MODELING EFFECTS OF IMPACT (SHOCK) -ABRASION WEAR OF IRON BASED HARDFACING

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Abstract: *The paper contains results for wear in conditions of impact between a standard welded and tested specimen realized in the presence of a layer of abrasive particles trailing in the contact zone. It gives an idea about the specifics of this type of wear depending on the impact force and the particle size of the abrasive at various hardness achieved by hard-facing with alloys with different carbon equivalent and a degree of hardening of the layer after the test. Based on an experimental research it was proved that the impact-abrasive wear has its specific features expressed via respective graphical relations. The research was funded by Fund "Scientific Research" at the Ministry of Education and Science of the Republic of Bulgaria.*

Key words: IMPACT-ABRASION WEAR; IRON BASED HARD-FACING; NUMERICAL APPROACHES;

1. Introduction

The mechanism and the basic laws of impact-abrasive wear are determined by a series of factors, the main ones being the energy of the impact and the hardness of the working parts and also the size of the abrasive powder. This type of wear has been introduced by Russian scientists V. N. Vinogradov and G. M. Sorokin [1]. In the overall assessment of the impact-abrasive wear, there must be taken into consideration the strengthening of the layer which in most cases has a favorable effect on the work of the equipment.

Using the research of strengthening of various welded layers it is possible to determine conditions that prevent the occurrence of brittle cracks, their development and the subsequent merger with others that decrease the wear resistance of the metal in the event of an impact.

The creation of engineering methodologies for calculating the intensity of impact-abrasive wear is an important need related not only to the dependencies of wear on the physical and mechanical properties but also to the strength characteristics and the micro-geometry of the tested surface. In the process for improving an existing stand [2] within a separate project (No.1242/11 funded by Todor Kableshkov University of Transport) there was performed a full modification of the construction and the mechanics of movement in conducting the experiments; also there was implemented advanced electronic control which expands the range of the tested-materials types (fig. 1.).

The timeliness of the research is reinforced also by the fact that taking into account the differences in the tribological research methods there cannot be made any analogy between the impact-abrasive wear and the methods of wear for sliding.

The direct dynamic implementation of solid abrasive particles on the surface of the contact creates favorable conditions for the emergence of cracks in the top metal surface that are easily merged with other similar cracks during the penetration of adjacent grains. Under these conditions, the most negative are the influence of the heterogeneous properties of the surface layer as well as the presence of brittle phases and locally hardened layers. These factors lead to the emergence of brittle cracks, their development and the subsequent merger with others that decrease the wear resistance of the metal in the event of an impact.

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The new solution of the stand imitates the process of wear that occurs after a direct blow to the tested body with a standard specimen in direct contact with free falling abrasive particles in the form of a sand table. The subsequent plastic deformation is heterogeneous and localized in separate micro volumes. On impact part of the energy and sometimes all the energy is absorbed by the metal.

It is spent for deformation strengthening which as a general property of the metal is manifested as a resistance against the subsequent deformation. The research of strengthening is of interest due to changes in the microstructure of the material.

The purpose of the present paper is to summarize the results of the experimental research which are related to the basic factors of testing in the newly created stand by application of a methodology from an established standard [2].

2. Defining the parameters of passive designed experiment

In Majlesi Branch of Islamic Azad University in Iran, there were welded with three types of electrodes of chemical compositions cited in Table.1, 30 pieces of standardized samples which were a subject of same technological conditions.

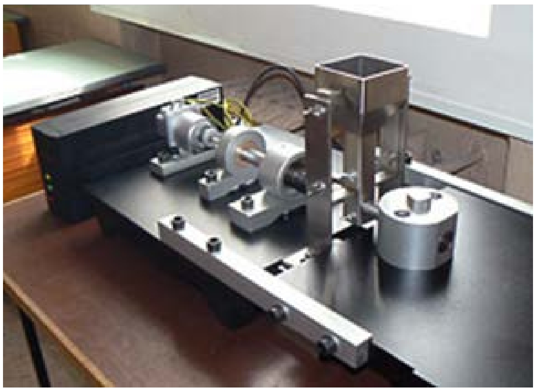


Fig.1. *General View of the stand for impact-abrasion wear*

Fig.2 *rough*

Fig.3 *processed*

General view of hard-facing samples

Fig. 1 shows the impact abrasion test device according to Gost 23.207-79 Russian Standard. Fig.2, fig.3 shows the general appearance of the rough and processed samples. Tabl. 1 shows the chemical composition of Iron based Hard facing electrodes that produced by Iranian AMA electrode company.

