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Čišćenje biorazgradnjom zauljenih livenih delova izloženih visokom pritisku u funkciji sanacije zavarivanjem

Cleaning by biodegradation of high pressure oily castings before welding repair work

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Izvod

Zavarivanje i navarivanje u cilju reparature delova izrađenih od konstrukcionih čeličnih livova predstavlja izuzetno težak praktični problem u obezbeđenju njihove funkcionalne ispravnosti. Ovo je posebno izraženo kod delova velikih dimenzija koji rade pod visokim pritiskom ulja, a na sebi imaju značajna eksploataciona oštećenja. U radu je, na osnovu analize mogućnosti i opravdanosti popravke data tehnologija čišćenja biorazgradnjom zauljenih površina, sa defektima, razvodnika ulja pre pristupanja sanaciji navarivanjem/zavarivanjem. Sanacija je predložena nakon što je uočeno curenje ulja iz kućišta posle ispitivanja pritiskom. Dodatnim pregledima i ispitivanjima NDT metodama uočena su i druga oštećenja i greške u materijalu razvodnika koje je bilo potrebno sanirati. Kućište je izrađeno od nodularnog liva ВЧ 45-5, ГОСТ 7293-70.

Abstract

Welding in order to repair parts made of structural steel casting is a very difficult practical problem in terms of their functional correctness. This is especially emphasized in parts of large dimensions that work under high pressure oil, and have significant operating damages. Based on the analysis of the possibilities and feasibility of repairs, this paper shows cleaning technology using biodegradation of oily surfaces. Rehabilitation is proposed after it was noticed oil leaking from the housing after pressure testing. Additional analysis and NDT testing were performed where other damages and material defects that needed to be repaired were observed. The housing is made of ductile iron ВЧ 45-5, ГОСТ 7293-70.

Introduction

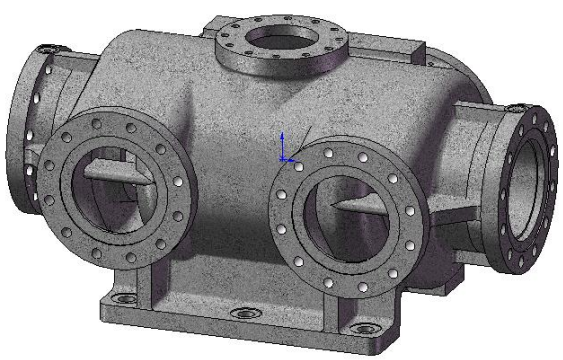
Welded parts where there has been a deterioration, or damage during operation is called repair welding. Rapair welding is used in machine building, mining, energy, construction, process industries, high temperature industry, food industry and agriculture [1]. The goal of repair welding is to reduce maintenance costs, decrease procurement costs of new parts or reducing the costs caused by halt due to long-term procurement of new parts. According to the literature [2] costs of repair welding are typically 10-50% of the price of a new part, which depends on the degree of damage. Repairation at a cost of 20-30% of the new part is cost-effective [3], especially when dealing with large spare parts which we usually do not have in stock, and which production requires a longer period of time. These parts are also large cast housings that work under pressure of oil in very difficult operating conditions.

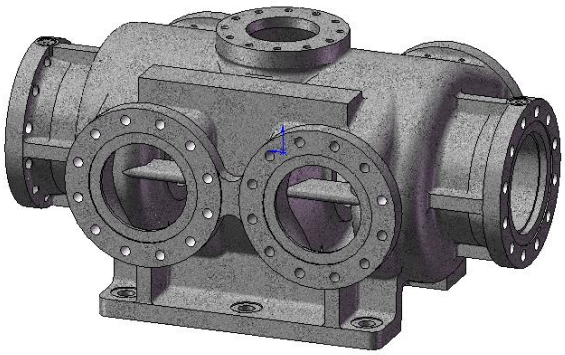
Determination of damage

For the purpose of prevention of integrity loss of cast housings it is necessary to make examination with hidro proof testing (HPT) and 100% visual inspection (VT), as well as liquid penetrant testing in order to determine the material degradation and damages of housing. Other tests like magnetic particle testing (MT), radiographic testing (RT), ultrasonic testing (UT), and if necessary, control of hardness (HT) of material and evaluation of microstructure by replica method (REP) can be used in order to get a reliable and useful results for determining the degree of qualitative level of material degradation over the lifetime. Related to above stated, housing of oil distribution, fig.1c, was tested under pressure, after which the oil leakage is observed, fig.1b, and further visual inspection (VT) and PT showed other damages like porosity of material, from fig.1a to 1e, and cracks, from fig.1d to 1e. The porosity of the material was created during the casting process, ie. making the housing. Places with cracks and leakage of oil occurred during the years of exploitation, as a result of the porosity of materials. Techno-economic analysis and calculation proposed repairs by welding critical damages.

