HIGH MANGANESE DOPED IRON-CARBON ALLOYS – A PROMISING MATERIAL FOR PARTS IN RAILWAY TRANSPORT WORKING UNDER WEARING CONDITIONS

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Traffic safety of the railway transport in many cases is determined by reliability and longevity of friction couples on rolling stock. The last, in its turn, depends on such substantial aspects as compatibility of surfaces and proper choice of materials [1, 2]. Majority of materials used for making different details in friction couples are metallic alloys. That is why at present the considerable attention is paid to metallophysics aspects of friction [3, 4].

Among the prevailing problems we can emphasise on such as wear of wheels and rails, break blocks, bearing, guides, etc [1, 4, 5].

The production of details consumes a lot of expensive metals, which is not always expedient. The availability of substantial sources of iron-manganese ores should and could be used for making alloys with special properties, including high resistance to wear, the substantial increase in which could be reached by complex alloying [6, 7].

Varying of content of manganese in iron-carbon alloys allows getting practically whole range of metallic matrices, characteristic for these alloys [8]. Thus, there appears the possibility to affect all structure dependent properties of alloys which.

Among the details which are being worn there are slider bearings and guides [1, 9]. One of the most dangerous types of wear of friction surfaces causing the intensive fracture is grasping. So, for example, to prevent tear in the box-tree slider bearings in freight carriages the special counter-measures should be elaborated.

The grasping appears not only under conditions of dry friction, but also during the border friction under high loading. Therefore, the determination of range of allowable loading–speed characteristics, at which material works without grasping is a very important applied problem.

The tribotechnical tests have been performed using the CMЦ–2 friction machine by the roller–show scheme, as the 45Г2 steel with 50–55 HRC hardness was chosed as a counterbody. Sliding speed was 0,628 m/s. Before the test of every couple specimens were worn-in up to complete adjoining of surfaces of friction and constancy of friction moment. During the estimation of resistance against tear samples were tested under loading from 25 kg during 10 min with stepped loading scheme. Loading at which tear appeared (as well as numerous points of grasping) in the friction couple, were used as characteristics of resistance against tear. The loading under which grasping of materials occurs will be understood not only as the stop of roller in the friction process, but also the formation of the numerous points of grasping, accompanied by the whiz of torn out material, and also by increase in values of constant of friction and temperature of both oil and specimens. Temperature in intermittent points of contact, to the opinion of leading specialists of this field [10] is the main reason for origination of jamming. Therefore during tests, the temperature of grease and material of shoe was measured as well. The I-20A, AC-8 and MC-20 oils were chosen as lubricants.

This work presents studies of high Mn-alloyed iron-carbon alloys, chemical composition and basic mechanical properties of which are provided in [11, 12]. The microstructure of alloys consists of austenitic metallic matrix with inclusions of lamellar graphite particles. In the structure of alloys there are composite carbides of $(Cr, Fe)_7C_3$, $(Cr, Fe, V)_{23}C_6$ types, which fact is confirmed by XRD data. The results experiments are provided in tables 1, 2, 3.

Table 1

Dependence of constant of friction on temperature

Time of test, min	Specific loading 2,5 MPa		Specific loading 5,0 MPa	
	Constant of friction	Temperature of oil, °C	Constant of friction	Temperature of oil, °C
1	0,063	32	0,053–0,092	33
10	0,07	45	0,067–0,092	59
20	0,073	56	0,092–0,130	78
30	0,08–0,09	61	0,130	84
40	0,063	64	0,053–0,06	86
50	0,06	67	0,11	88
60	0,063–0,09	68	0,130	89

As can be seen from *table 1*, during some 10–12 min period (after 30 minutes of work) the increase in the was observed. Further there occurs the decrease in the constant of friction indicating the structural adaptation of the alloy. It should be noted in addition that the temperature in the oil bath was stabilised. In [13] it had been stated, that for some materials the temperature of friction surfaces after work-out becomes stable and does not exceed 49° C. Thus, it could be considered that under applied friction conditions and at set loading–speed parameters the first 30 minutes (or the first 1000 m of way), are the time of continuation of work-out and adaptation of materials to the friction conditions. Unfortunately, values of wear of shoes after an hour of test under 2.5 MPa loading were rather low, changing in a fourth digit only, that made the analysis of results somewhat difficult. That is why we conducted tests with longer duration.