Table 1. *Chemical composition of the electrodes used for hard-facing*

Electrode	**C**	**Mn**	**Si**	**Cr**	**Mo**	**V**	**W**	**$C_{екv}$**
1105	0,9	0,5	0,5	4,2	8,5	0,9	1,1	3,305
1600	0,5	0,3	0,4	7	0,5	0,5		1,640
1622	0,2	0,4	0,5	2,8				1,440

An essential task of this section is to establish the possibility to find a possible relation between the loss of weight /LW/ and the four parameters of the experimental research.

- Layer hardness /HRC/;
- Impact energy /PI/;
- Size of the abrasive material / GS /;
- Carbon equivalent /Cekv/ of the welded material.

Tabl.2 shows the combinations of the explored experimental controlling factors and the values of the respective fixed meanings for the loss of weight

Table 2. *Relations between controlling managing factors and the examined factor*

№	**X_1 (HRC)**	**X_2 (PI)**	**X_3 (GS)**	**X_4 (C_{ekv})**	**LW [g 10^{-4}]**	**HRC after IAW**	**%Δ HRC**
1.	0.543	-1	-1	1	13	58,8	12,21
2.	0.850	-1	-1	-0.786	9	57,3	0,70
3.	-0.734	-1	-1	-1	23	42,54	26,23
4.	0.509	-1	-0.137	1	22	66,16	27,48
5.	0.372	-1	-0.137	-0.786	21	64,44	29,14
6.	-0.454	-1	-0.137	-1	25	38	0,53
7.	0.549	-1	1	1	101	62,16	18,40
8.	0.522	-1	1	-0.786	114	65,64	25,99
9.	-0.713	-1	1	-1	100	47,3	39,12
10.	0.563	0	-1	1	18	62,02	17,69
11.	0.468	0	-1	-0.786	16	65,98	28,62
12.	-0.993	0	-1	-1	27	45,1	50,84
13.	0.672	0	-0.137	1	49	60,98	12,30
14.	0.843	0	-0.137	1	48	62,56	10,14
15.	0.358	0	-0.137	-0.786	55	57,9	16,50
16.	0.556	0	-0.137	-0.786	59	60,76	15,51
17.	-0.679	0	-0.137	-1	97	44,0	27,54
18.	-0.904	0	-0.137	-1	125	45,0	44,23
19.	0.515	0	1	1	258	60,8	16,92
20.	0.256	0	1	-0.786	260	59,86	24,19
21.	-0.700	0	1	-1	255	36,28	6,08
22.	1	1	-1	1	48	65,52	10,86
23.	0.052	1	-1	-0.786	35	66,46	27,81
24.	-0.973	1	-1	-1	64	41,62	37,81
25.	0.529	1	-0.137	1	156	54,2	3,83
26.	0.420	1	-0.137	-0.786	106	65,98	30,40
27.	-0.474	1	-0.137	-1	125	43,72	16,59
28.	0.884	1	1	1	418	65,0	13,24
29.	0.427	1	1	-0.786	403	60,98	20,28
30.	-1	1	1	-1	510	33,74	13,22

The conversion key from coded meanings to normed ones is in Tabl.3; in this Table, there is also the range of change of the controlling parameters of the process.

Table 3. *Range of change of controlling factors*

Factors	**Variation levels of controlling factors**		
	Code [-1]	**Code [0]**	**Code [1]**
X1 (HRC),[/]	29,80	44,45	59,10
X2 (PI), [J/sm^2]	0,48	1,30	2,12
X3 (GS), [mm]	0,196	0,728	1,26
X4 (C_{ekv}), [/]	1,44	2,372	3,305

As a result of an implemented standardized procedure [5,6] at defining an experimental basis from Tabl.2, there was determined a regression model for the loss of weight depending on the specified above controlling factors the coefficients of which are presented in Tabl.4.

Table 4. *Coefficients of the model and its adequacy validations*

	For Loss of weight	For strengthening
b(00)=	272.775	103.911
X_1	-62.5362	-32.8925
X_2	85.2068	-6.22308
X_3	122.241	-1.85656
X_4	36.4447	18.5948
X_1^2	8.93410	24.5241
X_1X_2	-17.6384	11.3752
X_1X_3	-15.7202	7.27488
X_1X_4	33.6166	-5.52689
X_2^2	16.6244	-.652608
X_2X_3	77.1357	-5.62072
X_2X_4	12.9030	-6.46953
X_3^2	49.7648	-2.41272
X_3X_4	4.68954	-1.38608
X_4^2	-213.794	-93.1205
	R = 0.9933	R= 0.8596
	79.1201>2.4274 (a=0.05;14;15)	3.0328>2.4274 (a=0.05;14;15)

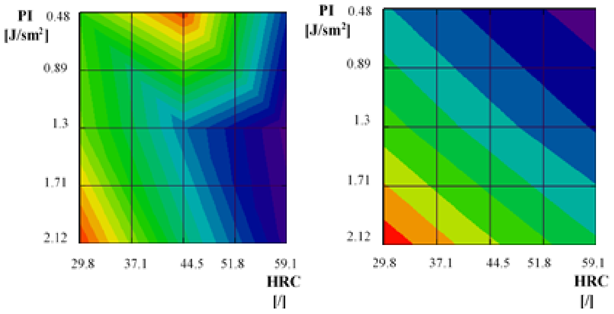
The estimation of the approximation-models quality is made on the basis of the regression coefficient R and Fisher F-criterion between the actually observed experimental and modeled values of resulting quantities. The meanings of these checks are contained in the last two rows of Tabl.4.

