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RESEARCH ON WELD NUTS FIXED BY RESISTANCE WELDING

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Abstract
This paper presents the principles of projection welding deriving from spot welding by resistance. In practice one would meet quite often situations where this welding process should be used in order to facilitate the use of wrench to make the structure envisaged. We present the findings of experimental research carried out in order to implement this process on the product, one resulting the technological parameters for welding

***Keywords*—** projection welding, resistance welding, spot welding, welding parameters, weld nuts

INTRODUCTION

In practice, there are frequent situations where at the making of *screw-nuts* releasable connections it is difficult or even impossible to reach at the nut positioning in order to assembly components. In such cases it is necessary to pre-set the nut on one of the components to avoid the use of the wrench, a fastening made in general by mechanical means or welding.

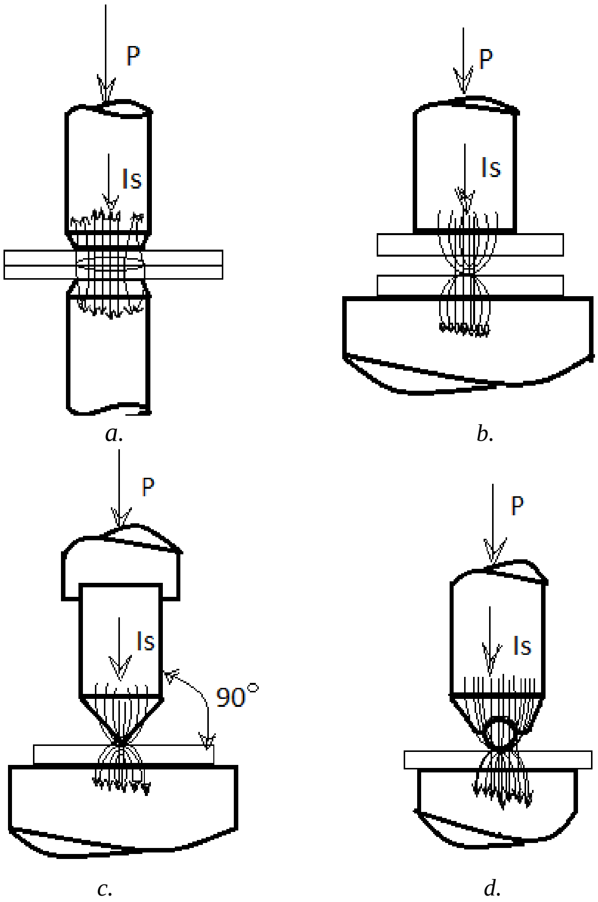
Weld nuts fixed by resistance welding (WNFRW) is a technical process used massively for such applications because of its advantages i.e. high productivity, low cost, saving energy and materials, simplicity, aesthetics, and last but not least, its reproducibility nature, strength and the high quality of welds. This method implies the use of specialized welding equipment, custom designed nuts and the mobility of the welding machine' parts or subassemblies; this is why this method is beneficial to large-scale series or mass welding.

In general electric weld nuts fixed by resistance welding is used frequently on thin plates. Welding of steel nuts on heavy plates presents some difficulties terms of assuring welding quality as compared to welding on thin plates <3mm, due to difficulty of ensuring plate's heating and melting which leads to a poor welding from the mechanical strength point of view.

I. WNFRW PROCESS' PRINCIPLE

Projection welding is a method of electric welding by pressure derived from spot welding by pressure to which the joint is made by flanges (embossments, bosses) placed on one or both parts to be welded, thus obtaining a focusing of welding current in the welding points.

Unlike spot welding (see Figure 1.a bellow) where the electrodes set the current flow area, in the case of projection welding the current focusing is achieved by the point contact made between the parts to be welded, enclosed between electrodes (plates) designed to send the current to the welding area, at the same time with applying the clamping force required. It is essential to replace the plan contact between surfaces by a point or linear contact. This is made by the embossments (flanges) which can be artificial ones (see Figures 1.b and 1.c bellow) or natural (see Figure 1.d bellow) /3; 8/.



a. *b.* *c.* *d.*

Fig. 1. Focusing current at projection welding: a) Spot welding; b) Projection overlap welding; c) T Welding; d) Cross welding

The flange delimits perfectly the welding current crossing area. It provides a good separation of the contact between components thereby concentrating the amount of heat generated, which is an advantage. It is noted that the welding current passes from one component to another only through the flange.

