THE FAILURES OF WELDED JOINTS ON CAR BODY STEEL SHEETS

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Abstract

The paper deals with description of failures of resistance spot welded joints on car body steel sheets. The basic physical conditions necessary for spot welds creation as well as primary and secondary parameters of resistance spot welding were defined. The particular failures of spot welded joints on hot-dip galvanized steel sheet DIN St 04Z (EN Fe PO4G) and high strength multiphase steel TRIP RAK 40/70 were investigated on metallographic scratch patterns by optical light microscopy. The resistance spot welding was conducted on pneumatic programmable spot welding machine BP 20.

Key words: resistance spot welding, quality analysis

INTRODUCTION

Resistance spot welding is one of the oldest of the electric welding processes used in the modern manufacturing technology. The weld is made by combination of heat, pressure and time, where no filler metals or fluxes are needed [1]. The resistance spot welding is for its characteristic properties predestined to widespread use in serial and mass production with high labour productivity. The automotive industry has experienced a great boom in recent years, and the resistance spot welding is the main joining method since 1930 [1,2]. A lot of spot welds are used to make a car construction to achieve the desired properties (from two thousand to five thousand spot welds). The need for lightweight construction become a great interest in the automotive industry to achieve the improvement of fuel economy. The high proportion of hot-dip galvanized steel sheets are utilized in car body construction in automotive industry. The zinc coating significantly affects the formation of the weld nugget and wear of welding electrode [2], especially when three or more steel sheets are welded together, which negatively affect the quality and load bearing capacity of welded joints [3]. The use of two welding electrodes limits the machine adaptability for resistance spot welding of car body sheets. Resistance spot welding is the main joint mode in car body manufacturing and it is a complex process containing the thermoelectricity, metallurgy and many other factors. The quality of spot welds directly affect the durability and crashworthiness of cars.

The resistance spot welding processes follow Ohm’s law and Joule's law [3,4].
Ohm's law:

$$I = \frac{U}{R} \quad [A] \quad (1)$$

where: 
I – current [A],
U – voltage [V],
R – electric resistance [Ω]

The voltage in resistance spot welding is in the range of 3 ÷ 20 V, therefore there is no risk of electrical injury.
Joule's law:

$$Q = R \cdot I^2 \cdot t \quad [J] \quad (2)$$

Amount of heat in the weld is influenced by the following [4]:

a) the higher welding current, the higher amount of heat in the weld,
b) the longer welding time, the higher amount of heat in the weld,
c) the higher weld resistance, the higher amount of heat in the weld.

The basic parameters of resistance spot welding

The pressing force of welding electrodes may be constant or changeable. Its function can be electrical – affect the contact resistance and metallurgical – prevents the molten welding nugget to expand as well as influences the grain growth during solidification. The pressing forces of electrodes are between 100 N and 50 kN [4,5].

The welding current and the welding time are crucial determinants affecting heat generation in the weld. The welding current may be constant or changeable during the welding process. As the current is in the square (Joule's law); the heat theoretically increases fourfold, the welding current increases doubly. The welding current is usually in the range of 100 A to 100 kA and welding times in the range of 0.001 s to 2.0 s [5,6].

These welding parameters are related to each other, resulting in hard and soft welding regimes (Fig.1) [6,7].
Besides the basic welding parameters, it is necessary to consider the other factors that influence the welding process such as minimum size of lapping, distance between sheet edge and spot weld, the diameter of spot weld, the minimum value of load bearing capacity and the others [5].

![Image of welding regimes](image)

**Fig. 1 Area of welding regimes [5]**

Considering the implementation of new steel grades (mainly high-strength steels) in the production, the resistance spot welding requires a consistent optimization of welding parameters according to type of material and its thickness. A key role in optimization of welding parameters plays identification of failures or problems in the welding process. These failures can be detected by non-destructive and mainly used destructive methods. Currently ultrasonic testing is a non-destructive method increasingly used for evaluation of spot welds. This method, however, is unable to identify the failures such as cold joints. The peel and chisel tests are typical destructive methods for evaluation of fusing joint. The important method of evaluation of spot welds is metallographic analysis; evaluation of macro and microstructures of resistance spot welds.

**The failures of spot welds**

The most frequently occurring failures of spot welded joints made by resistance spot welding are:

- cold joints (Fig. 2),
- cavities and pores in the middle of weld nugget (Fig. 3-6),
- hot cracks in the middle of weld nugget (Fig. 7),
- intercrystal cracks in heat affected zone (Fig. 8),
- impurities of the joint in the place of lapping due to expulsion of molten metal of weld nugget (Fig. 9),
- impurities of the joint in the place of lapping due to expansion of Zinc coating,
- impurities of the weld joint surface by brass layer during spot welding of hot-dip galvanized steel sheets,
- dimension failures of weld nugget:
  - significant marks of electrode tips on the welded sheet surfaces (Fig. 10),
  - insufficient dimensions of weld nugget,
  - failures of weld nugget shape (curvature of the weld nugget) (Fig. 11),

The occurrence of the most common failures are mainly affected by used welding parameters as well as grade and surface treatment of welded materials, thickness of welded material and surface layers, shape and geometry of welded tips [8-10].

![Image of cold welded joint](image)

**Fig. 2 Cold welded joint**

![Image of cavities in weld nugget](image)

**Fig. 3 Cavities in the middle of weld nugget**
Fig. 4 Cavity in the middle of the weld; small dimension of weld nugget

Fig. 5 Asymmetrical cavity in the weld nugget

Fig. 6 Microstructure of the cavities in the middle of weld nugget with the visible direction of solidification of weld metal

Fig. 7 Weld microstructure with cracks perpendicular to weld nugget

Fig. 8 Crack in the periphery of HAZ of TRIP steel

Fig. 9 Expulsion of molten metal from the weld

Fig. 10 Course-grained structure of the weld; significant marks of electrode tips (high value of welding current)
CONCLUSION

The paper presents the most frequently occurring failures of resistance spot welded joints. The metallographic scratch patterns with identified particular failures, realized within experimental works focused on optimization of welding parameters of hot-dip galvanized steel sheets, are documented. Based on the experiments it can be stated that the most risky failures are cold welded joints and cracks in the weld metal and heat affected zone. They occurrence rapidly decreases the load bearing capacity of the joints thereby increasing the risk of destruction of the car body part already under moderate stress. The presence of cavities in the middle of weld nuggets caused by zinc expansion or weld metal expansion did not have a significant negative effect on the load bearing capacity of the joints. However, for classification the spot welded joints in the highest quality these failures are unacceptable.

Reference


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