16th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2012, Dubai, UAE, 10-12 September 2012

THE SELECTION OF OPTIMAL TECHNOLOGICAL PARAMETERS FOR THE BUILT-UP WELDING PROCEDURE OF THE ELECTROMOTOR DRIVE ROTOR SHAFTS

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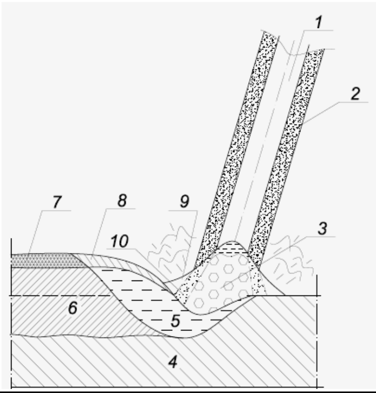
ABSTRACT
For the successful approach to the reparation process of rotor shaft parts by the built-up welding procedure, it is necessary to make a selection of the most favorable built-up welding procedure ([4]RIM2011, page 75-80). After we made a selection of built-up welding procedure, it is necessary to make an analysis and a selection of optimal technological parameters of the selected built-up welding procedure and to carry out the procedure of repair built-up welding itself. On the base of conducted research for the selection of optimal built-up procedure of the rotor shaft, the best procedure was the manual arc built-up welding (REL). The basic principles and parameters for this type of built-up welding procedure were presented: 1. Electrode type and diameter, 2. Volume, type and polarity of the built-up welding current, 3. Length of the electric arc, 4. Slope of the electrode, 5. Speed of built-up welding, 6. Technique of electrode conduction and 7. Type and quality of built-up welding preparation. For each of these welding parameters, the basic characteristics and recommendations for the selection of the most favorable characteristics for the repair of electromotor drive shafts were presented. The proposed approach for the selection of optimum technological parameters for the process of repair built-up welding of electromotor drive rotor shafts can be applied in other situations of repair of machine elements by welding or built-up welding procedure.
Keywords: built-up welding, built-up welding parameters, shaft, electromotor

1. INTRODUCTION
Based on research conducted for the selection of optimum built-up welding procedure of the shaft sleeve, the best showed result was the procedure of manual arc built-up welding (MAW) [4].

The basic principles of MAW built-up welding procedure:

MAW built-up welding procedure with a coated electrode is performed exclusively manually with an electric arc. The electric arc is created between the built-up welded metal and soluble metal electrodes coated with various types of cladding, whose mission is to provide easier and better built-up welding. Figure 1 shows the process of MAW built-up welding. For a successful selection of technological parameters for the built-up welding procedure it is necessary to know the meaning of term intermitation. Intermitation of the electricity source is the ratio of source by the maximum power of the electricity, and period of the entire interval of the use of source, expressed in percentages. For example, if a source has prescribed intermitation of 50%, this means that it should be on for a maximum of 2.5 minutes, and then 2.5 minutes of pause (no arc). The interval arc + pause, according to ISO regulations, is 5 minutes.



1. Electrode core
2. Electrode coating
3. Drops of molten core
4. Built-up welded metal
5. Metal bath
6. Solidified bath
7. Solidified slag
8. Liquid slag
9. Blanketing gases
10. Drops of molten coating

Figure 1. *The principle of built-up welding by MAW procedure*

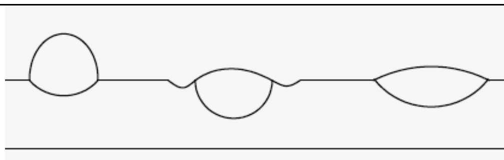
The basic parameters of MAW built-up welding procedure are: 1. Electrode type and diameter, 2. Volume, type and polarity of the built-up welding electricity, 3. Length of the electric arc, 4. Slope of the electrode, 5. Speed of built-up welding, 6. Technique of electrode conduction and 7. Type and quality of built-up welding preparation.

2. SELECTION OF OPTIMAL PARAMETERS OF THE BUILT-UP WELDING BY MAW-PROCEDURE

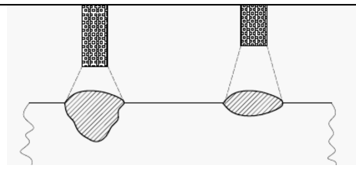
1. Electrode type and diameter: Electrodes that are essential for the MAW built-up welding process can be divided according to type of coating on: acid (oxide, mineral-acid and rutile), basic and neutral (cellulose) coating. According to the thickness of coating, electrodes are divided (according to DIN) on: 1. Thin coated (diameter of the coating is up to 120% of the core diameter), 2. Medium coated (coating diameter is 120-150% of the core diameter) and 3. Thickly coated (coating diameter is greater than 155% of core diameter). According to the purpose, the electrodes are divided in two ways: 1. Division by type of basic material intended for and 2. Division by the electrodes for welding, built-up welding and arc gouging applications (fluting).

