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EFFECT OF DOPING CHROMIUM STRUCTURAL STEEL AT ITS ABRASIVE WEAR RESISTANCE AFTER HEAT TREATMENT

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Effect was found no effect of alloying chromium in an amount of 1 - 5 % on abrasive wear resistance medium carbon steel shown the feasibility of rheological kinetic concept abrasive wear resistance for an explanation of said effect.

Key words: monolith doping chromium, hardness, abrasive wear resistance and rheological parameters.

Introduction

One of the most common types of abrasive wear of steel machine parts , equipment and tools in various industries are sliding against friction wear monolith - large pieces of rock or abrasive wheels, abrasives which is firmly connected to each other through links [1].

Friction monolith is accompanied not only wear metal, but also the destruction of the abrasive by chipping , crushing and shearing, which contributes to updating its wearing ability with respect to the metal.

The main feature of the picture quality wear steel surfaces sliding against a monolith - it is clearly visible streaks on it in the form of small scratches oriented in the direction of relatively abrasive metal or conversely, relatively metal abrasive.

Their origin streaks on the surface traces of abrasive wear is that formed by the destruction of the metal, its displacement in the dumps and plastic deformation of the surrounding areas.

It is known [2] that the plastic deformation of the metal is accompanied by an increase in volume due to the moisture content of the various types of defects, including cracks. Cracks start of embryonic microcracks that may already exist in the metal, and their presence is predetermined manufacturing techniques, that prior mechanical, thermal and chemical treatments. Length, spatial orientation and density of fractures in the metal to be randomly laws. Cracks are also emerging in the process of deformation of metal flow in the interaction of abrasive through inhibition of dislocation structures at different inhomogeneities. Therefore dumps consist of metal in almost ruined condition.

When moving neighboring particles previously formed near abrasive piles on the sides of strokes occur secondary deformation, reorientation toward the metal piles risks or final separation from surface wear. This, according to [3], lies the main mechanism of abrasive wear of ductile metals.

The presence of scratches on the surface of the wear gives reason to conclude that the work of their education are able to make abrasive particles, strength exceeds the strength of steel. Abrasive particles that do not meet the specified conditions will crumble without damaging metal, but worsening conditions of sliding friction them, due to the increased surface lesions. This interaction Abrasives - Metal manifested strength basis abrasive wear mechanism. Thus, the intensity of wear of sliding friction against the monolith defined by the strength characteristics of the metal and abrasive, which depends on the mechanism of action of force on the particle surface, which consists of her immersion into the metal and scratching during translational movement of the surface [4, 5].

Common in the process of dipping and scratching abrasive regarding steel is ductile deformation and fracture of metals, caused by these processes. Therefore, wear steel can be considered as the final result of the destruction of all the processes of plastic deformation and the interaction with abrasive monolith over a period of friction.

For a science - based solution to the problem of abrasive wear resistance of metals developed [5] concept based rheological kinetic understanding of the fundamental issues of communication between destruction and deformation of solids under abrasive wear. The essence of these ideas comes from the consideration of coexistence in the surface layer of the metal wearing two different processes - fracture and plastic deformation, the relationship between them is determined by the rheology of visco - elastic- plastic- destructive processes and the kinetic theory of fracture of solids.

According to the said concept underlying mechanism of abrasive wear is made in a sequential separation and removal of layers of wear particles of metal that formed as a result of the emergence of lateral subsurface cracks at the boundaries of plastic zones near the top of cracks and their initial distribution in the horizontal plane to the intersection with the other side cracks , different macroscopic defects in metal and so on. How to test durability in friction against the monolith can be rheological parameters [5 - 8], the physical meaning of which - the resistance emergence and development of lateral cracks in the metal.

The value of rheological parameters due to the structure of the metal, which may change under the influence of various factors. Because communication durability of rheological parameters steels are multifactorial problem solving which takes place in the following areas: structural components, crystal structure, chemical composition.