At the beginning of the welding process, the heat is very localized and intense at the between components due to the small contact area between the components which results in a high electric resistance, and a high current density respectively. As contact area gets heated, the current's crossing area increases by flattening the flanges and roughness, and when the entire volume of material forming the flange gets plastic the latter flattens thereby causing the components clustering and the formation of the melted nucleus and the welded joints are made under the action of pressure (downforce) of electrode plates.

The main advantages of WNFRW are as follows /1/:

- high productivity welding due to the possibility to weld multiple spots simultaneously;
- a better and localized heat focusing by means of the flange (boss);
- a less wear and tear of electrodes due to their plate shape thereof and the low density of current passing through.

Due to the fact that the flange is also known as boss, the EPWP process is also known as electric welding by pressure (downforce) through overlapping bosses.

Basically the flanges projections (bosses) can be divided into artificial flanges and natural flanges.

Flanges should meet the following conditions /2; 7/:

- They should be sufficiently rigid so as not to flatten under the downforce action before current is passing through and throughout the first passing times of current; the bosses' rigidity is provided by their mechanical strength and positioning, /1/;
- They have enough volume in order that the component it gets in contact with reaches the welding temperature required without melting the flange in advance /4/;
- They should be simple, easy to perform and have stable shapes /6/.

Artificial flanges are made by means of a mechanical process, plastic deformation or metal cutting. Flanges and bosses' sizes and dimensions are standard. They are featured by the height "h" and the boss base diameter "d".

Natural flanges are obtained by means of relative positioning of components in such a way that the passage of welding current be located in a contact area where the welded joint is to be made. The contact area can be achieved in a single point (spot) or line. The most typical case of EPWP with natural flanges welding is the cross welding of two bars, pipes or other round shape components. By crossing these components, one obtains a point contact area at the intersection of generators (intersection of two perpendicular cylinders).

II. WELDING TECHNOLOGICAL PARAMETERS

As with the spot welding, the main parameters of the projection welding are as follows: welding current (Wc), welding time (Wt) and the downforce applied to components (D) /4; 6/.

A. Welding current (Wc)

Welding current strength should be sufficiently large to generate the necessary thermal field before they flatten the flanges. At this moment the temperature in the contact area should get near to the melting temperature. On further heating, when flanges would have been already flattened, the current strength decreases and a slow increase of temperature occurs.

The use of excessive current leads to liquid metal blasting. The range of welding current strength depends on the nature of the basic material, the ratio between different components thickness, the bosses' size and shapes and the size of components to be welded. The dedicated literature recommends that the values of welding current strength be proportional to the number of bosses which are welded at the same time. In case the bosses are close to each other and the thermal fields emerging around each boss cross together, the welding current for each boss shrinks.

Welding current level should be large enough to generate the heat required to make the welding spot before bosses flatten. When flattening the temperature of the contact area should get near to melting point because after flattening by increasing the contact area, the current density decreases, and the temperature increases slowly.

If the welding current is too high splashes of molten occur as a result of the welding current increased density in the contact area and the excessive heating of the molten metal.

For medium and large thickness, the welding current can be adjusted within a wide range. For small thicknesses <0.8 mm, the optimal value for the welding current and the current time range are very narrow /1/.

When setting the welding current one should take into account the effect of shunting the flanges. In order to alleviate or suppress it is recommended to observe the minimum distance between the flanges stipulated in the dedicated literature or standards.

B. Welding time (ts)

Welding time is the same for all the flanges and it is set depending on the thickness of the components to be welded, the nature of the basic material and the size of the welding current.

When welding components encompassing a large number of bosses, due to unevenness of their height it is more likely to make contract with only a few of them, there is an increased tendency to splash molten metal; therefore we recommend to increase the length of welding time.

Flattening bosses too fast requires welding systems, for which the speed of the movable electrode should be very high, a requirement which can not always be met;

therefore, from this point of view, it is not desired a welding time span too short.

Usually welding time range is up to 0.5-s, i.e. up to 25 cycle times; one sometimes uses higher values /5/.