Table 2

Resistance of alloys to wear under greasing (I–20A oil) at specific pressure 2.5 MPa in 4 hours.

No. of alloy on a matrix mat. planning	Wear of pack, g	Percent of correlation	Hardness HV	Resulted wear, g/sm^2 on 1000 m.r.	Resulted wear, m^3/sm^2 on 1000 m.r.
1.	0,0112	100% (3)	250	0,0008845	0,118895
2.	0,0163	146 (7)	199	0,00128	0,185776
3.	0,0134	120 (4)	204	0,00105	0,14705
4.	0,0209	187 (9)	179	0,001642	0,23159
5.	0,0089	80 (1)	218	0,0006992	0,103279
6.	0,0183	164 (8)	162	0,00143	0,20169
7.	0,0143	128 (5)	184	0,001123	0,157946
8.	0,0155	139 (6)	161	0,001217	0,17766
9.	0,0095	85 (2)	223	0,0007464	0,10366

Analysis of data provided in table 2 allows drawing the conclusion that the intensity of destruction, according to the classification proposed by B. I. Kostetski [14] can be attributed to the normal mode of friction, or, more precisely, to the normal mechanochemical wear of metals and mechanochemical form of abrasive wear. For comparison, we tested high Ni-alloyed materials of ЧН15ДХ2 Niresist class the БрОФ6.5–0.4 bronze. The wear of Niresist for 4 hours was 0,0226, and of bronzes – 0,00243 g. Further increase in time of testing alloys up to 8, 12 and 16 hours, resulted in substantial reduction of intensity of alloys wear, indicating the adaptation of materials to the friction conditions and showing of the so-called phenomenon of structural adjustment. Therefore higher values of wear of specimens for shorter friction time in material can be considered as a period of working-out characterized by both the change in surface roughness and processes in the surface layers of material to the friction area. Taking into account time of presence of grease in the friction area, we can note that the durable process of periodic contact through thin boundary layers, including penetration of lubricant through graphite pores, works out superficial layers not only up to the optimum equilibrium roughness, but also to the certain structural state. It should be noted as well that the plastic form of graphite allows creating a relief on the friction surfaces well keeping lubricant on them. In addition, in the conditions of «grease starvation» the part of grease adsorbed in graphite pores feeds the friction surface, postponing thus the rise of catastrophic wear. We will note that bearing strength of grease film considerably rises with its saturation up to certain level by the low dispersive products of wear – graphite and phosphides. We have carried out tests in the conditions of the «grease starvation» when 3 drops of grease were applied to the surface of roller by a pipette. As a result, depending on specific pressure and material of counterbody, the film formed from graphite and rests of grease on the surface of roller was held during 1.5–4 hours. This is the confirmation of the positive role of graphite in conditions of friction both in grease, and in «grease starvation».

The intensity of wear is substantially dependent on strengthening of alloys under friction conditions. Earlier the author of this work found that these alloys strengthen under conditions of dry friction [11]. Further researches allowed finding that strengthening of subsuperficial layers of alloy also occurs place under conditions of boundary greasing.

It should be noted that tests of alloys 1, 5 and 9 with the highest hardness revealed approximately identical wear. Although the alloy #1 had maximum hardness, however as seen from Table 1, hardness under conditions of boundary greasing is not the only factor providing high resistance to wear. Coefficients of correlation between intensity of wear and hardness at the specific loading 2,5 and 5,0 made MPa were r = - 0,75 and r = - 0,85, respectively, so the increase in specific pressure weakens the role lubricant.

At the same time, in repeated tests, and also in longer test, the alloy #1 had a were, minimum of all alloys, and did not yield to the bronzes.

So, thanking to the peculiarities of structural–phase composition of the studied alloys, there is substantial reserve for decrease in of intensity of wear.

The next stage of experimental studies was determination of loading at which intensive grasping occurs.

ЧН15Д7Х2 nickel cast-iron, commercially called «Niresist» and the БрАЖМц bronze were chosen as comparison materials.

One of the most widely used criteria in engineering practice for estimation of tribotechnical capabilities of material, are those of heat proof and the thermal stress A_{mp} [13, 15].

