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ScienceDirect
Procedia Engineering 10 (2011) 1748–1753
Engineering Procedia
ICM11

A study on integrity assessment of the resistance spot weld by Infrared Thermography

Sangyun Lee[a*], Junyoung Nam[b], Woonggi Hwang[b],Jaeseong Kim[b], Boyoung Lee[c]

[a,b] *Department of Aerospace and Mechanical Engineering,*
[c] *Faculty of Aerospace and Mechanical Engineering,*
Corresponding author: Boyoung Lee, bylee@kau.ac.kr,

Korea Aerospace University, Goyang-city, Gyunggi-do, 412-791, Rep. of Korea

Abstract

In the automotive industry, the Resistance Spot Welding(RSW) has been applied for many years In order to reduce the vehicle's weight and production costs. Typically, a car body contains about more than 4300 spot welds joining sheets of different thicknesses for making just one car and this trend is expected to be continued. However, There are not many Methods to inspect the resistance spot weld. Although measurement of Tensile shear strength and nugget diameter is widely used, another method which is more efficient is required for time and cost savings. The scope of the present study was to find out the most effective approach to non-destructive evaluation of resistance spot welding. Three different techniques such as Photo infrared thermography, Ultrasound-infrared thermography and Lock-in methods were used to acquire information for evaluation of weld soundness. Through experiment, we were able to obtain infrared images and then compared the nugget size with using the naked eye. Eventually, we concluded The mean size of the nugget observed by the naked eye showed the difference of about 20% in the mean size of a nugget actually; The mean size of the nugget observed by infrared thermography showed the difference of about 8% in the mean size of a nugget actually.

Selection and peer-review under responsibility of ICM11

Keywords : Resistance spot welding, Infrared Thermography, Ultrasound infrared, Photo infrered, Lock-in infrared

* Corresponding author. Tel.: +82-2-300-0057; fax: +82-2-3158-0453.
E-mail address: sang830@kau.ac.kr.

1. Introduction

In the automotive industry, the similar and dissimilar metal welding of the high strength steel, aluminum ally, titanium alloys, Mg, and etc. are widely used for quality improvement and lightweight of a vehicle. Accordingly, the weld soundness between materials is considered to be an important subject. Although a car body contains about more than 8000 spot welds joining sheets of different thickness, the method appraising the soundness of resistance-spot-weld such as macro test, tensile shear test, and etc. which are specified in ISO 14273 is limited; This method has the disadvantage which is that wasted time and cost. Through research, a new method using Infrared Thermography is proposed to inspect weld soundness by measuring nugget size.

Infrared Thermography is examples of infrared imaging science. Thermal imaging cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 9000–14,000 nanometers or 9–14 μm) and produce images of that radiation, called thermograms. There are two kinds of the heat source. The first is passive type which is to determine the radiation energy of the object itself, and the other one is active type which is to determine the radiation energy after another heat source is given to an object. In this research, an experiment was progressed by the second way. Herein halogen lamp and vibration was given as a heat source. And also there are three kinds of detection methods such as Photo infrared thermography, Ultrasound-infrared thermography and Lock-in methods; herein we used all of them; the results were shown as follows.

2. Experimental method

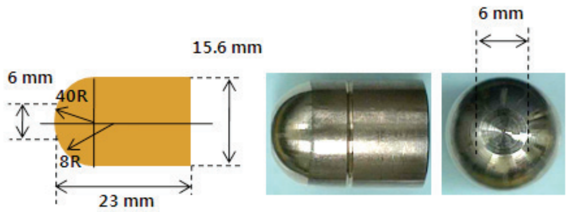
2.1 Materials

The cold rolled carbon steel sheet (SPFC590) and high strength galvanized steel (EZFFC590) which are commonly used as parts automobile body panel, were used for this study. The dimensions of the specimens are 1.0 mm and 1.4 mm in thickness and 100 mm in length and 30 mm in width. The composition and mechanical property of the specimen is given in Table. 1. An electrode in Fig. 1 is 16mm in diameter, 23mm in length and D-type electrode containing some chrome and copper. Using SCR-AC Resistance Spot Weld machine, we spot-weld automobile body panel specimen and then inspect the soundness of weldability.