In terms of friction against the monolith carbon steel with high wear resistance is not, therefore, the main objective of the study in the direction of the chemical composition is the development of new, more wear-resistant steels by alloying. Alloying elements should provide a selection of refractory compounds (carbides, borides or nitrides) during crystallization , which, along with high strength, should have little tendency to coagulation during tempering steel and sufficient solubility in austenite, which primarily provide strengthening component metal alloy.

The above requirements fully consistent structural steel alloying chromium, which forms the carbide phase and dissolved in austenite, as it strengthens and educated him martensite during heat treatment. In addition, the doping of chromium improves the stability of the structure of the steel to heat by friction action, which plays an important role in the mechanism of abrasive wear [4]. The higher the chromium content in the steel, so its structure is more resistant to thermal action. Therefore, even tempering temperature abrasive wear of chromium steels less than carbon, and the difference in wear of said steel is greater the higher the temperature of their delivery and content of chromium in chromium steels [9].

Note that this conclusion is in contradiction to [10], according to which the doping of carbon steel with chromium in an amount of 1 - 5 % has almost no effect on its abrasive wear resistance at any temperature tempering. However, the authors [10] did not pay attention to this important fact, as a proper explanation he received.

Inconsistency results [9] and [10] indicates a more complex influence of alloying chromium steel for durability during sliding friction against the monolith, to determine which, apart from its resistance to thermal action, it is necessary to take into account other factors.

Statement of the problem

The aim of this work is to further study the effect of alloying chromium medium carbon steel for its durability during sliding friction against the monolith after thermal processing from positions of strength and rheological kinetic approach.

Results of the study

For the study samples were made with medium carbon steels alloyed with chromium, grade and chemical composition are presented in Tab. 1

Table 1

Chemical composition of the investigated steels

Brand steel	Content, %						
	C	Mn	Si	P	S	Cr	Ni
45	0,44	0,78	0,35	0,027	0,025	0,05	-
45Cr	0,44	0,74	0,32	0,025	0,034	0,98	-
45Cr2	0,44	0,63	0,27	0,027	0,024	2,17	0,07
45Cr3	0,44	0,59	0,27	0,027	0,024	3,12	0,09
45Cr4	0,44	0,66	0,26	0,027	0,025	4,18	0,09
45Cr5	0,44	0,59	0,27	0,030	0,024	4,94	0.09

Samples of steel strengthened by heat treatment as follows: heating to a temperature above the upper critical point AC3, quenching with appropriate treatment (Tab. 2) and subsequent tempering at temperatures of 373 K, 473 K, 673 K, 873 K

Table 2

Profiles hardening steels investigated

Brand steel	Steel grade temperature during heating quenching, K	Holding period, s	Environment for hardening
45	1103	600	Water
45Cr	1113	600	Water
45Cr2	1123	720	Water
45Cr3	1143	720	Oil
45Cr4	1153	900	Oil
45Cr5	1173	1080	Oil

After the heat treatment of steel samples were subjected to mechanical testing in tension, indentation and friction against the monolith.

Tensile tests were carried out using a universal machine UMM -50, indentation - stationary hardness Brynelya TS - 2M, friction against the monolith - the upgraded device LKI -3 [11].

As a result of the tests defined boundary strength $\sigma_в$, HB hardness, wear resistance ε and rheological parameters R steels. Wear resistance ε expressing the reciprocal abrasion ΔG, which was measured by weighing on electronic analytical balance "Nagema" (value of a point 0,001 g).

Rheological parameter R was calculated by the formula [5 - 8]. Required for this feature - fracture toughness K_{1c} and thickness plastically deformed zone at the crack tip h_n determined by results of tests on friction involving techniques [12].

These research results trybomechanical and rheological properties of steels (Tab. 3) show that.