Thermal stress was calculated on the basis of experimental results by a formula (1).

$$A_{mp} = V * P_{уд} * f \quad (1)$$

where V is a speed of sliding, m/s. P_{yd} is specific loading, kg/sm^2, f is a constant of friction. The results of experiments are given in table 3.

For manganese cast-irons, loading at which material intensively grasped was found to range from 110 to 155 kg, whereas numeral values of thermal stress criterion ranged from 1102140 to 1314000 J/m^{2}sec. Maximum loading, at which the alloy #1 grasped exceeded the «threshold loading», at which grasping of the БрАЖМц bronze occurred. It was also much higher than the loading at which the «Nirezist» alloy grasped. So, the revealed features allow drawing conclusion that iron-carbon alloys additionally alloyed by manganese can successfully compete both with the non-ferrous alloys, and with the high-alloyed iron-carbon alloys.

It should be noted that the maximum resistance to grasping under conditions of friction in grease was revealed by material with maximum hardness and content of varying alloying elements, the same alloy possessed maximal resistance to wear under conditions of dry friction.

Table 3

Tribotehnical descriptions of the БрАЖМц and ЧН15Д7Х2 alloys

№	БрАЖМц Bronze						ЧН15Д7Х2				
	Loading, P, kg	$t_{spec.}$, °C	$t_{m.}$, °C	f_{fr}	PV_f, $\frac{kg \cdot m}{cm^2 \cdot s}$	PV_f, $\frac{J}{m^2 \cdot s}$	$t_{spec.}$, C	$t_{m.}$, °C	f_{fr}	PV_f, $\frac{kg \cdot m}{cm^2 \cdot s}$	PV_f, $\frac{J}{m^2 \cdot s}$
1.	25	28	29	0,029	0,455	45500	28	29	0,029	0,455	45500
2.	35	30	31	0,032	0,703	70300	38	33	0,035	0,769	76900
3.	45	38	36	0,050	1,413	141300	49	41	0,052	1,469	146900
4.	55	48	41	0,066	2,270	227000	61	54	0,146	5,042	504200
5.	65	67	71	0,073	2,979	297900	75	72	0,192	7,837	783700
6.	75	73	72	0,079	3,720	372000					
7.	85	89	78	0,122	6,512	651200					
8.	95	102	86	0,136	8,113	811300					
9.	105	117	107	0,158	10,418	1041800					
10.	115	133	121	0,170	12,277	1227700					
11.	125	143	135	0,177	13,894	1389400					
12.	135	152	147	0,188	15,938	1593800					
13.	145			0,288	28,033	2803300					

It worth to note as well that the performed complex researches on determination of capabilities of manganese cast-irons as tribotechnical materials allowed finding that there always is a chance to postpone the material's « grasping threshold».

For example, tests in the environment of the I-20A oil (200 ml bath volume), under 140 kg loading the temperature of oil reached 115° C, when the oil started to smoke. Critical temperature for the I-12 and I-20 industrial oils is 105–120° C [15]. The oil flash temperature is 165–180° C. It should be noted in addition that grasping was observed at elevated temperatures of both oil and shoe. It is clear that high temperatures in the contact zone substantially change the viscosity of oil. That increases the part of metal contacts and shear stresses in the zone of friction contact. High temperatures intensify oxidation of grease, desorb the oil layer, lowering his lubricating properties. According to the to the contact–hydrodynamic theory of greasing, nature of lubricating material and viscosity define its behaviour in the gap between bodies, rolled with sliding. Large viscosity of greasing is favorable for formation of thicker oil films, and, consequently, for reduction of gradient of speed in the layer of greasing, shear stresses and decrease of constant of sliding friction during the contact of bodies [10].

Therefore we proposed to use oils with higher critical temperatures, to avoid their destruction. Testing in the larger oil bath (which allowed some lowering of it temperature as well), with oil of other characteristics allowed postponing «threshold of intensive grasping» by 10–20 kg, that is likely not to be the limit for this type of materials. The data obtained can be a valuable source of information for determination of contact endurance and bearing strength of details made from the explored alloys.

On the basis of stated above, to further increase of resistance of materials against grasping we can recommend the forced cooling of grease, and extraction of worn particles from the friction area which act as abrasive particles, use of anti-scoring additives to grease, removal the presence of juvenile surfaces serving as points for formation of «bridges of welding». In addition, complex alloying of the explored alloys, allows multiplying heatproof of alloys, and consequently and promoting their resistance against «thermal grasping».