3. Results and discussion.

The analysis is supported by a copperplate research of each group. There can be found in [7] the microstructures of explored samples with similar dendritic microstructures of specimens welded with electrode materials 1105 and 1600. They represent martensite and carbide in the inter-dendritic spaces. The microstructure of the specimen welded with electrode 1622 is of a cell type and with bainite in the cell volumes.

It is possible to prove important statements as a consequence from an organized and planned parameter changes at impact-abrasive wear. They are deduced on the basis of the obtained regression model for the loss of weight (Tabl.4) and they follow the natural logic of this type of wear. As it is clear from the graphs in Fig.4, the big loss of weight is observed at low hardness and at high impact energy. The bigger particle size of the abrasive, the bigger wear value; this is confirmed by the graph on Fig.6 b) and c).

GS – 0.196 [mm]; C_{ekv} – 2.372 GS–0.848 [mm]; C_{ekv}– 2.372



GS – 1.46 [mm] ; C_{ekv} –2.372

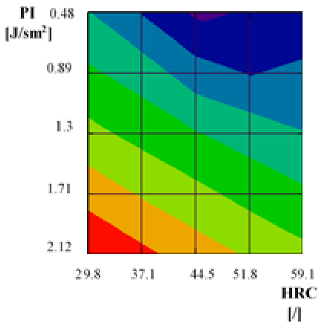
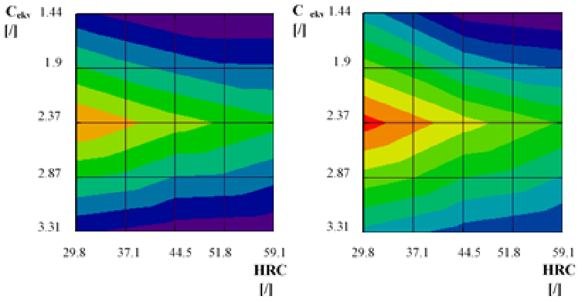


Fig.4. *Dependence of loss of weight for IAW (impact-abrasive wear) on the variation of hardness and the impact energy*

Regardless of the fact that hard-facing samples with electrodes 1105 and 1600 possess similar dendritic microstructures, the included alloying elements create different conditions of wear. It is clear from Fig.5 that the most intensive wear occurs for coated electrodes 1600 forming C_{ekv} near to 2.37. This statement is confirmed also by the graph in Fig.6 a).

GS–0.196 [mm]; PI–1,3 [J/sm^2] GS–0.848 [mm]; PI–1,3 [J/sm^2]



GS–1.46 [mm]; PI–1,3 [J/sm^2]

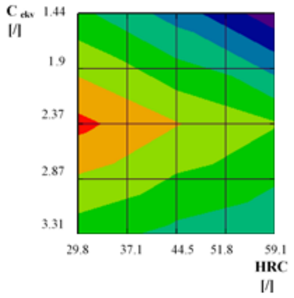
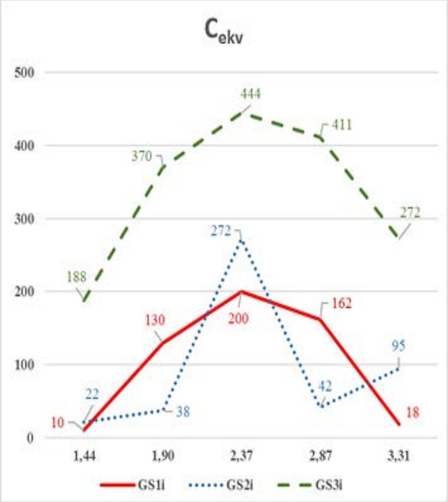
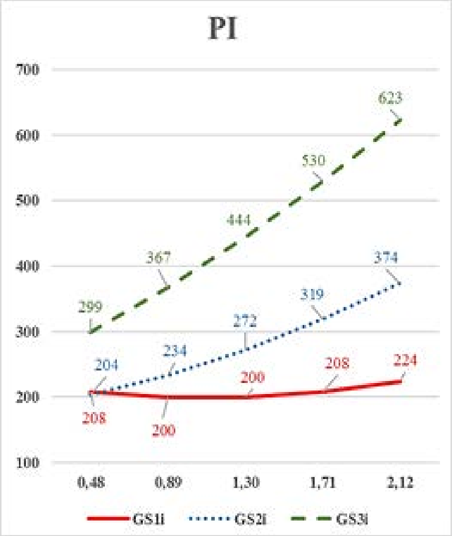