Table 3

Trybomechanical and rheological properties of chromium steel after heat treatment

Brand steel	Temperature issue T, K	Flexural strength $\sigma_в \cdot 10^3$, MPa	Hardness HB $\cdot 10^3$, MPa	Wear resistance $\varepsilon \cdot 10^2$, g $^{-1}$	Rheological parameters $R \cdot 10^4$, MPa
45	373	1,7	5,34	1,6	3,92
	473	1,7	4,95	1,32	3,24
	673	0,94	3,26	1,12	2,75
	873	0,73	2,19	1,05	2,57
45Cr	373	2,18	5,89	1,6	3,92
	473	2,05	5,55	1,46	3,57
	673	1,49	4,29	1,17	2,86
	873	1,03	2,77	1,1	2,69
45Cr2	373	2,22	6,01	1,52	3,74
	473	2,09	5,67	1,4	3,42
	673	1,55	4,44	1,19	2,92
	873	1,15	3,11	1,1	2,69
45Cr3	373	2,22	6,01	1,6	3,92
	473	2,09	5,67	1,4	3,42
	673	1,55	4,44	1,22	2,98
	873	1,15	3,11	1,14	2,79
45Cr4	373	2,22	6,01	1,53	3,76
	473	2,09	5,67	1,36	3,34
	673	1,55	4,44	1,16	2,84
	873	1,15	3,11	1,1	2,69
45Cr5	373	2,22	6,01	1,53	3,76
	473	2,09	5,67	1,4	3.42
	673	1,87	5,34	1,1	2,69
	873	1,22	3,3	1,1	2,69

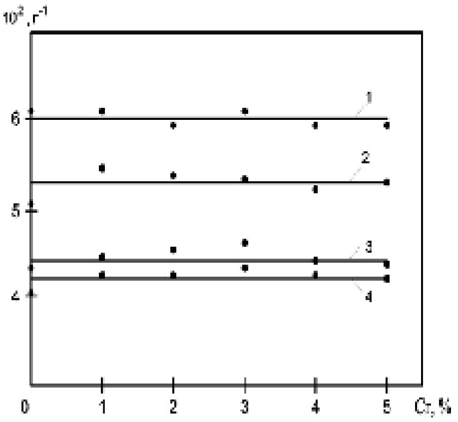

Fig. 1 – The dependence of the wear resistance ε of steel on the content therein chromium Cr for temperature tempering: 1 – 373K; 2 – 473 K; 3 – 673 K; 4 – 873 K

Wear resistance ε hardened steel depends strongly on the temperature tempering: highest wear resistance is observed after tempering at a temperature of 373 K (tetragonal martensite structur), and the lowest - at a temperature of 873 K (structure sorbitol) (Fig. 1).

Under the influence of alloying chromium wear resistance of steels in various structural states varies between 5 - 10 % higher than the wear resistance alloy steel (Tab. 3). These changes are not significant and therefore we can say that the doping of chromium in the range of 1 % - 5 insignificant effect on the wear resistance of medium carbon steel. Thus, these results are consistent with the data [10].

Strength $\sigma_в$ hardened steel also depends strongly on the temperature tempering: the greatest strength of a steel after tempering at temperatures of 373 K and 473 K (tetragonal structure and tempered martensite), and the smallest - 873 K (structure sorbitol) (Fig. 2).

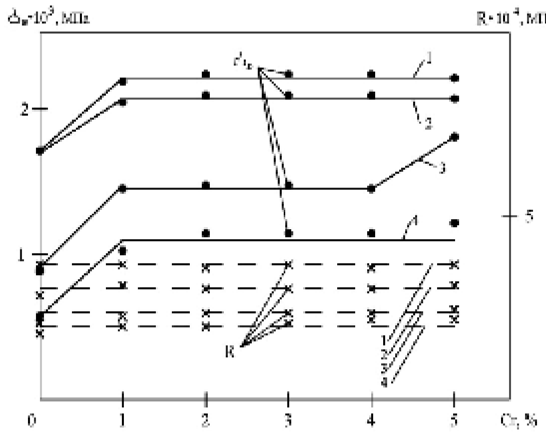

Fig. 2 – Dependence of boundary strength, rheological parameter *R* of steel content in it chromium Cr for tempering temperature: 1 – 373 K; 2 – 473 K; 3 – 673 K; 4 – 873 K

