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Investigation of the Performance Properties of Parts Surfaces to Be Recovered by Semi-Automatic Hardfacing

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Abstract. *The purpose of the study is to scientifically substantiate the choice of optimal technological modes of hardfacing of parts during restoration in order to ensure high performance of the operational stability of the deposited coatings. Mathematical dependencies have been obtained that make it possible to evaluate the effect of electric current strength, voltage and feed rate on the hardness and wear resistance of the deposited layer. The hardness and wear resistance of semi-automatic hardfacing with SV-08G2S wire in various technological modes are determined. The dependences of the coefficient of friction on the distance of passage of the counter body are established. For semi-automatic hardfacing with low-alloy wire, it was found that the optimal technological modes are: hardfacing speed – from 2 m/min, voltage – 135 V, amperage – 17.5 A. In this case, the hardness reaches a maximum value of 25.6 HRC, and the wear coefficient is 0.57.*

Keywords: *restoration, semi-automatic hardfacing, wear, hardness, tribological testing.*

Introduction

Studying the work of repair enterprises of the Karaganda region, it was found that most often the shafts of dynamic equipment of complex geometry with various types of defects after operation are subject to repair [1, 2]. Such defects include wear of seating surfaces, corrosion, cracks, chips, burrs, notches [3, 4]. Defects exceeding wear of 5% of the shaft diameter are subject to restoration by hardfacing. Hardfacing is a method that allows, during repair, to give not only the original geometry, but also increased, improved mechanical properties compared to the base metal [5]. In addition, the deposited surfaces are characterized by high resistance to abrasive wear in the presence of impact loads, corrosion and oxidation at normal and elevated temperatures.

The most economical method of hardfacing is semi-automatic in shielding gases, so it is most often used in the restoration of parts [6]. In addition to being economical, this surfacing method provides high adhesion between the base and weld metal.

It is known that deposited coatings have high technological properties, can provide the specified requirements for operational properties [7], due to the correct choice of electrodes, welding wires and powders for wear-resistant surfacing, appropriate grades, alloying fluxes, thermal and other types of treatments after surfacing [8].

It is also assumed that the technological modes of hardfacing can affect the quality of operational properties (hardness, wear resistance) of the restored parts. Thus, the purpose of the study is to establish the influence of technological modes of semi-automatic surfacing during the restoration of parts on the performance properties of the restored surfaces.

Research methods

The experiment was carried out on samples of Steel 3 with semi-automatic hardfacing with Sv08G2S welding wire. Steel marking and chemical composition are presented in tables 1, 2.

Hardfacing of prototypes for further mechanical testing was carried out according to the sketch shown in Figure 1.

The experiment was carried out according to the classical method of a multifactorial experiment (full three-factorial). The experiment planning matrix is presented in Table 3.

Figure 2 shows samples with semi-automatic hardfacing in the amount of 6 pieces.

Semi-automatic hardfacing was performed on flat samples 70 × 55 mm in size to analyze the hard-

Table 1 – Chemical composition of Steel 3

Steel grade	Mass fraction of elements, %				Hardness
	C	Mn	Si	Cr	
St3	0,14...0,22	0,4...0,65	0,05...0,17	≤0,3	HB 10^{-1} = 131 MPa

Table 2 – Chemical composition of the welding wire Sv08G2S

Wire grade	Mass fraction of elements, %				Hardness
	C	Mn	Si	Cr	
Sv08G2S	0,05...0,11	1,80...2,10	0,70...0,95	≤0,2	180...210 HB

Table 3 – Experiment design matrix

Factors	Variation parameters			Pair interactions			The hardness of the deposited layer, HRC (average value)
	Amperage, I, A	Voltage, U, V	Wire feed speed, U, m/min				
Upper level	260	24,5	4,5				
Lower level	135	17,5	2				
Center	197,5	21	3,25				
Variation interval	62,5	3,5	1,25				
Code	X_1	X_2	X_3	X_1X_2	X_2X_3	X_1X_3	
1	135	17,5	2	+	+	+	18,92
2	145	18,5	2,5	-	-	+	25,6
3	205	22	3	-	+	-	16,24
4	220	23	3,5	+	-	-	16,9
5	240	24	4	+	-	-	17,42
6	260	24,5	4,5	-	+	-	15,22

