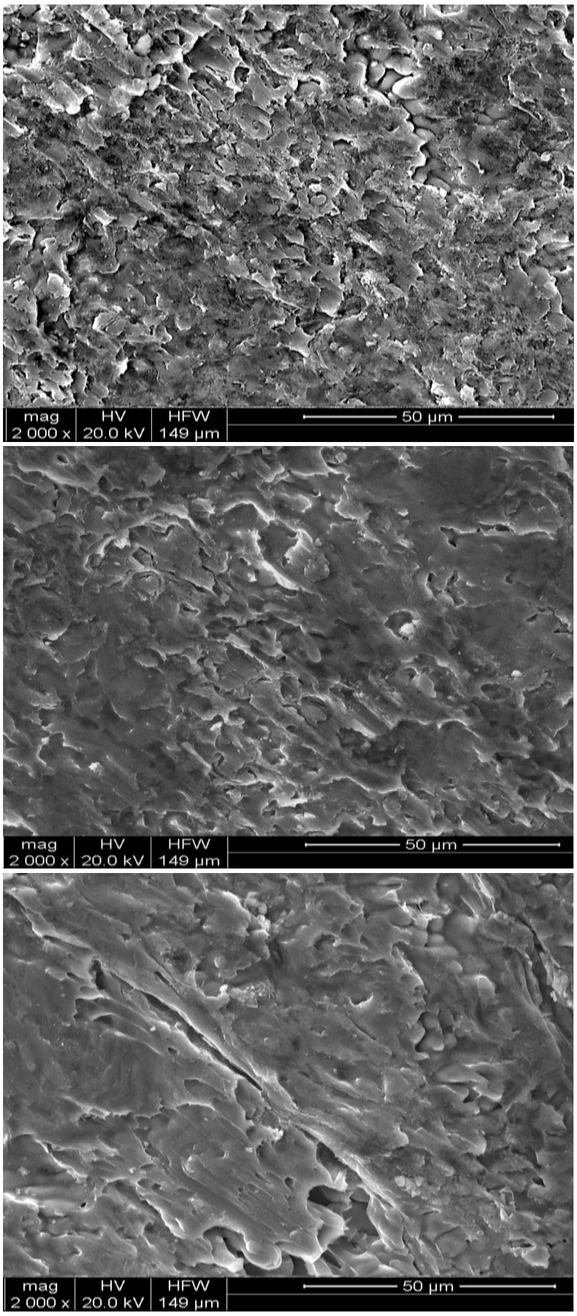
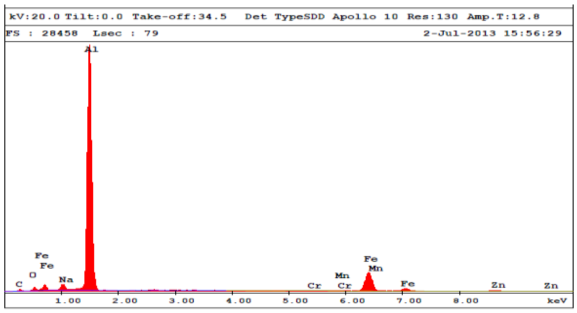


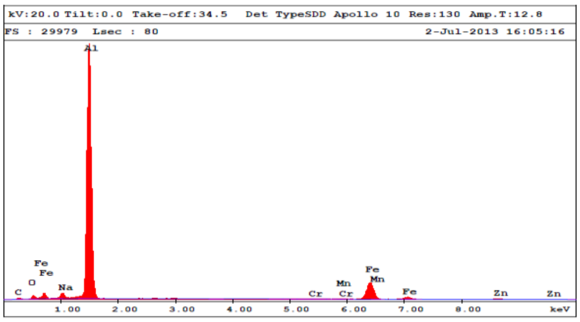
Figure 2. SEM images of 1xxx aluminium side.

When SEM photographs were examined, it was observed that different structures were formed from the steel broken surface. Considering that these structures are not ductile, it is thought to play an active role in the breaks. Structures in the form of plaster were identified in this region.