Alloying with chromium in an amount of 1 % contributes significantly to the strength of steel. Thus, the increase in strength depends on the structural state of steel varies from 99 % (structure trostytu) to 23 % (tempered martensite structure) compared with the strength of non-alloy steel (Tab. 3). The greatest strength has a steel structure with tetragonal martensite (increase of strength is 31 %) and the lowest - Steel structure with sorbitol (an increase of strength is 67 %).

For steels with a martensitic structure (tetragonal martensite or released) increase in strength due to the formation minutely bristled martensite after quenching, which is achieved by grain refinement in the original austenite doped with chromium [13].

For steel structure with ferit - cementite mixture of different dispersion (trostyt, sorbitol) increase in strength is explained by the decomposition of carbide particles by slowing down the collapse of martensite during tempering after doping with chromium [13].

Further increase in the chromium content up to 2 - 5 % level practically does not change the boundary strength achieved after alloying 1 % chromium. Therefore, in terms of increasing the strength of steel alloying chromium 45 in excess of 1 % is unreasonable.

Temperature level does leave an impact on rheological parameters R hardened steel: the largest rheological parameters observed after tempering at a temperature of 373 K (tetragonal martensite structure), and the lowest - in temperatures 873 K (structure sorbitol) (Fig. 2). Under the influence of alloying chromium rheological parameters of steel in different structural states varies between 5 - 10 % compared to the rheological parameters of non-alloy steel (Tab. 3). These changes are not significant and therefore influence the doping of chromium in the range of 1 - 5 % of the rheological parameter steel should recognize immaterial.

Comparison between a dependence of wear resistance (Fig. 1), strength (Fig. 2) and rheological parameters (Fig. 2) have content of chromium in it show no correlative link between wear resistance and durability, as well as between strength and rheological parameters, while between wear resistance and rheological parameters of this relationship can be traced.

Therefore, we can note the following peculiarities of chromium doping on trybomechanical and rheological properties of steel: first - structural factors that increase the strength by heat treatment (grinding grains of austenite and carbide phase particles) do not impact the durability and rheological parameters; secondly - evaluation of criteria for durability in friction sliding against monolith rheological parameters is more appropriate indicator than the boundary strength and thirdly - the foundation of strength abrasive wear mechanism consists in resisting the formation and development of lateral cracks in the plastic zones within vertical cracks near the top of surface layer in the fourth - abrasive destruction is different from the bulk, not only in scale localization, but also the morphology, the emergence and spread of cracks.

Conclusions

Based on these results it can be stated as follows.

1. Doping medium carbon steel with chromium in an amount of 1 - 5 % did not have an impact on its abrasive wear resistance under sliding friction against the monolith as a method of protecting the surface from abrasive wear is inappropriate.

2. In terms of increasing the strength of steel alloying chromium in excess of 1 % is unreasonable .

3. Doping medium carbon steel with chromium in an amount of 1 - 5 % has no effect on its rheological parameters .

4. To assess the impact of chromium doping on abrasive wear resistance of steel rheological parameters is more appropriate indicator than limit strength.

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Дворук В.І., Борак К.В., Добранський С.С. **Вплив легування хромом конструкційної сталі на її абразивну зносостійкість після термічної обробки.**

Встановлено ефект відсутності впливу легування хромом в кількості 1 - 5 % на абразивну зносостійкість середньовуглецевої сталі, Показано доцільність застосування реолого-кінетичної концепції абразивної зносостійкості для пояснення вказаного ефекту.

Ключові слова: моноліт, легування хромом, міцність, абразивна зносостійкість, реологічний параметр.