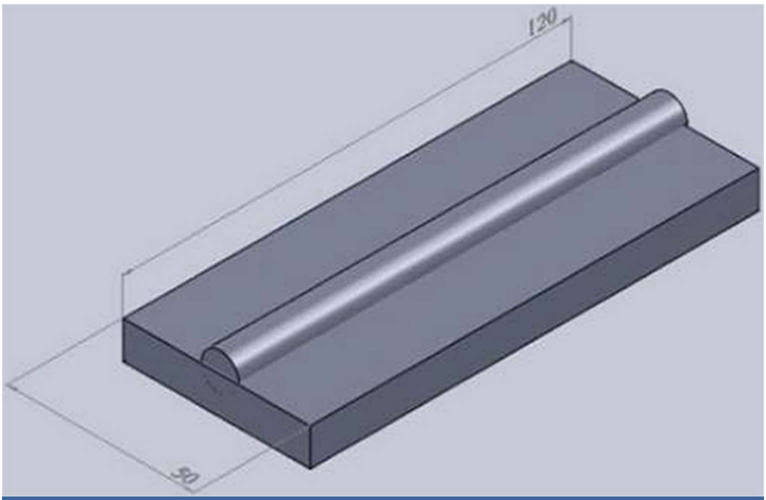


Figure 1 – Sketch of a prototype for semi-automatic hardfacing

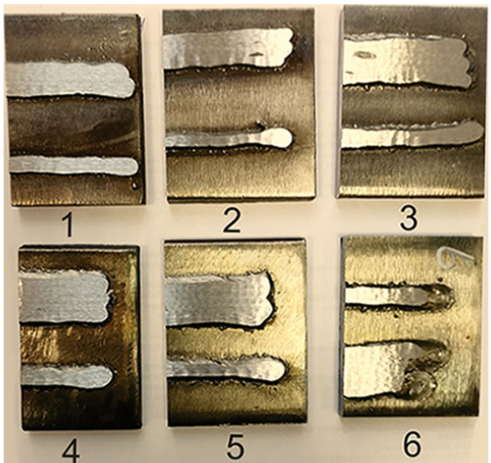


Figure 2 – Samples with semi-automatic hardfacing

ness and geometric parameters of the weld with a single-pass weld at specified parameters. To determine the amount of wear on the samples, a section with several welds was made in multi-pass hardfacing without changing the selected parameters.

The hardness of the deposited welds was controlled by the Rockwell method (Figure 3). A diamond cone was used as an indenter. The hardness values were determined on the HRC scale at a force of 150 kgf after careful grinding of the deposited surface with a Mitutoyo HR-530 series hardness tester.

The measurements were carried out at least five points, as shown in Figure 3, then the average values were calculated for each analyzed surface. The standard error in determining the hardness was within ± 1-2 HRC.

Results and discussion

The experimental data obtained are presented in Table 4.

The obtained mathematical and graphical dependences of the hardness of the deposited layer on the parameters of the technological process of semi-auto-