When welding parts with two or more flanges, one recommends a longer welding time because if there are differences of elevation between the bosses, the contact is made only on some of them resulting in an increased current density within these points and thereby an increased tendency to splash the molten metal. This is because using short current times it is necessary to use a high welding current.

Using short current time cycles is not suitable also because to the risk of reducing the downforce at welding following the inertia of electrode movable plate causing the closing speed of the electrode be lower than the speed of flattening which is in this case higher (flattening duration is approximately 25% of current time cycle).

C. Down force (P)

Down force depends on the nature of the basic material, its thickness and the number of flanges.

When welding single flange parts applying downforce should be performed smoothly enough. A too rapid descent of the upper electrode plate results in flanges deformation and therefore to larger contact areas between the surfaces to be welded. Thus, the current density decreases too much generating a ring weld lacking molten metal in its core area.

If components are provided with several flanges, the descent of the upper electrode plate can be increased. In general, the downforce is proportional to the number of prominences.

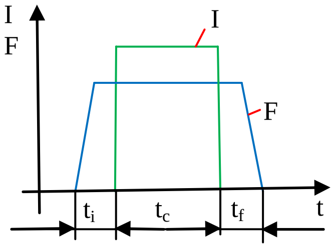
Reduction of downforce below the in the optimal level causes liquid (molten) metal splashes. Downforce should ensure complete flattening of the flanges after finishing this operation. During a welding time cycle the downforce can fluctuate.

The downforce is applied before connecting welding current. Flattening flanges is fast because of the latter heating under the action of the heat released in the contact area between the components. If the movement of movable electrode plate is not sufficient to follow the flattening of the flanges one will result in a decrease in the contact pressure between the components causing expulsion of the molten metal and the weld spots will show shortcomings. The downforce should ensure a complete flattening of the flanges after welding so that the distance between the components tends to zero (virtually no gap between the parts to be welded).

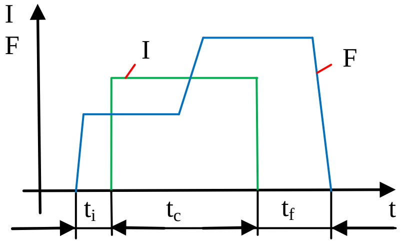
If the downforce is too high, the diameter of the welded spot will be reduced because the rapid flattening of the flange reduces the contact resistance R' and therefore reducing the amount of heat released and the subsequent reduction of temperature reached in the contact area. In this case a circular, annular weld usually occurs.

D. Welding cycle time by constant downforce and current / 2; 8/

It represents the simplest welding time cycle meeting a wide range of technological needs. See Fig. 2 bellow:



a. $F_{ap}=ct;\ I_s=ct.$



b. $F_{ap}\neq ct;\ I_s=ct.$

Fig. 2. EPWP Welding time cycle /4; 3/

However, when welding heavy steel components pf low carbon contents, the following problems occur:

- Porosity and cavities occurs in the welded material, as a result of the flow of molten metal between the components;
- Splashes of molten metal which occurs at the beginning of the welding process with the removal and partial combustion of the flanges due to the high current densities generated by the high strength of current thereof and the initial small contact area respectively.

III. PRODUCT PRESENTATION

The application relates to welding on some parts (rings) within the composition of the navvy equipment chassis of some M8 type nuts. Figure 3 shows the drawings of rings. In reality it is about 4 rings of standard dimensions types on which 2 nuts are welded, totaling 8 M8 type nuts. The basic material of the metal product is a low carbon – plain steel, standard S235J0/SR EN10025/2004, 8mm thick, which lends itself well to welding, namely it shows a good behavior during resistance welding by pressure because of the following features:

- It has a plastic behaviour within a large temperature range;
- It is less sensitive to hardening;
- It generates easily melting and easily removable oxides during jointing.

As one may notice, the designer requires welding the nuts by means of WNFRW - **Weld Nuts fixed by resistance welding process** - (DIN 929). The reasoning for choosing this method of jointing is the following: high productivity imposed by a relatively large number of welds (8 welds), safe and reproducible quality welding, preventing nut damaging through burning, the small size and shape of the parts to be welded, and last but not least welds aesthetics.