<Table. 1 SPFC590 and EZFFC590 composition and mechanical property>

	Chemical composition						
	C	Si	Mn	P	S	S-AL	Fe
SPFC 590	0.08	0.27	1.6	0.002	0.002	0.006	B
EZFFC 590	0.098	0.98	1.5	0.073	0.002	-	B

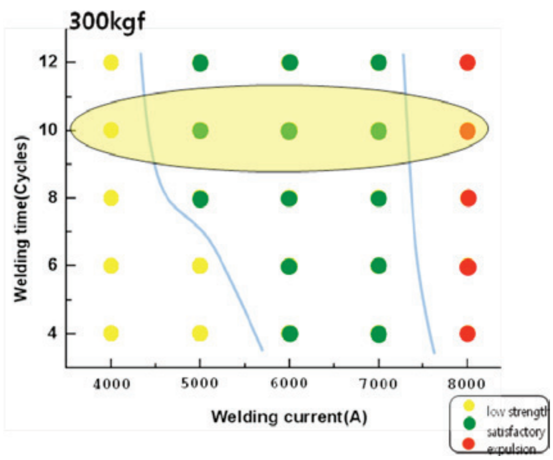
	Mechanical properties					
	YP (MPa)	TS (Mpa)	EL (%)	BEND	IMPACT	HARDNESS (HRB)
SPFC 590	509	623	27	G	G	89
EZFFC 590	420	617	34	-	-	-



<Fig. 1 Electrode>

2.2 Selected welding range

This research didn’t experiment on all welding ranges; so we limited extent of welding and then made experiment on like figure and table below. The figure was obtained from previous studies. In the middle of the figure we chose welding range which is drawn a circle. For SPFC 590, spatter was generated from 8kA when the thickness was 1.0mm and from 10kA when the thickness was 1.4mm. For EZFFC590, spatter was generated from 9kA when the thickness was 1.0 mm, and from 9kA when the thickness was 1.4mm. The experiment shows that spatter seems to be easily generated in high current and thicker condition.

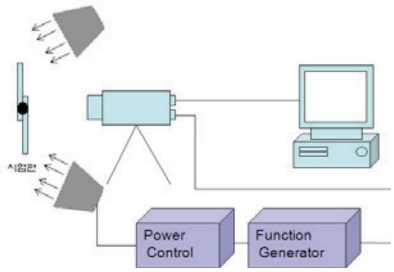


<Fig. 2 Selected welding range>

<Table. 2 Welding conditions>

<table>
<tr><th>Type/thickness(mm)</th><th>Current</th><th>Cycle</th><th>Kgf</th></tr>
<tr><td>CR, GA 1.0X1.0</td><td>6,7,8,9kA</td><td rowspan="4">10</td><td rowspan="4">300</td></tr>
<tr><td>CR, GA 1.0X1.0</td><td>6,7,8,9kA</td></tr>
<tr><td>CR, GA 1.4X1.4</td><td>7,8,9,10kA</td></tr>
<tr><td>CR, GA 1.4X1.4</td><td>7,8,9,10kA</td></tr>
</table>

2.3 Equipment

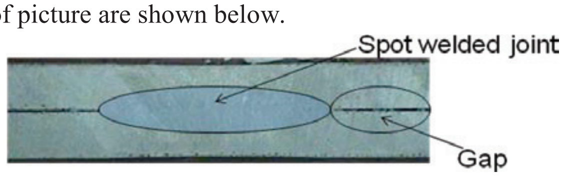


<Fig. 3 Equipment set-up>

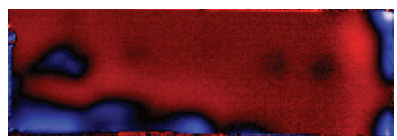
The camera is Cedop Silver 480m (NEDT : 25mk). The distance between heat source and the camera is around 1 m; the heat source is 1000W for each lamp and oscillation frequency varies from 100 to 300 mHz; before the experiment, the black paint was coated with the specimen in order to give the same emissivity.

3. Analysis of results

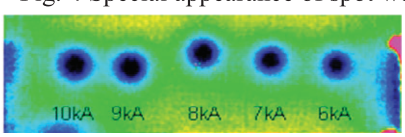
By applying three thermal image techniques, an experiment was conducted. And we found out that the special appearance in Fig. 4 between sections of spot welded joint including weld which are closer to each other influence image quality. When it comes to ultrasound, Ultrasound infrared thermography didn't indicate a good quality image because of the special appearance. However, when it comes to Photo infrared and Lock-in method, the image quality was better. Especially, when it comes to Lock-in, we could get much better image quality and even we could measure the nugget width size quantitively. Three kinds of picture are shown below.



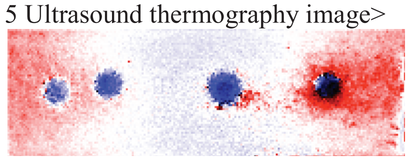
<Fig. 4 Special appearance of spot weld>



<Fig. 5 Ultrasound thermography image>



<Fig. 6 Photo-infrared thermography image>



<Fig. 7 Lock-in infrared thermography>

Figures show that For the Ultrasound technique we couldn't see any outline of the weld shape; there seems like appearing little circle in the middle of specimen, but it is not clear. For Photo-infrared, the shape of weld is clear to see, but it is not suitable for measuring the nugget size quantitively because of low resolution, you can see outside of the nugget seems to be cloudy. For Lock-in thermography, it is possible to measure the nugget size quantitively; we can get much clearer image and high resolution.

