Journal of Materials Processing Technology 230 (2016) 21–25

Contents lists available at ScienceDirect

Journal of Materials Processing Technology

journal homepage: www.elsevier.com/locate/jmatprotec

Poor fit-up condition in resistance spot welding

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ARTICLE INFO

Article history:
Received 6 July 2015
Received in revised form 8 October 2015
Accepted 10 November 2015
Available online 1 December 2015

Keywords:
Resistance spot welding
Poor fit-up
Welding force
FEM

ABSTRACT

An experimental setup for poor fit-up condition research, which makes it possible to analyze poor fit-up conditions of different intensities and also quantify them is presented. The intensity of poor fit-up condition can be estimated by measuring the welding force during the initial contact between the electrode tips and the weldpieces. In order to reduce the negative influence of the poor fit-up condition on weld strength an addition of preheating phase was studied. Although it helps to increase the weld strength, a significant gap remains between the weld strength of non-deformed welds and poor fit-up welds even at large preheating currents.

1. Introduction

Resistance spot welding (RSW) is a welding process that joins two (or more) faying surfaces by the application of heat and pressure. For a good quality spot weld it is most important that the weld nugget has an appropriate size. This size is related to the welding parameters such as welding time, welding current, welding force, etc. An optimal combination of these parameters of course varies with varying sheet thicknesses, weldpiece(s) material(s), possible coatings and so on. The problem is however that the optimal combination of welding parameters varies due to various disturbances as well. Podržaj et al. (2008) gave an overview of all the major disturbances. The most important ones are variable surface conditions, variable contact area between the electrodes and the workpieces, variable sheet and coating thicknesses, poor fit-up of the workpieces, shunting, edge proximity, disturbances in the power supply, etc. The most elegant approach to solve this problem is the application of a feedback control system. The majority of control systems use one or more signals, which are related to the weld nugget growth, as a feedback and adjust the welding parameters accordingly. Recently, a lot of research is being done in this field. The most commonly used feedback signals are electrical signals. Zhao et al. (2013) for example used the welding voltage, Zhou et al. (2015) the welding current and Zhou and Cai (2013) the dynamic resistance. Other signals are being used as well. Zhang et al. (2014) for example used the electrode displacement signal as an input for a neural network. The problem of this approach is that the thermal expansion of the electrode holders is included in the signal as well. This problem was solved and experimentally verified by Simončič and Podržaj (2014) using image processing. Other signals such as acoustic (Luo et al., 2013) and sonic emission (Podržaj et al., 2005), ultrasound transmission (Martín et al., 2014), and temperature (Podržaj and Simončič, 2013) are not used so often. Of course these signals can also be used in combination and often such an approach gives more reliable results. Podržaj and Simončič (2011) for example used them as an input to fuzzy logic based control system. When analyzing the suitability of different input signals for an artificial neural network Podržaj et al. (2004) found out that the most influential signal for the detection of expulsion happens to be welding force. Although there are applications where welding force is used as an output signal of a control system (see Ikeda et al., 2014 for example) in the research presented here it is used as a feedback signal. The phenomenon that we want to relate it with is the poor fit-up. This type of disturbance has already been considered in some previous research. It has been found out that such a disturbance results in a smaller weld nugget being formed due to the small workpiece contact area at the initial stage of the welding process, when the fit-up is poor (Jou, 2003). It has also been shown, that poor fit-up results in a much narrower weld lobe (Cho et al., 2006), which implies a less robust welding process. Beside that, the welds are much more prone to expulsion (Zhang et al., 2012). All the above mentioned papers simulated poor fit-up with just a single experiment setting. This would indicate that poor fit-up can only be of one type. In the presented research poor fit-up conditions of different intensities have been analyzed. Possibilities of the reduction of a negative influence

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http://dx.doi.org/10.1016/j.jmatprotec.2015.11.009
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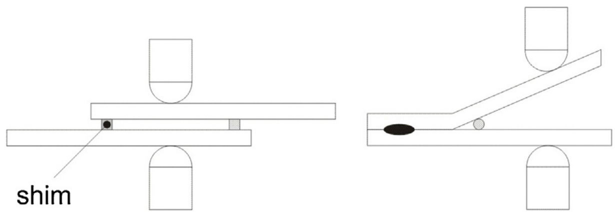

Fig. 1. Possible poor fit-up experimental setups found in the literature (Jou, 2003; Cho et al., 2006).

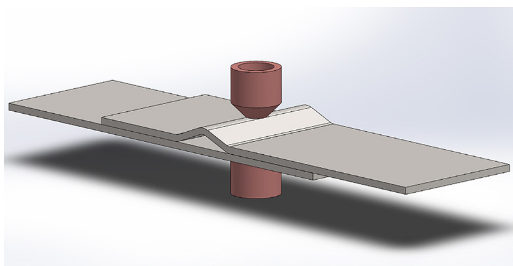

Fig. 2. Poor fit-up experimental setup.

that poor fit-up condition has on the weld strength have also been researched.

