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Drakče Tanasković[1], Slobodan Petrović[2], Branislav Đorđević[3], Albin Matavž[4], Tamara Mijatović[3]

ALGORITHM FOR DEFINING QUALITY OF BASE MATERIAL FOR REPAIR WELDING

ALGORITAM ODREĐIVANJA KVALITETA OSNOVNOG MATERIJALA ZA REPARATURNO ZAVARIVANJE

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Adresa autora / Author's address:
[1] HBIS GROUP Serbia Iron & Steel, Smederevo, Serbia
[2] College of Applied Sciences, Užice, Serbia
[3] University of Belgrade, Innovation Centre of the Faculty of Mechanical Engineering, Belgrade, Serbia
email: b.djordjevic88@gmail.com
[4] MAMUT TIM, Ltd., Zreče, Slovenia

Keywords
- base material quality
- repair welding
- material database

Abstract

The paper shows the comparison of different methodologies for defining the quality of base material due for repair welding as one of the basic and initial problems during the repair of damaged parts or machine equipment. The quality of a previously damaged repaired machine part depends on successfully defined quality of base material. In addition to the analysis of discussed methodologies, the paper also provides an algorithm for decision flow between different methodologies. The overall analysis is performed in cooperation with employees in HBIS GROUP company Serbia Iron & Steel, Smederevo, as result of experiences and cases during maintaining of the facility. The proposed algorithm is designed in order to predominantly help engineers in the decision making with the goal to establish and create an appropriate repair welding procedure so to achieve required integrity of the machine/structure.

Ključne reči
- kvalitet osnovnog materijala
- reparaturno zavarivanje
- baza podataka materijala

Izvod

*U radu je urađeno poređenje različitih metodologija u cilju određivanja kvaliteta osnovnog materijala za reparaturno zavarivanje, kao jedan od osnovnih i početnih problema u reparaciji havarisanih delova mašinske opreme postupkom zavarivanja. Kvalitet repariranog havarisanog mašinskog dela zavisi od uspešno definisanog kvaliteta osnovnog materijala. Osim analize metodologija, u radu je predložen i algoritam toka odlučivanja između različitih metodologija. Celokupna analiza je sprovedena u kompaniji HBIS GROUP Serbia Iron & Steel, Smederevo, kao rezultat iskustava i studija slučajeva tokom više godina u održavanju opreme. Predloženi algoritam je namenjen prvenstveno inženjerima sa ciljem propisivanja odgovarajuće tehnologije reparaturnog zavarivanja radi postizanja odgovarajućeg integriteta mašine/*konstrukcije.

INTRODUCTION

During all these years, repair welding remains an insufficiently defined scientific and technological field, despite exceptional technical improvements in the area of welding, along with research of new materials. Unlike the manufacturing welding, repair welding is usually more complex due to several unknown elements and factors that follow the repair welding process. With an increase in the need for maintenance and repair of power plants, underwater structures, space stations and satellites, along with conventional civil and mechanical structures, a systematic approach to repair welding has become extremely important. Maintenance and repair are different operations, but with many similarities. Both require a good knowledge of the welding process and material properties.

Most metallic materials have good weldability or can be welded under certain conditions /1-5/. After the failure of machine/structural parts, repair welding be executed instead of replacing the damaged part with a new one, which could lower economic losses caused by failure, as Tanasković et al. have shown in their studies with crane wheels, burner pipe /2, 3, 6/. However, retaining the characteristics of the base material after repair welding can be very difficult to achieve, or may require a good, prescribed technology process. In order to perform a good repair welding technology of a damaged part, it is necessary to know the base material composition, as well as all its characteristics, (mechanical, physical, etc). This is also necessary to prepare and perform a successful repair welding procedure. After a successful repair, the part could be returned into service, but sometimes this is not the case, because post-welding activities are not carried out accordingly, such as cases in /7-8/, or when there are some other issues not taken into account, such as base material quality at that particular moment, and after years of service.