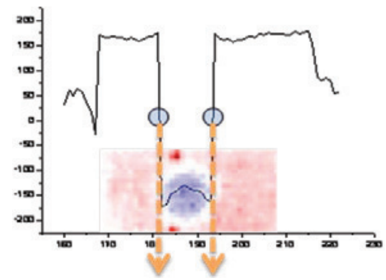
Finally, the experiment has been shown that we can measure a nugget size by Lock-in thermography, and Lock-in thermography is the best method among them.

The remaining experiment is to compare among the nugget observed with naked eye and the real nugget size observed inside the specimen and the nugget size observed by Lock-in method.

3.1 Measurement data analysis

3.1.1 Measurement procedure

Here, we suggest a simple practical technique for quantitative determination of the nugget size. We can get a graph according to the color difference. First find maximum gradient line in figure and then select the middle point of a slope and drop straight line with a bottom. After that size of the dimension is measured by the number of pixels counted. With that method we can measure the nugget size quantitively.



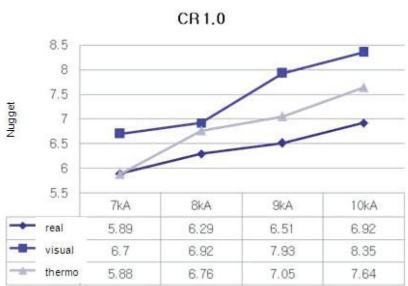
< Fig. 8 measurement of resistance spot weld size>

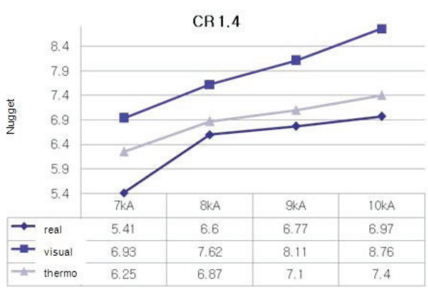
3.1.2 acquisition data

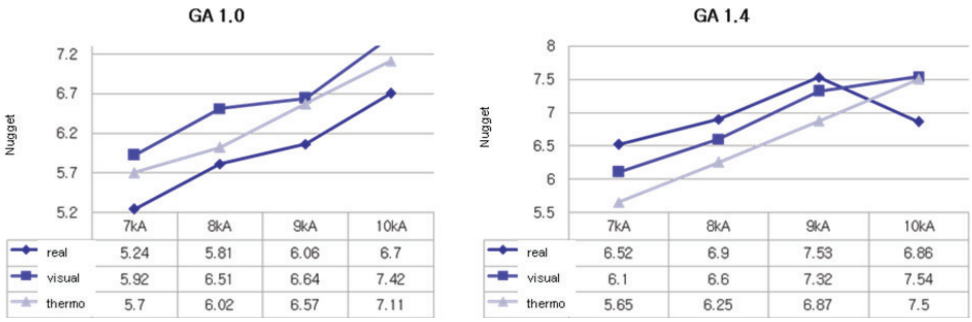
< Table. 3 acquisition data by Lock-in method>

	CR1.4	CR1.0		GA 1.4	GA1.0
7kA	6.25	5.88	7kA	5.65	5.7
8kA	6.87	6.76	8kA	6.25	6.02
9kA	7.1	7.05	9kA	6.87	6.57
10kA	7.4	7.64	10kA	7.5	7.11

The nugget size is measured according to the current, thickness, steel type. And we can easily find the difference between GA steel and CR Steel about sizes at the same current. The current is getting higher, also the nugget size is getting bigger. And this is not big influenced by the thickness.







<Fig. 9 Comparison of the mean nugget size>

For CR steel, the mean size of the nugget observed by the naked eye shows the difference of about 22% in the mean size of the real nugget. However, the mean size of the nugget observed by Lock-in thermography shows the difference of about 9% in the mean size of the real nugget. And for GA Steel, The mean size of the nugget observed by the naked eye shows the difference of about 20% in the mean size of a real nugget. However, the mean size of the nugget observed by infrared thermography shows the difference of about 6% in the mean size of the real nugget. This experiment shows that using infrared thermography is more accurate than the naked eye with 15%, when measuring the nugget size.

4. Conclusion

This study conducted the nugget size measurement to acquire information for evaluation of resistance spot weld soundness by the naked eye, cutting and measuring inside the weld and using infrared thermography. The result confirmed that Lock-in technique is the most effective method to inspect the soundness of resistance spot weld in non-destructive testing. Infrared thermography with Lock-in displays having much more accurate than the naked eye with 15%.

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