Fig.5. *Dependence of loss of weight for IAW on hardness and the carbon equivalent of welded metal*

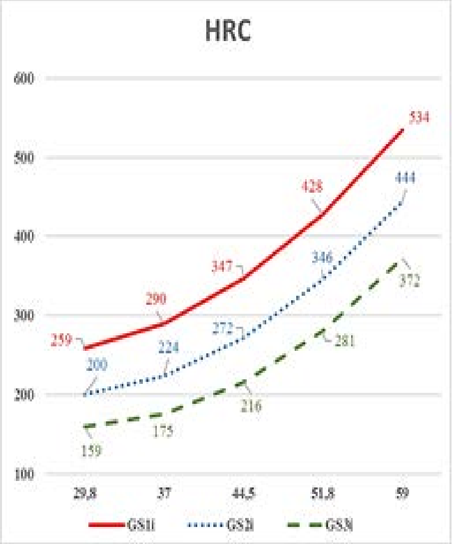
The analysis of the model for strengthening shows that it is stronger expressed for the smaller initial hardness of the welded surface. It is strongly influenced by the structure of the welded material; most hardened layers are obtained with electrode 1600. This can be seen in Fig.7.



a) carbon equivalent



b) impact energy



c) hardness

Fig.6. *Dependence of loss of weight for IAW on carbon equivalent, impact energy and hardness*

The analysis of the model for strengthening shows that it is stronger expressed for the smaller initial hardness of the welded surface. It is strongly influenced by the structure of the welded material; most hardened layers are obtained with electrode 1600. This can be seen in Fig.7.

Table 5. *Multi criteria decisions determined on the basis of the regression models*

SOLUTION PARAMETER	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
X1 (HRC) ,[/]	29,8	29,8	44,45	59,1	59,1	51,27
X2 (PI),[J/sm^2]	0,48	0,89	1,3	1,71	2,12	0,48
X3 (GS) ,[mm]	0,196	0,728	0,196	0,462	0,196	0,994
X4 (C_{ekv}) ,[/]	3.305	3.305	2.372	2.372	2.372	2.372

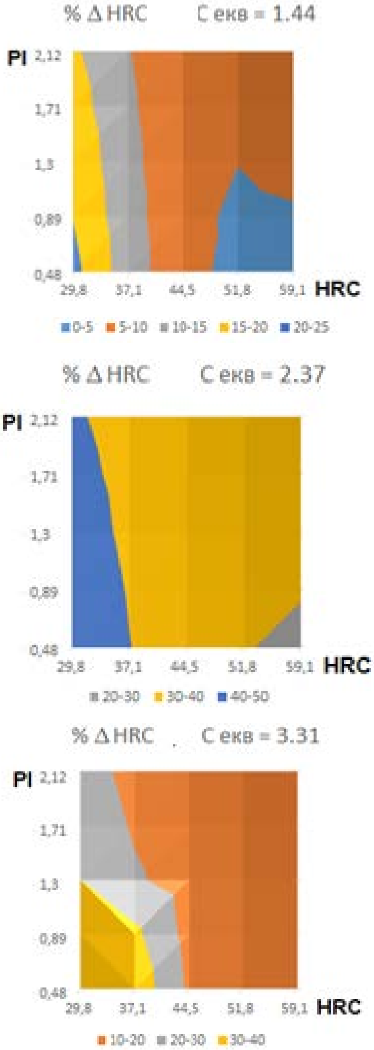


Fig.7. *Dependence of strengthening in IAW on the variations of hardness, the impact energy and the carbon equivalent*

It is proven in [7] that most intensive wear refers to coated electrodes 1600 which forms C_{ekv} near to 2.37. This contradiction between the most intensive wear and strengthening of this electrode leads to a solution to a multi-criteria problem. The formulation of its goal is related to the determination of input parameters for testing at IAW guaranteeing the minimal loss of weight and the maximal strengthening. Tabl.5 contains the solutions of this problem. The values of the controlling IAW parameters guarantee strengthening bigger than 35% and wear less than 30%.

4. Conclusion.

The paper presents a designed experiment with four factors of variation during the tests – coating hardness, impact energy, abrasive-material size and carbon equivalent of the hard-facing material. Based on the vast experimental database from the research there have been drawn conclusions about the influence of various factors on the loss of weight and the hardening of the layer. There have been obtained regression dependencies and there have been built graphical dependencies that allow a precise analysis of the loss of weight due to impact-abrasive wear. There have been determined six technological solutions that guarantee the minimal loss of weight, stability, and the maximal strengthening.

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