For the optimal selection of electrodes is necessary to use certain rules and know the characteristics of certain types of electrodes and the influential factors on the MAW built-up welding process, namely: 1. Properties of base material that is built-up welded, 2. Mechanical characteristics and required quality of built-up welded joint, 3. Technological requirements set by the built-up welding process, 4. Available source of electricity and the level of training of built-up welders, and 5. Required efficiency and productivity of the process. One of the most important requirements of built-up welding is the efficiency and productivity in the application of additional material from which follows the use of thickly coated high-productive electrodes. It is recommended to make the sample testing of the melting coefficient and the coefficient of utilization of the electrode, because very often the data provided by the manufacturer are increased in terms of productivity. Electrode melting coefficient defines the amount of molten metal of electrodes at a given strength of electricity per unit time. Electrode utilization coefficient ranges from 90 to 250%, depending on the relationship between core and coating, and the amount of metal powder in coating, which melts down and becomes the part of welded joint. Calculation of electrode consumption can be determined in two ways, by computing and tabulating. In case of improper (inadequate) selection of electrodes, various problems arise in built-up welding, and the quality of built-up welded joint is very unreliable. It is clear that there would be no production of so many types of electrodes, that each of them can achieve the desired welded joint.

2. Volume, type and polarity of the built-up welding electricity (built-up welding): This is the most influential parameter in the MAW built-up welding. On the base of location and type of material we make the selection of preparation type and the diameter of electrode, and then based on the selected diameter of the electrode we select the volume of electricity. If we do not have that information from the manufacturer, then as a general rule, an ordinary steel electrode can be taken as I[A] = 40xd [mm]. From the above we see that neither too little nor too much volume of electricity is not appropriate, therefore it is necessary to know the optimum volume of electricity for various types of welded joints (Figure 2). Voltage of the electric arc in MAW built-up welding is not the parameter that can be set in advance, and in built-up welding it ranges from 20 to 40 [V]. Voltage depends on the length of electric arc on which the only effect has the built-up welder.



(too weak – too strong – adequate electricity volume)
Figure 2. The influence of electricity volume on the shape of built-up welded joint



(optimum – too large length of the arc)
Figure 3. The influence of arc length on the shape of joint (butt weld)

3. Length of the electric arc: The optimal length of electric arc for built-up welding depends on the type of electrode used. In built-up welding of unalloyed steels with all kinds of electrodes other than basic, recommended length of the electric arc is approximately equal to the electrode core diameter. In built-up welding with basic electrodes, high-alloyed and non-ferrous metal electrodes, arc length should be about twice smaller than the diameter of the electrode. By increasing the length of the arc, the thermal energy per unit time is also being increased, which has primary influence on the rate of melting of the electrode. Longer arc gives a higher voltage, larger amount of heat, faster melting of the electrode, but it is considerably less warming of the material, resulting in a smaller depth of penetration (Figure 3).

4. Slope of the electrode in built-up welding: The slope of electrode in built-up welding has a significant effect on penetration (depth of welding point) and on the length of electric arc. If the electrode is more inclined, the length of the arc will be increased, which has a negative impact. When the electrode is perpendicular to the built-up welded material, the strength of arc is the most used and provides the greatest penetration. If the slope of the electrode is greater, then the penetration is smaller (Figure 4). Basic electrodes should be guided perpendicular to the material, because they require a short arc, while other types of electrodes should be guided at an angle from 70° to 90°. Angle greater than 90° is unacceptable, because the arc pushes the bath onto the cold (still non-heated) basic material, which provides substandard built-up welded joint.