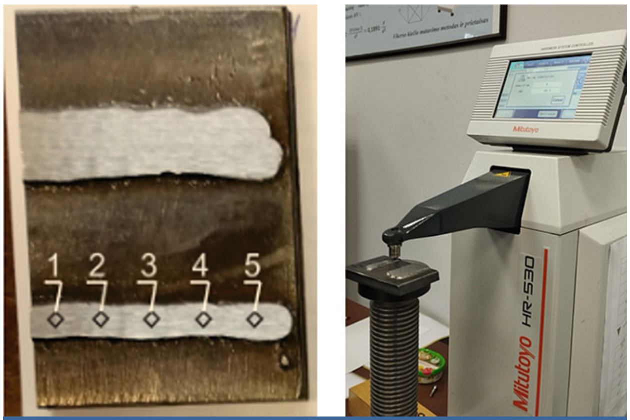


Figure 3 – Hardness control

Table 4 – Experimental data for hardness control

Number mode	Amperage, I, A (X_1)	Voltage, U, V (X_2)	Wire feed speed, U, m/min (X_3)	Hardness of the deposited layer, HRC (Y)	Average value, HRC (Y_{cp})
I	135	17,5	2	23,6	25,6
				25,2	
				26,4	
				26,4	
				26,4	
II	145	18,5	2,5	18,7	19,04
				18,7	
				19	
				19,3	
				19,5	
III	205	22	3	16	17,4
				17,2	
				17,6	
				18,1	
				18,1	
IV	220	23	3,5	16,8	16,84
				16,4	
				16	
				17,1	
				17,9	
V	240	24	4	17,9	15,45
				17,5	
				14,9	
				15	
				15,9	
VI	260	24,5	4,5	15,6	15,22
				15,6	
				14,7	
				14,7	
				15,8	

matic hardfacing are shown in Figure 4.

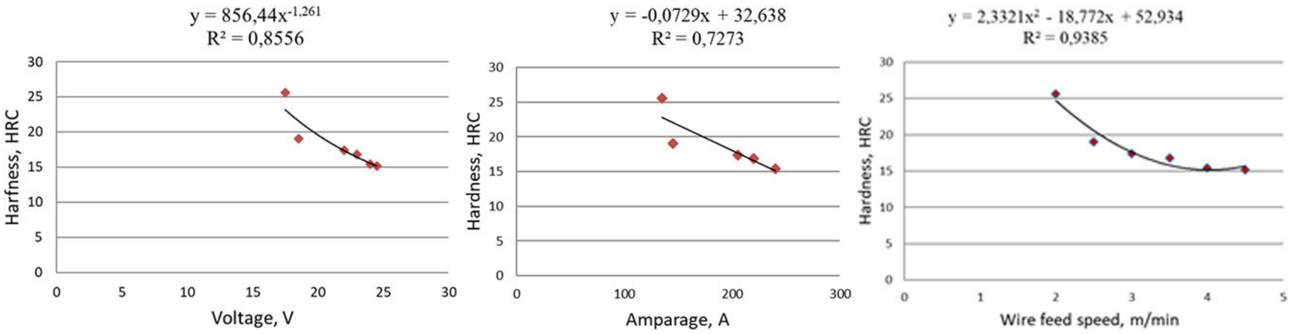
To determine the performance properties, mechanical wear resistance tests were carried out.

Tribological studies were carried out according to the «Ball-disk» friction scheme on a Microtest tribometer (Microtest, SA, Madrid, Spain, Figure 5) under the following experimental conditions:

- sliding distance – 200 m;
- sliding speed – 200 rpm;
- radius trajectory – 3 mm;
- load – 20 N;
- test temperature – 22.1°C;
- time – 50 min.

The indenter was a ball made of hardened stainless steel AISI 52100 with a diameter of 6 mm, hardness 64 HRC.

Wear tests were carried out on each of the 6 samples (Figure 6). The amount of wear of the material



R – correlation coefficient at a confidence level of 95.0% and a significance level of 0.05

Figure 4 – Results of statistical processing according to the planning matrix for the dependencies of hardness on the technological parameters of the hardfacing