The designation and characteristics of the base material can be given by the machine or material manufacturer, within technical documentation, etc. If necessary, the chemical composition of the base material could be analysed, even if the material designation is known. This could be caused by exploiting conditions that the machine/structure is exposed to that can change the chemical structure and the composition. Sometimes, the base material of damaged part could just be unknown, due to a number of reasons. One of them is just the fact that damaged equipment (e.g. may be easily repaired) is very old and the loss of the required documentation, /9/. Unknown base material characteristics may lead to establishing an inappropriate repair welding procedure, which could lead again to failure.

In this paper we discuss a few different methodologies for defining the quality of the base material due for repair welding, which may be one of the basic and initial problems during the whole repair process. The problem of defining base material quality reflects in the unlikelihood of undertaking the next step in the repair procedure of the damaged part, but also in developing the welding technology, etc. All known parameters, which the base material belongs to, lead to getting adequate repair welding procedure and placing the damaged part back into service. A proposed algorithm represents an original approach and provides steps in the 'decision flow' during the repair. The algorithm is designed in order to predominantly help engineers in decision making for establishing and creating an appropriate repair welding procedure to achieve the required integrity of machine/structure.

PROPOSED ALGORITHM

Defining the quality of the base material represents one of major problems due for the repair welding of damaged parts or structures. In practice, several cases (with an impact on further flow) can be distinguished. According to the aforementioned, the quality of the base material of damaged part that needs to be repaired can be defined and presented with the algorithm in Fig. 1. The first question defines two basic ways (branches) on further algorithm steps - are there any drawings or technical documentation of the damaged part? Further sections in the paper provide more detailed explanations of this algorithm, leading to the final steps - establishing the repair welding technology of the damaged part.

Defining base material quality by using technical documentation

As can be seen from the algorithm in Fig. 1, the simplest case represents the one with complete technical documentation or drawings of the part/structure to be repaired. Based on material designation (e.g. according to relevant standards), chemical composition and mechanical properties of the base material can be obtained from this documentation, which is a good ground for defining the welding procedure, additional (or filler) material, adequate heat treatment, i.e. data sufficient for developing the repair welding technology /2, 3, 6, 10/.

One of the most complete steel material databases is the Total Materia database, /11/, Fig. 2, which provides:

- the largest data source in the world, a database with material properties of over 12 000 000 records, for more than 450 000 materials,
- the most powerful system of comparison tables; the fastest and most comprehensive system of international comparison tables, with a unique categorization of equivalents and with the additional application of SmartCross technology that represents a patented algorithm based on artificial intelligence,