2. Theoretical background

Although other poor fit-up simulation experimental setups have been used (see Fig. 1), in our case a decision was made to use weld specimens deformed into a triangular shape. The setups shown in Fig. 1 are namely based on the insertion of a foreign object between the weldpieces. This object stays there during the welding process and therefore does not reflect the reality very well. In our opinion during welding process there should be no object between the weldpieces. Therefore an experiment, a 3D model of which is shown in Fig. 2, is preferred. Whereas lower weldpiece is of normal (non-deformed) shape, the upper one is deformed in such a way that there is a triangular shaped bulge present in the place where the upper weldpiece will be pressed on by the upper electrode. In order to make this kind of deformity a special purpose tool was made (see Fig. 3). It has three pins which are welded to a metal sheet in such a way that a weldpiece can be inserted between the pins. The pins have to be long enough in order that they deform elastically when the tool together with the weldpiece is inserted into a vise

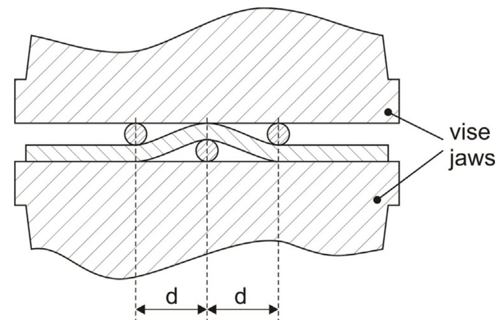

Fig. 4. Sample preparation using a vise.

and the vise jaws are pressed. The resulting weldpiece is shown in Fig. 4. Tools with different distances between pins (parameter *d* in Fig. 4) were made. The appropriate range of parameter *d* was determined based on the simulations performed in Ansys. The Ansys model was made in order to study the contact between the weldpieces after the weld force is applied. Due to symmetry a 3D half model was used (see Fig. 5). For weldpieces a bilinear elasto-plastic material model was used with tangential module of 2000 MPa, and the yield point of 235 MPa. The surface-to-surface contact elements (TARGE170 and CONTA174) were used for modeling of mechanical contacts and sliding between two steel sheets, and between sheets and electrodes. A high quality mapped mesh was ensured comprising of brick shaped finite elements only (Fig. 5). The element size between 0.5 mm and 1.0 mm is small in comparison with the thickness of the steel plates assuring 4 elements along the thickness. The result (Mises equivalent stress) is shown in Fig. 6. The most important conclusion of this analysis is the fact that despite the plastic deformation (gray color) there is a gap between the weldpieces. The same experiment was made for different values of parameter *d* and in accordance with the expectations the size of the gap depends on this parameter.

In order not only to detect but also to quantify the intensity of the poor fit-up condition, the welding force during the initial contact between the electrode tips and the weldpieces was measured. An assumption was made that the intensity of the deformation (parameter *d*) must be related to the welding force curve, because the deformity acts like a spring with a certain spring constant.

As it is well known that poor fit-up in general implies smaller welding nugget and consequently inferior weld strength, the influence of a significant preheating on the weld strength has also been researched. For that purpose we applied the welding current profile

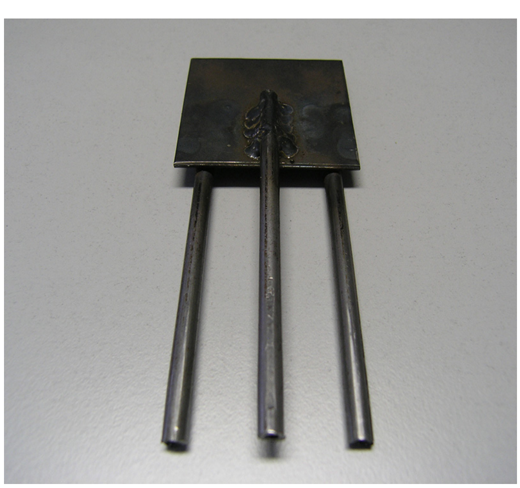

Fig. 3. The tool inserted into the vise.

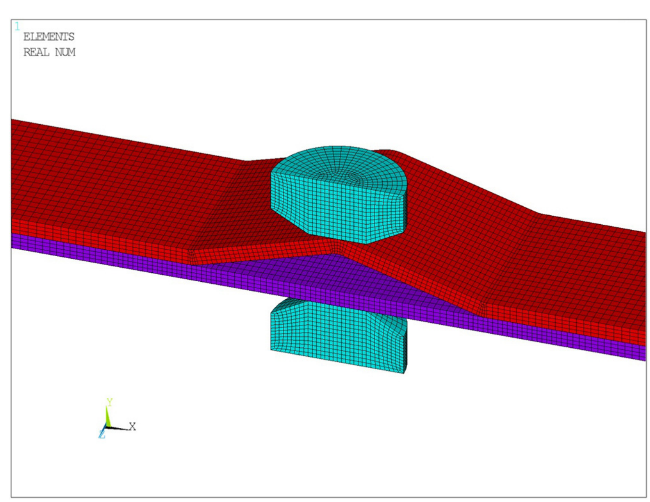

Fig. 5. The meshed finite element model.