a) porosity

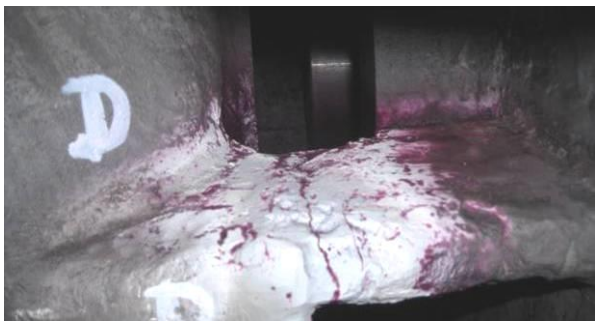
b) place of leakage and porosity





c) perspective view of the housing

d) cracks and porosity



e) through cracks and porosity

Figure 1. *Sketch housing of oil distribution with photos of defects identified by testing HPT, VT and PT*

Housing materials

Considered housing of oil distribution was made of nodular cast iron labels ВЧ 45-5, with chemical and mechanical characteristics defined with standard ГОСТ 7293-70, that are presented in tables 1 and 2.

Table 1. *The chemical composition of the material of housing of oil distribution [4]*

Designation of the base material		Chemical composition in% by weight						
Notations	ГОСТ	C -min	Si	Mn	P -max	S -max	Cr	Mg
ВЧ 45-0	**7293/70**	**3,2**	**2,5-3,2**	**≤0,5**	**≤0,1**	**≤0,02**	**≤0,1**	**0,04-0,08**

Table 2. *Mechanical properties of materials of housing of oil distribution [5,6]*

Designation of the base material		Mechanical properties in the normalized and tempered condition				
Notations	ГОСТ	Yield Strenght, $R_{p0,2}$ min, MPa	Ultimate Strength, R_m min, MPa	Elongation, A min, %	Impact resistance, KV, J	Hardness, HB
ВЧ 45-0	**7293/70**	**330**	**450**	**5**	**2.5**	**170-207**

Nodular cast iron is an alloy of iron and carbon with most of the carbon extracted in the form of a ball races - nodular graphite. Ductile iron is an alloy of iron and five essential supporting elements: carbon, silicon, manganese, phosphorus and sulfur (like cast iron), but for the formation of nodular graphite necessary to introduce a certain proportion of magnesium. Carbon and silicon have the greatest impact on the tensile strengthness and hardness. The higher the content of these two elements, the lower values of tensile strengthness and hardness, where in the yield stress and elongation percentage increase [7]. Alloying of ductile iron with copper, nickel, molybdenum and chromium is achieved corrosion resistance at elevated temperatures.

Welding of these types of iron is defined by the requirements of the technological processes in the standard ГОСТ 30430-96.

The oil types in the housings and possibility of biodegradation

Mineral oils are liquid fuels derived from plant and mineral base as a product of the distillation of petroleum, tar, coal, wood, etc. The major parts of the composition of the mineral oil are hydrocarbons. Mineral oil is a substance of relatively low prices, which is produced in large quantities. Due to the low cost of production and secured supply, are very exploited in various fields of life. Until recently, the mineral oil as the only option, were used in the industry, but technological progress and technical training, standards have changed, and mineral oils do not meet modern standards for lubricating mechanical assemblies.

Synthetic oils are lubricants that consist of chemical compounds synthesized artificially. They consist of synthetic PAO (Polyalphaolefin) base oil and additives. The continuous increase in the level of machine performance is achieved by using synthetic base oils. Synthetic oils are used as an additive to lubricants refined from crude oil, which operate at extreme temperatures because they offer superior mechanical and chemical properties compared to conventional mineral oils.

Semi-synthetic oils (also known as "synthetic compound") are the compounds of mineral and synthetic oils, but the largest proportion of the synthetic oil in the mixture is not more than 30%. Semi-synthetic motor oils have a lower price than a pure synthetic oil, [8].
The process of biodegradation of the oil can be defined as the ability of a chemical compound to be degraded by biological action of living organisms. The concept of biodegradability can include partial degradation of initial molecules to a level of acceptable degradation. There are three factors in measuring the intensity of biodegradation and overall performance: (1) creation of water (H2O) or carbon dioxide (CO2) as the final degradation products, (2) oxygen consumption, and (3) the release of energy, or heat. The presence of the additive in the oil has a significant effect on the speed of biodegradation. Additive components containing the metals, have a very negative influence on the biological degradation, [9].