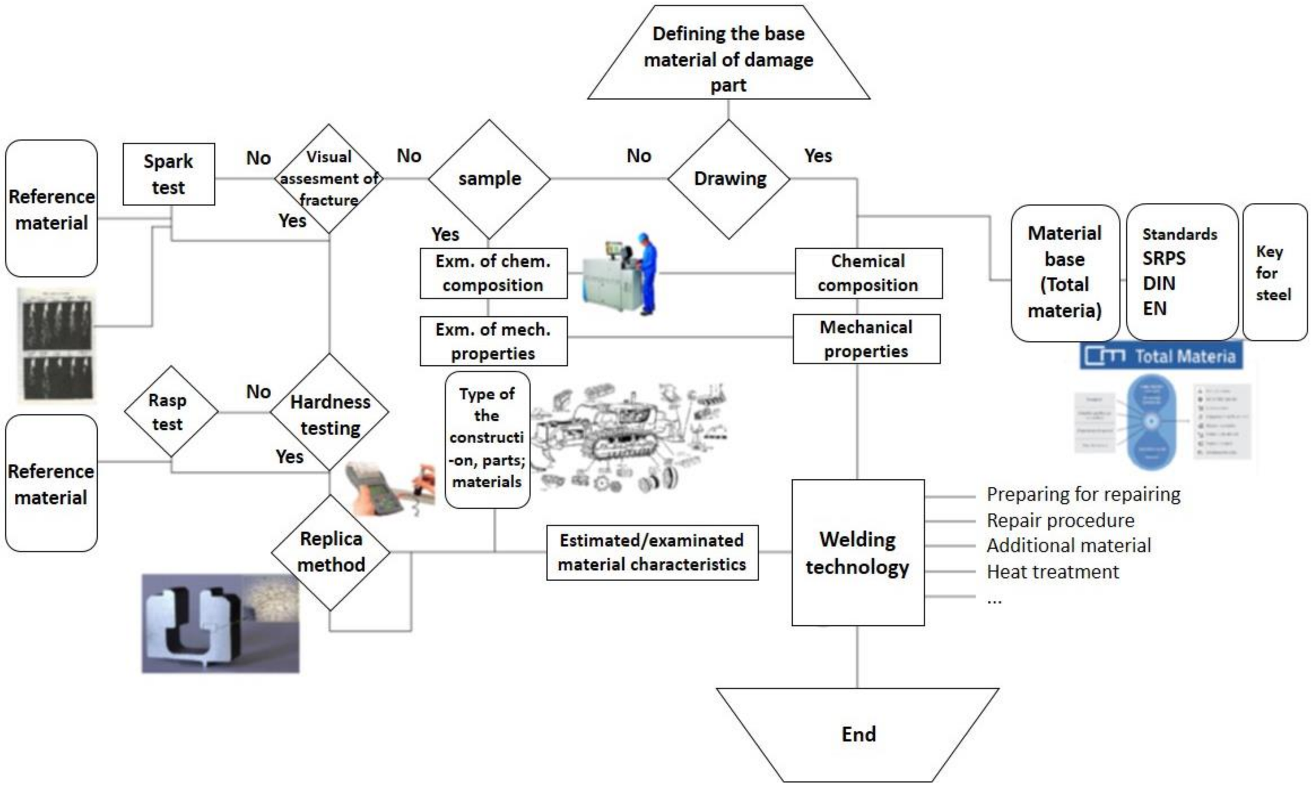

Figure 1. Equipment used for plasma welding.

- advanced calculation properties; the largest collection of data on stress-strain, fatigue, and plasticity curves. Besides that, it supports linear and nonlinear calculations and opens up new possibilities in structural design,
- unique material identification; based on the patented chemical composition-based metal identification algorithms recognized by leading spectrometer manufacturers around the world which allow identification of unknown materials per second,
- certified quality, reliable and always updated data; high quality and maximum reliability, unique multiple certified quality of process and information security in industry, with a unique update policy, including the possibility of uploading data for each material.

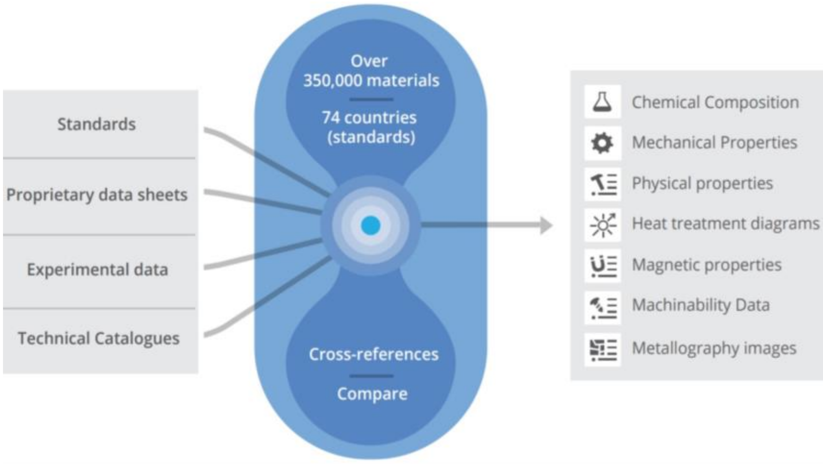

Figure 2. Total Materia database.