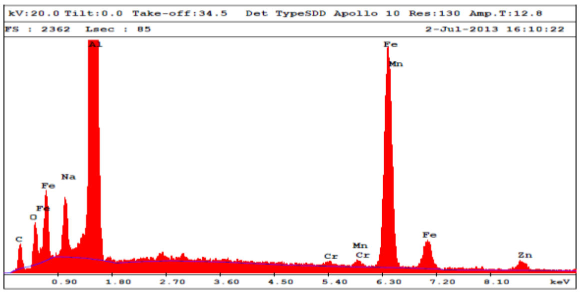
EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
NaK	2.15	2.94	0.0082	1.0266	0.3666	1.0086
AlK	70.09	81.66	0.4432	1.0211	0.6191	1.0002
CrK	0.27	0.16	0.0026	0.9319	0.9720	1.0646
MnK	0.48	0.28	0.0044	0.9149	0.9829	1.0028
FeK	24.05	13.54	0.2228	0.9320	0.9901	1.0041
ZnK	2.96	1.42	0.0262	0.9014	0.9816	1.0000
Total	100.00	100.00				



EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
NaK	1.93	2.61	0.0076	1.0249	0.3833	1.0093
AlK	72.39	83.30	0.4729	1.0195	0.6407	1.0002
CrK	0.24	0.15	0.0023	0.9302	0.9716	1.0597
MnK	0.56	0.32	0.0051	0.9132	0.9826	1.0024
FeK	22.37	12.43	0.2067	0.9302	0.9899	1.0036
ZnK	2.51	1.19	0.0222	0.8996	0.9829	1.0000
Total	100.00	100.00				

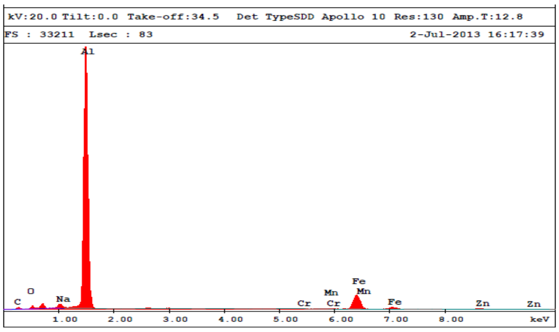


EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
NaK	1.73	2.35	0.0067	1.0259	0.3729	1.0090
AlK	71.35	82.73	0.4607	1.0204	0.6327	1.0002
CrK	0.29	0.18	0.0028	0.9312	0.9719	1.0636
MnK	0.50	0.28	0.0045	0.9141	0.9828	1.0021
FeK	23.88	13.38	0.2209	0.9312	0.9900	1.0032
ZnK	2.25	1.08	0.0199	0.9006	0.9817	1.0000
Total	100.00	100.00				

3.2. EDS Results

EDS results are given separately for both surfaces. The first group of analyzes are the EDS results of the steel surface side of the fracture surface.



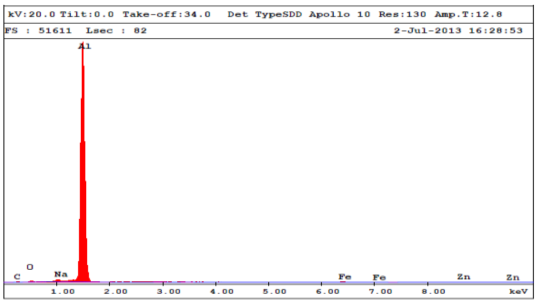
EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
NaK	1.53	2.04	0.0065	1.0226	0.4087	1.0103
AlK	75.68	85.66	0.5177	1.0172	0.6724	1.0002
CrK	0.18	0.11	0.0017	0.9278	0.9709	1.0533
MnK	0.44	0.24	0.0039	0.9108	0.9820	1.0020
FeK	20.10	10.99	0.1851	0.9277	0.9896	1.0031
ZnK	2.07	0.97	0.0183	0.8970	0.9849	1.0000
Total	100.00	100.00				

Figure 3. EDS result of steel fracture surface

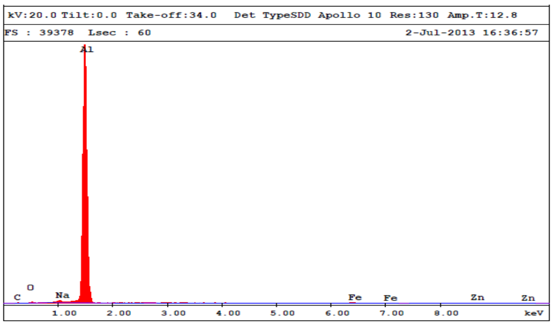
According to EDS results, the ratio of Aluminum as an elemental analysis on the steel side was approximately wt 70%, 71, 72 and 75%. Fe element was 20%, 22, 23 and 24% wt. The close ratios of each other indicate the accuracy and consistency of the results. Another active element is the element Zn. Zinc coated DP450 cause this situation. It has been determined that the zinc element between 2 and 3% has a role for fracture.