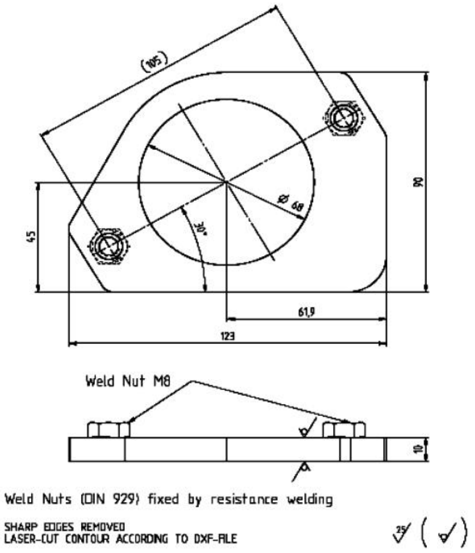


Fig. 3. Blueprint of ring making of

When performing the projection welding of nuts one using special nuts. Basic metal of nuts should be also a steel showing good behavior throughout welding, i.e. a low carbon plain steel (therefore different from the basic metal of which standard nuts are usually made of, E295 (OL 50, E335 (OL60) according to standard EN 10025 or STAS 500/80). Thus, we preceded to set-up effectively the actual chemical composition of the real nuts by using spectrometry. Table 1 bellow presents the results of measurements.

TABLE 1
CHEMICAL COMPOSITION OF NUTS MATERIAL [3]

Element	1	2	3	4	Avg	SD
Fe	99.41	99.40	99.30	99.41	**99.38**	0.0525
C	0.0576	0.0602	0.0917	0.0700	**0.0699**	0.0155
Si	<0.008	0.0117	0.0121	<0.004	**<0.009**	0.0034
Mn	0.3013	0.2999	0.3054	0.2910	**0.2994**	0.0060
P	0.0014	0.0000	0.0000	0.0000	**0.0004**	0.0007
S	0.0090	0.0089	0.0131	0.0086	**0.0099**	0.0022
Cr	0.0192	0.0198	0.0164	0.0166	**0.0180**	0.0017
Ni	0.0203	0.0229	0.0168	0.0194	**0.0199**	0.0025
Mo	0.0207	0.0202	0.0133	0.0228	**0.0192**	0.0041
Cu	<0.008	<0.009	<0.004	<0.009	**<0.008**	0.0022
Al	0.0401	0.0416	0.1178	0.0454	**0.0612**	0.0378
Ti	<0.002	<0.002	<0.003	<0.002	**<0.002**	0.0006
V	<0.000	<0.000	<0.001	<0.000	**<0.000**	0.0005
Co	0.0055	0.0064	0.0061	0.0039	**0.0055**	0.0011
Nb	<0.000	<0.000	<0.000	<0.000	**<0.000**	0.0000
W	<0.000	<0.000	<0.000	<0.000	**<0.000**	0.0000

Analysis of constituents and their average values (see column Avg in Table 1) leads to the finding that the basic metal is classified as a type of carbon steel of OLC 10 quality level (Carbon content - C <0.10%).

Figure 4 bellow shows the appearance of nuts for WNFRW purposes.

Fig. 4. The appearance of nuts for WNFRW purposes

These nuts are characterized by the presence of three prominent flanges or bosses arranged at a 120° angle to form an isosceles triangle placed on the hexagon edges showing increasing sizes depending on the nut size.

IV. EXPERIMENTAL RESEARCH

Experimental research was carried out under a research contract at the request of S.C. PRELMET Inand-Bihor company in order to implement the M8 nuts welding by resistance technology in the production process.

Experiments aimed at establishing an optimal welding technology to meet the requirements in terms of resistance required by jointing (torque), and the quality and reproducibility conditions on real products required by the customer.

Welding was done on a specialized installation present in the IMF pressure laboratory of the department namely the Zgb80 welding by resistance machine (Poland). Measurement and recording of welding parameters were performed using the WELDCHEKER MM326B (Miyachi) meter type, see Figure 5 bellow, for measurement and control of welding current and voltage between the electrodes, and the welding time (all performed at the same time).

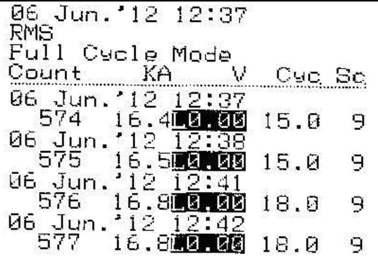
Fig. 5. Measurement and recording of welding parameters Miyachi meter

The welding technology was set by means of experimental method. See Figure 6 bellow.