Defining the quality of base material by examination of chemical composition

In many cases, there is no documentation or any data on the material quality of the damaged part. In these cases, if it is possible, a sample needs to be taken from the damaged part (a small plate with minimum diameter of 40 mm and 5 mm thickness) for required chemical composition examination. Examination of the chemical composition needs to be performed on adequate equipment, such as spectrometer represented in Fig. 3.

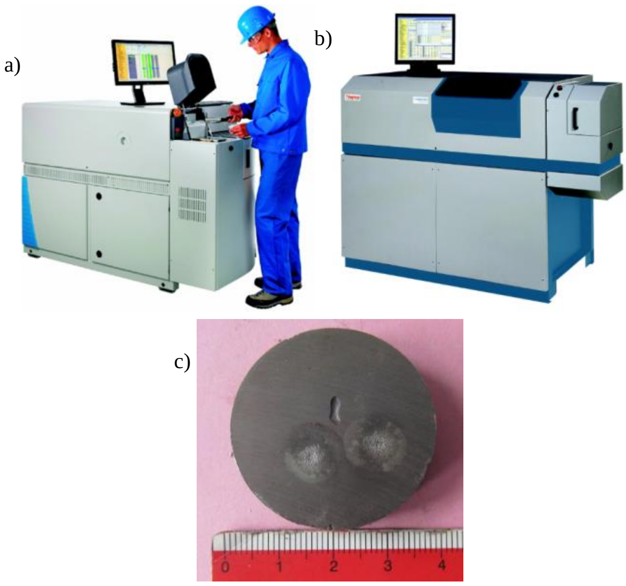

Figure 3. a) iSpark series optical-emission spectrometer; b) ARL 4460 optical-emission spectrometer; c) sample.

Quantometers or spectrometers are automatic spectral devices with photoelectric spectrum registration that provide direct measurement and reading. While photographic registration of the spectrum requires a special procedure for measuring and evaluating the blackening of the emulsion, the quantometer directly determines the intensities of the spectral lines. The advantages of such measurement are:

- fast analysis,
- high accuracy,
- higher precision at higher contents,
- linear dependence between concentrations and intensities in a wide range of concentrations,
- possibility of comparing distant spectral lines,
- possibility of automation.

Optical emission spectrometers (such as ARL 4460 and 3460) are used for simultaneous examination of concentration of chemical elements in samples with Fe-base (iron and steel) /8, 12/. Quantometers or spectrometers with direct reading are automatic spectral devices with photoelectric registration of spectrum. While the photographic registration of the spectrum requires special procedure for measuring and evaluating the blackening of the emulsion, the intensities of spectral lines can be directly determined by quantometer. Such devices are very expensive and are usually in the possession of rich companies and institutes.

Testing of mechanical properties requires taking samples of larger sizes and longer testing period (including making test samples). Taking larger samples further affects the geometry of the already damaged or failed part or structure.

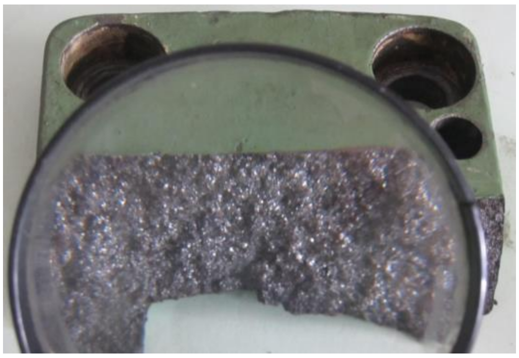

Figure 4. Broken part made of gray cast iron.

Figure 5. Parts made of aluminium.

Defining the quality of base material by visual inspection

Based on visual inspection, visual appearance, by using methods such as colour identification, or magnet properties, it is possible to determine and evaluate the material group from which the machine or part is made of (i.e. steel, stainless steel, cast iron, copper, bronze, brass, aluminium, etc.). It is possible to also determine the base material by visual inspection of the ruptured surface, and visual observation of its macrostructure, such as the case represented in Fig. 4, with typical gray cast iron structure. The typical aluminium surface is represented in Fig. 5, with clear indications, such as gray colour along with lightweight of the part in comparison to cast iron and steel. It is known that all metals are gray except copper, which is red (Fig. 6), and gold which is yellow.