Figure 5 – Microtest SMT-A/0100 tribological setup

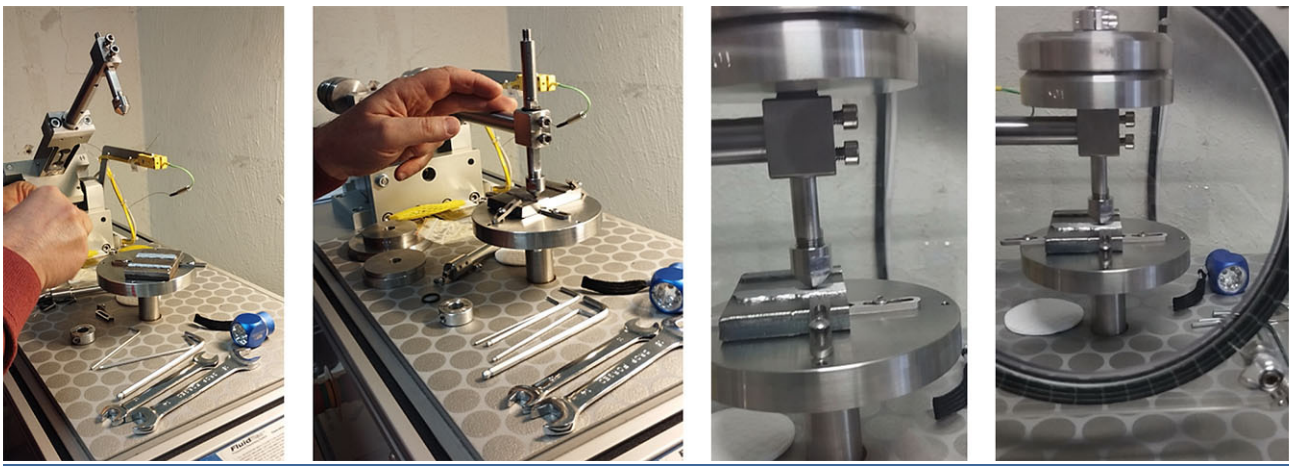


Figure 6 – Prototypes in the process of testing for abrasive wear

with surfacing was evaluated by weighing prototypes before and after testing on an analytical balance. The weight loss of the ball was recorded on a laboratory scale with an accuracy of 0.00001%, the weight loss of the sample was recorded with an accuracy of 0.001.

The obtained dependences of the hardness of the deposited layer on the change in the mass of samples and balls are shown in Figure 7.

A summary of the results of all experiments is presented in Table 5. Analyzing the results of these experiments presented in Table 5, it was found that the optimal mode of semi-automatic surfacing is mode I, which provides the maximum hardness of the deposited layer and the lowest coefficient of friction. In general, it can be concluded that by changing the technological modes, the hardness of the deposited layer varies by 10.38 HRC units from the minimum to the maximum value.

Conclusions:

1. An analysis of the statistical processing of experimental data showed that there is a dependence of hardness and wear resistance on the following factors: amperage, voltage and wire feed speed.

2. With an increase in wire feed speed – from 2 to 4.5 m/min, voltage – from 135 to 260 V, amperage – from 17.5 to 24.5 A, the hardness increases by 10.38 units on the HRC scale, which is approximately 39%, the friction coefficient varies from 0.57 to 0.93.

3. Optimal modes of semi-automatic hardfacing: I = 135A; U = 17.5 V; Ʋ = 2 m/min. With the specified parameters, the required hardness of the deposited layer, penetration depth, weld geometry and minimum wear are provided.

4. Restoration of mating parts using semi-automatic hardfacing allows you to create coatings that are superior in properties to the material of the part.