Fig. 6. Experimental setting of the welding technology - M8 nut

Choosing the best welding technology was based on the test at the torque test and visual appearance, the presence of no nut deformations and no liquid metal splashes, welds aesthetics. The control of thread integrity after welding was done by screwing a M8 screw. In the Table 2 bellow one may observe the values measured for optimum welding parameters.

TABLE 2
RECORDING WELDING PARAMETERS

Parameter	M8 (1 nut)	
Fret adjustment	II/1	
$I_{1\ (kA)}$	P6 (16kA)	
$t_s(p)$	15p	
$P_{a\ (kN)}$	1,4kN	

```
06 Jun.'12 12:37
RMS
Full Cycle Mode
Count        KA      V   Cyc Sc
...............................
06 Jun.'12 12:37
   574   16.4L0.00 15.0   9
06 Jun.'12 12:38
   575   16.5L0.00 15.0   9
06 Jun.'12 12:41
   576   16.8L0.00 18.0   9
06 Jun.'12 12:42
   577   16.8L0.00 18.0   9
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By analyzing the experimental process parameters one found that in the case of heavy plates >2mm the welding current and time have higher values to obtain a higher heating of the plate.

By means of experimental set welding technology for the nut M8 one move forward to the actual welding of these nuts on the four sizes of the rings. Figure 7 bellow illustrates a moment during welding.

Fig. 7. Positioning the ring on the faceplate

Welding nuts on the rings is made easy due to the smooth access to welding; the only measure that is imposed is the positioning of the nut in the hole and centering the collar to avoid the shunting phenomenon of the welding current. Welding nuts can be done individually or simultaneously. In the case of individual welding to prevent shunting of the welding current by the nut previously welded one uses a copper plate placed on the nut to be welded. In the case of simultaneous welding, the copper plate is placed on both nuts. Use of this copper plate aims at preventing damages to the upper faceplate of the machine by forming machines impressions or some micro-welds. Moreover, in the case of nuts welded simultaneously one doubles the welding current and the downforce respectively while maintaining the level of the welding current constant.

In the Figure 8 bellow one shows the look of the welded parts.

Fig. 8. The look of the welded parts (rings)

Checking welds was made by technological breaking test by torsion through a suitable wrench. This test aims at checking the welding regime, based on the examination of break surface appearance. One can determine by orientation the maximum torque and twist angle. The test consists in the twist moment up to fracture. For this the plate is fixed in a device and the nut is tested by using a spanner or torque indicator handle wrench.

The result of the test is acceptable if the surface breaking surface of the spot point is not plain and breaking is done with the separation of the basic material, respectively. When submitted to more rigorous testing one can also set the appropriate torsion moment, a situation which requires the use of a torque indicator handle wrench. In the test a spanner was used to check the welded spot and the extended spanner was used to fracture the nut, respectively.

Fig. 9. Torque testing

The Figure 9 bellow presents test torsion by means of a spanner, and the breaking torque test.

Considering the a 300 N force applied by the operator and a spanner arm of 0.2 m one results in a torque of about 60 Nm, using a pipe wrench extension of 0.5 m the nut fractures occurs at a moment of force of about 150 Nm. It is believed that resistance of welded spots is guaranteed as against the stress imposed by operating the product.

The fracture appearance is presented in the Figure 10 bellow.

Fig. 10. Fracture appearance

One may notice that the breaking of the welded occurs within the material for two of the welded spots, and in the separation plane for the right point, respectively. This also shows that when welding a shunting effect of the welding current occurs as a consequence of the poor positioning of the nut on the screw or the lack of parallelism of the benches. The appearance of the fractures surfaces reveals a slight tendency towards material brittleness due to welding technological conditions considering the higher concentration carbon of the basic metal flute thereof, breaking being in HAZ.

V. CONCLUSION

This paper presents the shortcomings in achieving quality welds as compared to thin plates welding <3mm, with applications in welding the parts of the navvy chassis structures. The paper presents the findings of experimental research on M8 nuts welding technology.

The paper aims at dissemination of research results among professionals in the industry.

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