Figure 6. Part made of copper.

Defining the quality of base material with spark testing

By grinding the surface of the machine part and comparing it with reference materials, it can be precisely confirmed to which group of damaged part the material belongs. Experienced technician and engineer can determine it with great certainty. Spark testing is used because it represents quick, easy, and an inexpensive way of testing and determining the chemical composition in the most approximate way. Test samples do not require any preparation; thus a piece of scrap can often be used for testing. The main disadvantage of spark testing is its inability to positively identify the material. The spark comparison method also damages the material being tested. Figure 7 shows some examples of the spark testing of different steels.

Defining the quality of base material with hardness testing

Most often, even if the base material is known, it is necessary to have additional information about material quality in order to prescribe the adequate repair welding technology, along with additional material, post weld heat treatment, etc. Upon hardness testing of the material, the obtained data needs to be compared with hardness values of reference materials. Hardness values above 350 HV for non-alloys and 450 HV for low-alloy steels show high hardenability of steels as well as low weldability /7, 13/. Based on the measured hardness, the material strength can be approximately determined, as well as material designation itself. Based on high hardness value it can be concluded that the material is high-strength, and so high-alloy electrodes should be used for repair, as well as better-designed welding procedures, along with control of material preheating and heat input.

(a)

(b)

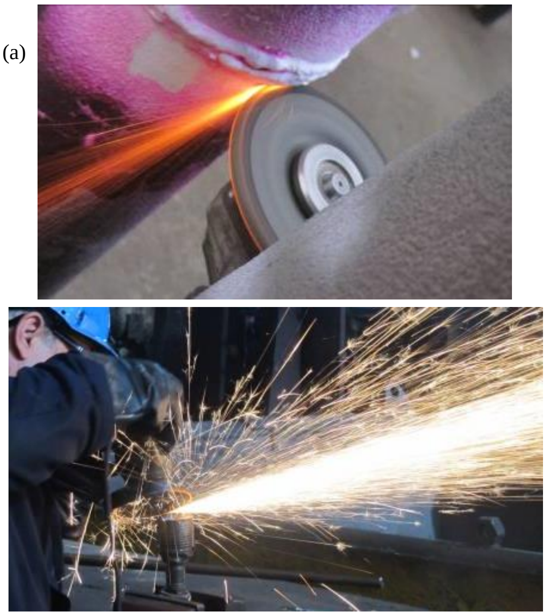

Figure 7. a) Burner pipe spark test (base material X12NiCrSi35-16); b) spark testing of 42CrMo4 steel.

(a)

(b)

Figure 8. a) Instrumentation for hardness testing; b) indentations of Brinell hardness measurement.

Castings and forgings can be categorized in a similar way. During hardness tests care should be taken of surface coatings caused by heat treatments, such as cemented, nitrided, chromed, etc. Devices used for hardness testing have a broad application nowadays, epically in repair welding, /6/. An example of hardness testing is given in Fig. 8a. The example of Brinell hardness testing of a gear tooth, and indentations are shown in Fig. 8b. Hardness tests could be used in order to discover if there is some microstructural change in the base material as a consequence of the previous welding technology, such is the case of carrying clamps levers, /9/. The hardness of the material can be measured with a rasp as well.

Defining the quality of base material by replica method

This method is a non-destructive method based on the analysis of the fractured surface. It is possible with this method to determine the causes of structural failure, either due to high temperature application or corrosion, /14, 15/. The imprint of the parts microstructure has to be performed using appropriate equipment. Before testing itself, it is necessary to prepare the surface. The steps in this test include grinding, polishing, etching the tested surface with reagents, while control of these steps can be performed using a small optical microscope. The next operation is taking the imprint from the prepared surface with a replica coated with a softener, by applying the replica on the prepared surface. After a certain time, the dried replica has to be placed between two glass plates (steps in the replica method are shown in Fig. 9). The imprint on the replica can then be observed on optical microscope, either on a mobile-type or in a laboratory.