Preparation for repair

Preparation of oily surface for repair by welding consists of degreasing, washing with water, cleaning and dusting.
The methods and degrees of surface preparation for recovery are determined based on the degree of oiliness and porosity of housing surface, shape and accessibility of areas for rehabilitation. The main requirement for welding start is completely clean and degreased surface and removed porosity from the part which should be repaired.
Degreasing should be done with alkaline and detergents or organic solvents (petrol, white spirit, trichlorethylene). Also, degreasing can be done with preparations for hot degreasing by biodegradation. Using environmental resources for the removal and biodegradation of mineral oil, it is possible to draw a deep oil stains from the pores in the concrete and metal, [10]. Microorganisms and bacteria decompose mineral oil to H_2O and CO_2. These resources are used in gas stations, garages, workshops, factories, power stations, warehouses. Biodegradation in closed cleaning system ensures a long service life of a degreasing agent and its economical use.
Before welding start, oil from the pores of the metal needs to be pulled out. This is partly achieved by biodegradation, and using appropriate products, adhering to the manufacturer's instructions precisely.
In our example, this technique for degreasing, in workshop conditions, fig. 2, was used on parts of the housing with high porosity defects, fig. 3, where oil accumulated and other resources could not be used for degreasing. We used Uniprep CC-W and UniPrep SP B (EU) [11].

Figure 2. *Workshop conditions degreasing biodegradation of housing of oil distribution*

Uniprep CC-W and UniPrep SP B (EU) are preparations for biochemical alkaline degreasing. These are alkaline fluids suitable for cleaning by spraying. Due to its high performance enables excellent

removal of various types of impurities from the main surface of the workpiece. They can be used on various base materials such as steel, aluminum, copper, brass and zinc alloy.
In steady-state conditions provide constant work efficiency. Liquid concentrate is easy to use and maintain. The working solution can be adjusted optimally 2.0-4.0 vol.% (10-100 ml / l), or in the range of 1.0-10.0 vol.% (10-100 ml / l) [11].
Tubs of plain or stainless steel, as well as chlorinated polyvinyl chloride (CPVC) are used. Heaters are of ordinary or stainless steel, teflon. Spray nozzles are made of ordinary steel, CPVC. Filtration is not required, but recommended.

Figure 3. *The treated surface and the traces of degraded oil which left the porous structure of the metal*

Working conditions at spraying (injection) with biodegradation are temperature: 40-52 ºC, pressure 0,7-2 bar, the processing time 1-3 min, ventilation required at the time when the injection is not performed, the pH (the setting) 10-12, pH (during operation) 9-10 pH.
In case ultrasound is used to improve the efficiency of the degreasing, it will significantly decrease the biodegradation which will result in a reduction of the lifetime of the working solution.
Because of the loss in the removal and consumption of active ingredients of working solution during normal operation, it is necessary to periodically add concentrate Uniprep CC-W, or SP B UniPrep (EU).
The loss of solution due to evaporation should be compensated by running water. It is not recommend the use of recycled water. The concentration of the working solution is controlled by the analysis. In normal operating conditions, and with minimal removal of working solutionfor, for each 1 m^2 of the surface of the treated part is added the amount of ~ 5 mL of the preparation Uniprep CC-W or UniPrep SP-B (EU). Although Uniprep CC-W and UniPrep SP-B (EU) slightly foamy degreasers when compressed, because of the introduction of impurities, foaming is undesirable. By adding UniClean Antifoam DB at a concentration 0.1-1.0 g/l, foaming will be reduced and will not adversely affect the bacteriological characteristics of the process.

Repair by welding and surfacing

Due to the presence of finely machined surfaces inside and outside the body of oil housing manifold, performance of preheating is limited, so it is carried out by cold welding process. Based on the parameters, which determine the selection of the welding process (weldability of the base material, energy capabilities of the proceedings, the geometric complexity of the structure and comparative techno-economic analysis) welding covered electrode method was selected (Manual Metal Arc Welding, or process 111).
Testing conducted on the outer surface of the oil housing manifold, fig. 4, acceptable results in terms of bonding with the base material, the appearance of defects and others, gave coated electrode 2222 Castolin Xuper NucleoTec based on Ni-Fe [12], so welding was carried out using this particular electrode.