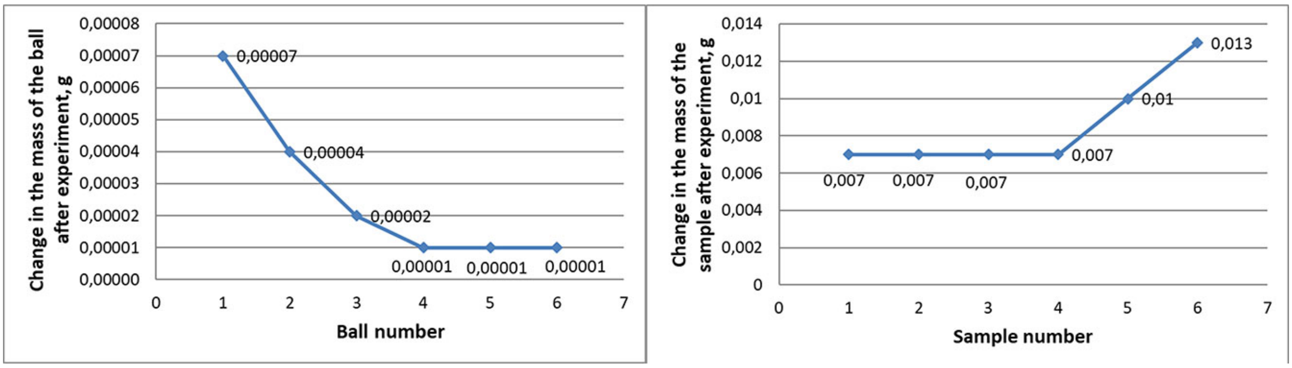


Figure 7 – Graphical representation of the change in the mass of samples after tribological tests

Figure 8 – The dependence of the coefficient of friction on the distance of passage of the counterbody in tribological tests

Table 5 – Summary of experimental results

Number mode	Hardness of the deposited layer, HRC	Change in the weight of the ball after the experiment, g	Change in the weight of the samples after the experiment, g	Average friction coefficient
I	25,6	0,00001	0,013	0,572854
II	19,04	0,00001	0,007	0,811208
III	17,4	0,00007	0,007	0,716026
IV	16,84	0,00002	0,007	0,727906
V	15,45	0,00001	0,007	0,932176
VI	15,22	0,00004	0,01	0,801742

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Жартылай автоматты балқыту арқылы бөлшектердің қалпына келтіретін беттерінің пайдалану қасиеттерін зерттеу

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Аңдатпа. *Балқытылған жабындардың пайдалану төзімділігінің жоғары көрсеткіштерін қамтамасыз ету үшін қалпына келтіру кезінде бөлшектерді балқытудың оңтайлы технологиялық режимдерін таңдаудың ғылыми негіздемесі зерттеудің мақсаты болып табылады. Электр тогының, кернеудің және беру жылдамдығының балқытылған қабаттың қаттылығы мен тозуға төзімділігіне әсерін бағалауға мүмкіндік беретін математикалық тәуелділіктер алынды. Әр түрлі технологиялық режимдерде СВ-08Г2С сымымен жартылай автоматты балқытудың қаттылығы мен тозуға төзімділігі анықталды. Үйкеліс коэффициентінің контрдененің өту қашықтығына тәуелділігі анықталды. Төмен қоспаланған сыммен жартылай автоматты балқыту үшін оңтайлы технологиялық режимдер орнатылған: балқу жылдамдығы – 2 м/мин, кернеу – 135 В, ток күші – 17,5 А. Бұл жағдайда қаттылық максималды мәнге жетеді 25,6 HRC, тозу коэффициенті 0,57.*

Кілт сөздер: *қалпына келтіру, жартылай автоматты балқыту, тозу, қаттылық, трибологиялық сынаулар.*

Исследование эксплуатационных свойств восстанавливаемых поверхностей деталей полуавтоматической наплавкой

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Аннотация. *Целью исследования является научное обоснование выбора оптимальных технологических режимов наплавки деталей при восстановлении для обеспечения высоких показателей эксплуатационной стойкости наплавленных покрытий. Получены математические зависимости, позволяющие оценить влияние силы электрического тока, напряжения и скорости подачи на твердость и износостойкость наплавленного слоя. Определены твердость и износостойкость полуавтоматической наплавки проволокой СВ-08Г2С на различных технологических режимах. Установлены зависимости коэффициента трения от расстояния прохождения контртелом. Для полуавтоматической наплавки низколегированной проволокой установлено, что оптимальными технологическими режимами являются: скорость наплавки – от 2 м/мин, напряжение – 135 В, сила тока – 17,5 А. При этом твердость достигает максимального значения 25,6 HRC, коэффициент износа 0,57.*

Ключевые слова: *восстановление, полуавтоматическая наплавка, износ, твердость, трибологические испытания.*

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