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CAVITATION AND EROSION WEAR RESISTANCE OF CARBON STRUCTURAL STEELS

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In the paper, based on the analysis of literary sources and own researches of authors, the results of cavitation and erosion wear resistance of structural steels are systematized depending on their thermal processing (structure) and type of environment.

The structural structure of steels is based on the analysis of wear resistance during cavitation and erosion fracture of surfaces, and the mechanisms of cavitation fracture of dodectoid, zavectotoid and perlite steels are considered.

Destruction of dodectoid steels begins with ferrite, and then extends to perlite grains. The wear resistance of the pearlite grains of the plate-shaped form is higher than that of perlite of the granular form. Cavitation wear resistance of zeutectoid steels is determined mainly by the properties of perlite. The mechanical properties of which depend on the dispersion and shape of the particles of cementite.

In perlite steels, reducing the size of its grain increases their erosion resistance, especially in the presence of cementite in the structure of the grid, and not ferrite grids.

Using different types of thermal and thermocyclic heat treatment, it is possible to form appropriate structures and, accordingly, increase the cavitation and erosion wear resistance.

Key words: cavitation fracture, structural steels, thermal and thermal cyclic machining, cyclic strength.

Formulation of the problem

Unique dependencies of the intensity of the cavitation destruction of materials surfaces on the type of medium, the material, its phase composition and structure have not succeeded until now. This is primarily due to the fact that until now, an installation has been created that fully takes into account the real conditions for the cavitation, which is explained by the extraordinary complexity of the cavitation process and, accordingly, the difficulty of its implementation in the laboratory.

Analysis of recent research

At present, hydrodynamic tubes or Venturi nozzles are used to model cavitation processes under laboratory conditions [1, 2]; installation with a rotating disk [3, 4]; shock erosion stands [5, 6] and installations with a magnetostrictive vibrator (MSV) [7, 8, 9]. The test method for MRI is based on the American Association for Testing Materials (ASTM) G32-72 standard [4]. It has high reproducibility of the results, is simple and relatively inexpensive and that is why it was accepted by us for testing on cavitation and erosion wear resistance of materials.

At present there is a very large number of different quality and composition brands of carbon structural steels. Data on their properties and purpose are given in the relevant reference literature, but there are no data on cavitation, hydro-erosion resistance.

Carbon steel, depending on composition and state, can have different structures and properties [10] and, accordingly, different resistance to cavitation fracture [7, 8]. As numerous studies have shown, for example, [1 - 9], the main effect on resistance to cavitation destruction is their structure, and therefore when conducting tests of carbon steels on cavitation it is convenient to use their classification according to the structure. Such a system is also chosen to analyze the characteristics of the cavitation wear resistance of carbon steel structures.

The purpose of the research

On the basis of own experimental data and analysis of literary sources, to systematize the laws and mechanisms of cavitation and erosion destruction of carbon structural steels depending on their heat treatment (structure) and the type of medium.

Presentation of the main material and the received scientific researches

Cavitation stability of dodectoid carbon steels is determined mainly by the properties of two structural components - ferrite and perlite. Ferrite, other than carbon, can contain other elements (chromium, vanadium, titanium, etc.), which significantly affect its properties. Properties of perlite depend mainly on the form of cementite. Its grains may have a lamellar or globular shape [10].

In heterogeneous alloys, a less firm structural component is first deformed, for example, in carbonaceous steels the fracture begins with a ferrite, and then extends to the perlite grains. The degree of deformation of perlite depends on its structure. Plate perlite has a higher resistance to plastic deformation than granular. In the granular form of cementite, the main volume in the structure of perlite is ferrite [10] and as a result of resistance to plastic deformation decreases. In perlite steels, the centers of destruction occur on a ferrite grid or on the boundary between the ferrite and the carbide and extends to the side of the ferrite.

The perlite with carbides of the plastic form is destroyed uniformly, it has higher elastic properties, and in this case the ferrite-carbide mixture is more homogeneous and each of its components takes almost equal participation in the resistance of the micro-impact load.

Such a mechanism of destruction of surfaces of carbon dodectoid steels has been repeatedly confirmed by a metallographic analysis of samples with hydro-erosion, cavitation wear [5, 6, 7, etc.].

It is desirable to use high-quality carbon steel for the production of cavitation-resistant parts. In steels of standard quality, the digestion of phase components is considerably developed, which increases its electrochemical heterogeneity. In addition, in ordinary quality steels, there is a large number of nonmetallic inclusions and residues of deoxidation products. The accumulation of these impurities worsens cavitation wear resistance of steels. As a result, high-quality steel, despite the same mechanical characteristics, has 17 ... 20 % higher cavitation wear resistance [5].

Cavitation wear resistance of zeutectoid steels is determined mainly by the properties of perlite. The mechanical properties of perlite depend on the dispersion of particles of cementite. As the degree of dispersion of the lamellar perlite increases, the boundary of strength and plasticity increases. The strength of the granular perlite is much less than the strength of the lamellar, but it has a higher plasticity [10]. Therefore, increasing the cavitation resistance of zeutectoid steels is primarily due to the increased level of their mechanical characteristics. These steels after quenching and low release have significantly higher cavitation wear resistance than pre-eutectoid steels. In this case, both types of steels are characterized by low corrosion resistance, and according to the technological properties, the pre-eutectoid steels considerably exceed the zeutektoid and therefore the use of the latter for the manufacture of cavitation-resistant parts is significantly limited, and for the manufacture of components of complex form they are almost not used [12, 13, 14, 15].