Based on the analysis of the tested surface imprints, the replica method test makes it possible to perform the following assessments:

- the remaining life of material in service,
- types of defects in the material and their causes,
- the cause of structure/machine failure,
- monitoring of micropores and occurrence of cracks,
- structural changes in welded joints,
- corrosion damage of the metal surface.

Also, this method is often used in combination with other non-destructive testing methods, such as magnetoflux, penetrants, ultrasonic test methods /16/, or hardness tests, /17/.

Figure 9. Replica method testing procedure.

Defining base material quality based on machine part material group similarity

Machine/structural parts are made of certain materials that mostly depend on the type of loading the parts are exposed to in exploitation. Based on this, in certain cases the base material of the damaged part can be approximately determined. Machine elements as shafts, sleeves, and gears are usually made of tempered or cemented steel, /18-20/. Wear-exposed machine parts, as excavator, crushers, are mostly made of manganese steel, /2/. Manganese steel guarantees wear and work hardening properties but is non-magnetic and ideal for use in electrical transformer assemblies and industrial lifting magnets. Crane structures are made of structural carbon steel /2, 21/, while structures exposed to high temperature are made of boiler sheet or fireproof steel /14, 15/.

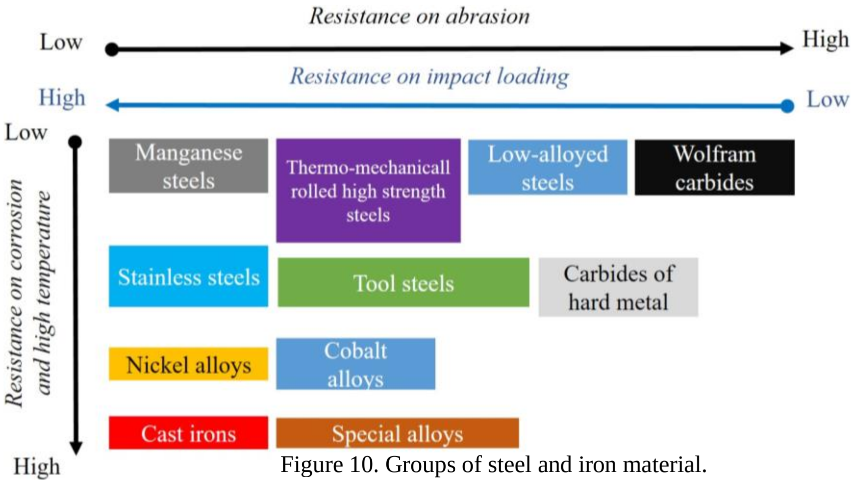

Figure 10. Groups of steel and iron material.

Concerning the aforementioned, Fig. 10 shows a group of materials (steel and iron) divided according to their application and resistance on abrasion, impact loading, and corrosion and high temperature.

CONCLUSIONS

A proposed algorithm is given and created for easier definition of the base material quality due to repair welding of damaged parts and aimed to solve problems that occur in practice in many cases, concerning the definition of base material quality. As pointed out in the previous section, the wrong assessment of base material quality can lead to improper welding technology establishment, and thus to poor quality of welded joints with catastrophic consequences. Many damaged parts, where the repair welding procedure is easily performed, simply do not have all the defined parameters necessary for performing the adequate repair welding procedure. The algorithm offers solutions to overcome this problem.

Some of the advantages of the proposed algorithm are:

– a simple flow of steps in order to get a proper definition of the base material quality of the damaged part that needs to be repaired,
– easier identification of problems in defining the appropriate welding technology,
– the possibility of simple and fast establishment of appropriate repair welding technology, which is actually a consequence of appropriate material quality assessment,
– clear overview of necessary and appropriate documentation and equipment as well, in order to define the base material,
– the possibility of defining the base material using several methodologies of the proposed algorithm.

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