a) treated surface preparation for biodegradation of oil *b) try surfacing*

Figure 4. *Start welding*

General specification of welding procedures includes welding activities on the housing of oil distribution from nodular cast iron and method of implementation, table 3

Table 3. General specification of procedure at cold welding/surfacing of nodular cast iron

Procedure	**Manual Metal Arc Welding (MMAW-111)**	**Surfacing/Welding**
Consumable material	**Coated electrode**	**2222 Castolin Xuper NucleoTec**
Activity	**Method of implementation**	
Preparation	Cleaning and classic degreasing surfaces for surfacing/welding	
	Grinding defects and control of slices with penetrant liquids (PT)	
	Molding welds in V-shaped to half the thickness of the material with an angle of 90^{o}. The other side is sanded after welding as 2/3 of the height of the groove. Limited depth of defects is locally removed in the form of the letter V.	
	Degreasing grinding surface biodegradation	
	Final cleaning and drying grinding surfaces	
The thermal cycle of welding/surfacing	No preheating	
	Air cooling after each pass.	
	Weld metal is cooled to a temperature where it can be touched with bare hands.	
	No heat treatment after complete repair	
Welding	Without swinging electrode, with the length of the weld metal to 15 mm and a width of up to 2.5 x d, and then cooling (d - diameter of the electrode). Groove filled symmetrically.	
Other processing	Mechanical treatment to reduce residual stresses. After each pass the weld metal, upon termination arc, forging hammer with a rounded tip of radius R 3-5 mm.	

Before use, the electrodes were dried in a furnace at a temperature of 350 ^{o}C for 2h. By the use of the electrodes were stored in the individual heating elements, at a temperature of 100 to 120 °C.
During the process of rehabilitation surveillance of welding technologists or international welding engineers is provided. Welding was performed by certified welders according to EN 287-6:2012, with experience in welding cast iron.
As recommended by the manufacturer of electrodes, blowtorch with direct current electrode set at + pol was used. Welding was performed with short arc electrode diameter of 2.5 mm, current 50-70 A in the horizontal grooves and crater filling at break arch with continuous removal of slag. On completion of the groove weld face is sanded in preparation for PT testing.

Quality control of performed welding and surfacing

Before welding, control of all preparatory work was carried out. During the welding, control of basic parameters from welding technology was performed: appearance of weld, weld overshoot, notches, undercuts, surface cracks and surface porosity. After the welding, VT was performed, and weld was PT tested. VT testing, according to the standard EN ISO 17637:2012, and PT, according to EN 571-1:2005, performed the operators trained and certified according to EN 473:2011.

In the most critical parts, such as ribs of housing of oil distribution, the eligibility criteria according to DIN EN ISO 5817:2008 for the quality level C weld and level 3 for the indication according to EN ISO 23277:2011 were met. PT testing, fig. 5, was carried out after the completion of the mechanical treatment of facial suture, the surface condition - nice area, defined by this standard.

Quality requirements and acceptance criteria in other cases were limited within the following reasons: size, design, the level of damage and the condition of the base material (old iron with enough porosity) of oil manifold did not allow the full implementation of cleaning biodegradation, so that the basic material still has residual amounts of oil in porous places, which is quite hard for welding, and in those places badly affected the quality of repairs.

a) approved indications for the required criteria

b) limitation because of constructive solutions

Figure 5. *The appearance of welding repaired ribs after tests PT*

Conclusion

Welding is one of the basic steps of a repair of any assembly in the industry because of the relatively short time needed for repair, costs and the possibility of securing a satisfactory quality The difficulty in performing such repair, except the welding itself, is an appropriate preparation which involves fully or partially degreasing of workpiece and surface preparation for repair, before joining repair. This paper describes the preparation of a porous surface by oil biodegradation. Based on the analysis of the possibilities and feasibility of repairs, this paper shows cleaning technology using biodegradation of oily surfaces.

Due to time limitations for treatment of surfaces and a limited workshop requirements in terms of preparation and adherence to precise manufacturer's instructions, degreasing biodegradation results were modest, but enough to make repairs by welding on the most critical parts with satisfactory performance.

For any subsequent remediation, where degreasing by biodegradation will be used, requires detailed preparation and precise adherence to the guidelines laid down by the manufacturer, which are given in the instructions for use of the preparation.
Dealing with the problem described above requires interdisciplinary knowledge from different fields - chemistry, engineering, physics, metallurgy and tribology. Only well organized and systematic approach as well as teamwork can lead to satisfactory results and reliable answers in order to perform high quality welding repairs.

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