The second group of analyzes are the EDS results of the steel surface side of the steel fracture surface.



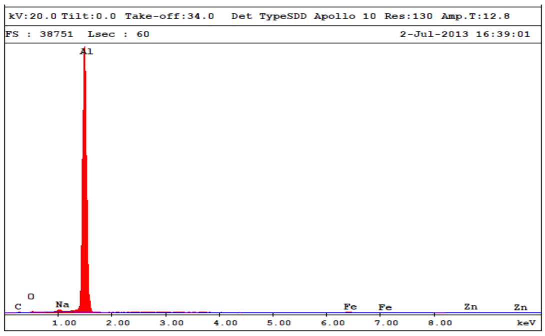
EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
NaK	0.91	1.09	0.0067	1.0074	0.7144	1.0240
AlK	96.26	97.64	0.8928	1.0022	0.9254	1.0000
FeK	1.24	0.61	0.0112	0.9115	0.9870	1.0032
ZnK	1.58	0.66	0.0140	0.8803	1.0015	1.0000
Total	100.00	100.00				



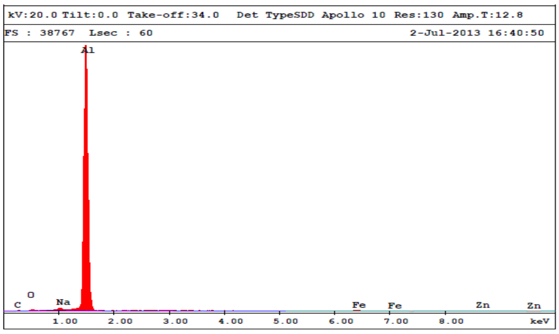
EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
NaK	0.76	0.91	0.0056	1.0073	0.7187	1.0244
AlK	96.60	97.90	0.9022	1.0021	0.9320	1.0000
FeK	1.22	0.60	0.0110	0.9114	0.9870	1.0029
ZnK	1.42	0.59	0.0125	0.8801	1.0015	1.0000
Total	100.00	100.00				



EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
NaK	0.80	0.96	0.0059	1.0075	0.7109	1.0239
AlK	96.23	97.70	0.8921	1.0023	0.9249	1.0000
FeK	1.38	0.68	0.0125	0.9116	0.9870	1.0032
ZnK	1.58	0.66	0.0140	0.8804	1.0013	1.0000
Total	100.00	100.00				



EDAX ZAF Quantification (Standardless)
Element Normalized
SEC Table : Default

Element	Wt %	At %	K-Ratio	Z	A	F
NaK	0.83	0.99	0.0060	1.0078	0.7031	1.0234
AlK	95.88	97.52	0.8821	1.0026	0.9176	1.0000
FeK	1.49	0.73	0.0134	0.9119	0.9870	1.0037
ZnK	1.80	0.76	0.0159	0.8807	1.0012	1.0000
Total	100.00	100.00				

Figure 4. EDS results of aluminium side.

As the elemental analysis on the aluminum side, the aluminum ratio was measured as approximately wt 95% and 96%. This measurement shows that steel cannot play an active role in joining in this region. The element of Fe was about wt ranging from 1.2

% to 1.4%. The zinc element was more than iron. Their rates range from 1.4% to 1.8% wt.

In addition, it was found that other elements don't affect mechanşical properties of joinings. SEM photos have shown that soft aluminum is more and has been proven by EDS analysis.

Ranfeng Qiu et al. [10] examined the fracture surface EPMA images of A5052 aluminum alloy and low carbon SPCC steel. He reported that iron, aluminum and magnesium alloys are seen in a prominent figure. It has been reported that iron is more in the middle part of the button part and aluminum is more in the edges.

4. Conclusion

As a result of the joining of DP steel with aluminum by resistance spot welded:

1. It was seen that the fracture surface images change according to which side of the joining.
2. According to SEM analysis, while the spherical structures appear darker on the steel side and different ovality, longitudinal and plastered images were obtained on the aluminum side.
3. According to EDS results, the ratio of aluminum elements at steel was high.
4. The iron element on the steel side was higher than the aluminum side. In addition, it was determined that the zinc ratio was higher than iron in the analysis on the aluminum side.

Acknowledge

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