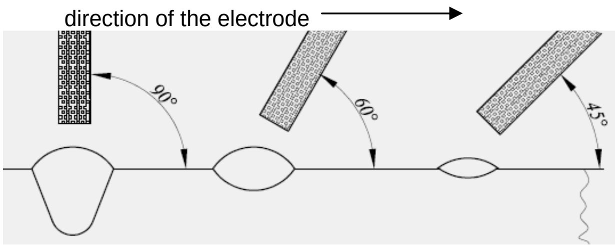


Figure 4. Influence of the electrode slope on the shape of joint (butt weld) in built-up welding in a horizontal position

5. Speed of built-up welding: Built-up welding speed depends on the shape and dimensions of joints, type of material and electrodes. It is determined empirically by monitoring the formation of the desired shape of built-up welded joint. Basic electrodes generally provide lower speed of built-up welding than the other types of electrodes. High-alloy steels are built-up welded with greater speed to reduce heat input into the basic material. When built-up welding is too quick it reduces the penetration which causes the appearance of non-welded spots, while low-speed of built-up welding leads to slag inclusions in the built-up welded joint. When there is a properly selected built-up welding speed, without transverse oscillations, the width of built-up welded joint will be 2 to 3 mm larger than the diameter of the electrode. For certain technological processes the productivity is considered as a very important parameter, i.e., the amount of molten material per unit time. This is usually the case where it does not require a special quality of built-up welded joints or in built-up welding of robust elements. The higher volume of electricity, the greater is the productivity, but it goes up to a certain point where it starts to appear the over-bursting of electrode and then the quality of joint (butt weld) begins to decline drastically.

6. Setting-up, termination, transverse oscillation and generally technique of electrodes conduction: The way of ignition, maintenance-conduction and termination of arc are also important parameters that affect the properties of built-up welded joints. Proper ignition of arc requires special attention, especially when built-up welding with basic electrodes. The most convenient way of arc ignition is by scratching or so called tindering, because it sets-up an arc without damaging the coating, where the arch length is regulated by increasing and not by its reduction, which is easier than in the case of ignition by touch.

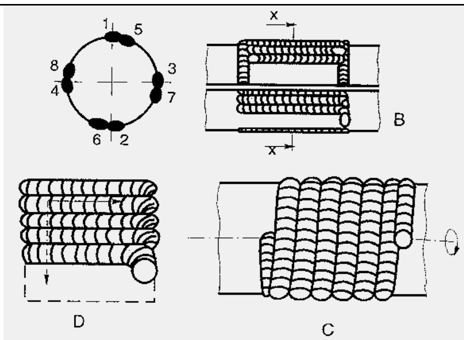


Figure 5. Example of welded joints position for avoiding the heat affection zone


Figure 6. Picture of built-up welded electromotor shaft sleeve

In order to avoid the emersion of internal tensions and deformations due to heat exposure, it is necessary to make a plan of sequence (order) of welded joints. In case of built-up welding of shaft sleeve, the sequence of welded joints can be seen in Figure 5. under B and C.

The most appropriate way of arc termination is pulling it back to the hardened slag and in that position to terminate the arc. Re-ignition of arc i.e., continuation of welding, after replacing the worn-out electrode with a new one, should not be done on the final crater, because that spot will almost certainly be porous. The arc should be set up in front of the crater on a previously placed layer, go back to the crater with arc, fill it up, and then continue with built-up welding.

7. Type and quality of built-up welding preparation: For successful built-up welding, the use of preheating of repair built-up welding objects is important too. Preheating depends on: the type of material, chemical composition, thickness, method of heat dissipation, ambient temperature and the amount of energy input during the built-up welding. For an efficient preheating it is necessary to implement the following principles: 1. Preheating is carried out in the zone beside the prepared joint so the preheating zone width is about 10 thicknesses of the material, on each side of the joint (not exceeding 250 mm), 2. Measuring the temperature of preheating is required. Measurements are usually made by contact thermometer or by thermo chalk. 3. Preheating temperature is also controlled by the opposite side of the heating spot. In this way we check the preheating throughout the entire section of the material, and 4. Preheating is performed by regulated speed (slow and gradual).

3. CONCLUSION

A quality selection and application of appropriate methods of repair built-up welding of electromotor drive rotor shafts is significant for the maintenance of high values of the entire effectiveness of electromotor drives. Repair built-up welding process consists of several phases: 1. Delectation of damage, 2. Selection of repair built-up welding procedure, 3. Selection of technological parameters of built-up welding, 4. Finishing of built-up welded parts and 5. Control of repaired part. In this study the importance was given to the built-up welding process itself, through the selection of appropriate parameters for built-up welding process of electromotor drive rotor shafts. Presented content and theme field of the selection of optimum parameters for electromotor drive rotor built-up welding process, can be also applied to other machines with rotating elements, such as: turbines, fans, pumps, compressors, internal combustion engines etc. Thereby, it is necessary to know all the peculiarities of respective parameters of the selected built-up welding process, analyze them and select those that will give the best results in terms of quality and economy.

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