Thus, it has been shown, that the high manganese-alloyed iron-carbon alloys do not yield to the non-ferrous and high-alloyed alloys of Niresist type, used as tribotechnical materials in the friction couples in railway transport.

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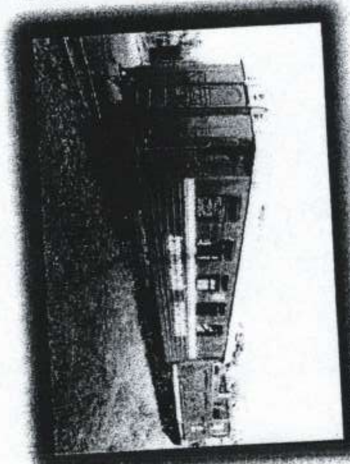

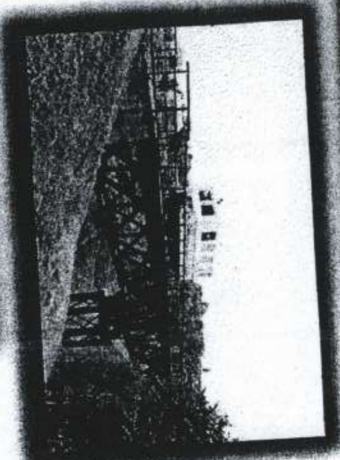

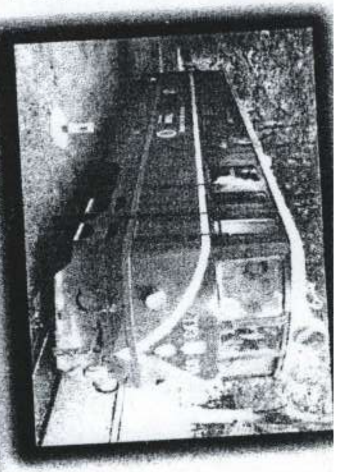

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PREFACE

It is the finish of the third year of active interest of community, government and business structures in the destiny of narrow-gauge railways of Galychyna and the Carpathians and two years of our „Industrial and tourist transport" journal. Not far ago we said farewell to the 1st International "Carpathian Tram Forum", and then we had the 2nd International Forum, which mustered operation specialists, amateurs, representatives of official circles and social structures of Ukraine and neighbouring countries of Central Europe, Russia and Baltic states. Among them, it worth mentioning Mr. D. Morgan – President of the European Federation of museum and historical railways (FEDECRAIL), Mr. S. Wiggs – Head of NERHT, Mr. V. Tsybukh – Head of State tourist administration of Ukraine, Mr. S. Gustiak – a councillor of a governor of Prešov Region (Slovak Republic), Mr. A. Klimashevsky – Head of Department of resorts and tourism of Lviv RSA and many other respected persons. This year forum was performed along the Irshava-Vyhoda-Lviv route, in order to emphasize on the necessity to preserve a part of Borzhava narrow-gauge railway. Between two forums there were visit of NERHT experts J. Fuller and F. Cooper, a number of presentation journeys with the participation social organisations and foreign guests, meetings in the Ministry of Transport participated by Mr. S. Wiggs and Mr. D. Morgan, inspection journeys by Ivano-Frankivsk RSA, several publications in the press. As the result of these activities, today we have no need to convince the community, government and business structures in the expediency of tourist exploitation of narrow-gauge railways, including tram lines and other historical technical objects. However at this time this still do not facilitates the fate of organisations bearing these objects on their balance. Since the maintenance of their vital activity to large extent lays exclusively on these organisations, tourist routes are still not formed, railways perform technological functions, staffs are few in number, technical capabilities are far not sufficient. Therefore we should create centralised programs on the local and all-Ukrainian budget levels for the renovation of historical technics, jointly with operation organisations provide the maintenance of track sections, which are included into the route. The creation of light freight-passenger locomotive and some other equipment on the local base still remains a question. The other question is insufficient legal basis of this activity without legally defined notion "tourist railway", etc., departmental Rules for technical exploitation are out-of-date. Our issues will further promote the popularisation of transport topics and preservation of transport heritage.

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