The influence of carbon on cavitation and erosion stability is considered in works [5, 6, 15]. Of these, it follows that with an increase in the amount of carbon, the hydro-erosive stability increases for both annealed and tempered steel (Fig. 1) [5].

For annealed steel, increased erosion resistance is observed with an increase in carbon content from 0.6% to 0.8%. With further increase in carbon content, the erosion resistance is practically unchanged. For hardened steel, the optimum carbon content is 0.4...0.5% and, with a further increase in its content, wear resistance is practically unchanged (Fig. 1). Apparently, a higher carbon content after quenching and low release does not increase the wear resistance of martensite.

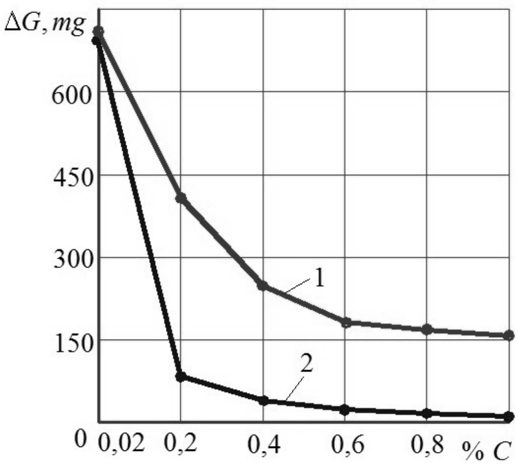

Fig. 1 – Hydrozoerosic wear resistance of carbon steels depending on the carbon content: 1 in annealed and 2-in tempered state [9]

Numerous studies [5, 7, 8, 9, 15, etc.] indicate an increase in the cavitation stability of carbon steel with a fine-grained structure compared to large grain steels. The authors of the works note that, as a rule, weaker micro-sites, which can be found both in the body of grain and on its borders, are initially destroyed.

For fine-grained alloys, due to greater distortion of the crystalline lattice, greater resistance to plastic deformation of the boundary layers is observed rather than the grain itself [16, 17]. In addition, the fine-grained steel structure has higher rates of fatigue multicycle endurance in CAS than coarse-grained [16]. Therefore, when cavitation steel with a fine-grained structure is destroyed mainly by grain, and coarse grains - along the boundaries of grains.

In perlite steels, in the presence of cementite in the structure of the grid, destruction begins in the middle of the grain of perlite and on its boundaries; while the grid of cementite is stored for a long time (steel У12). In the presence of a ferrite mesh (steel 45) perlite grains are stored for a long time, and the ferrite network quickly collapses. In this case, with a smaller grain size of perlite, a finer ferrite mesh is formed that has an increased strength compared to a thick mesh formed with a relatively large perlite grain [10]. Consequently, a decrease in the value of perlite grain also leads to some increase in the erosion stability of steel [5, 18].

The conducted studies [1, 5, 14, 15, 21, etc.] show that the cavitation, hydrocarbon wear resistance of structural carbon steels of perlite and martensitic classes is determined mainly by the nature of the structures obtained as a result of their thermal treatment.

The largest cavitation and erosion wear resistance has the most homogeneous and strong structure of steel martensitic. At the same time, cavitation wear resistance of martensitic depends on its structure, carbon content and alloying elements of steel. With increasing carbon content, the hardness of martensitic during hardening increases [10] and simultaneously increases cavitation wear resistance [15].

The process of catastrophic destruction of steels tempered by martensitic develops gradually and begins after a long period of accumulation of deformations. This is characteristic of steel with a mild-to-fine structure of martensitic.

When quenching from high temperatures, when martensitic has a coarse-grained structure, the fracture develops much faster.

The holiday is the final heat treatment operation, which gives the steel its final properties, and is therefore decisive for the formation and cavitation wear resistance. For carbon steels, the general tendency is that, with increasing temperature, the hardness, strength ($\sigma_в$, $\sigma_{0,2}$) decreases, and the plasticity (δ, ψ) increases [10]. However, the change in these properties with increasing temperature of release is not monotonous. The release at 300 °C leads to an increase in the strength and elasticity. The greatest ductility corresponds to the release at a temperature of 600 ... 650 ° C (for steel 40).

Conducting VV Fomin study of the wear and tear wear resistance of carbon steel 40 and U12A alloy steel 40X (perlite class) also showed the exceptional importance of tempering tempered steels for their wear resistance (Fig. 2).

Mass losses increase sharply with the complete disintegration of martensitic, when sorbite appears in the steel structure (the temperature of release is above 400 °C).

At the release temperatures of 200 °C, martensitic is retained and the steel is characterized by high resistance to micro-shock destruction. At the release temperatures of 400 °C, troost appears in the structure of steels [10] and the erosive stability is somewhat reduced. At a release temperature of more than 400 ... 600 °C, the structure of the steel has a sorbitol-like structure, and at 600°C, the part of the carbides coagulates and takes the spheroidal shape, which dramatically reduces wear resistance.

At high release temperatures, ferrite-carbide mixtures in alloy steels have a greater dispersion than carbon steels [10], which increases their erosive wear resistance (straight 3 in Fig. 2).

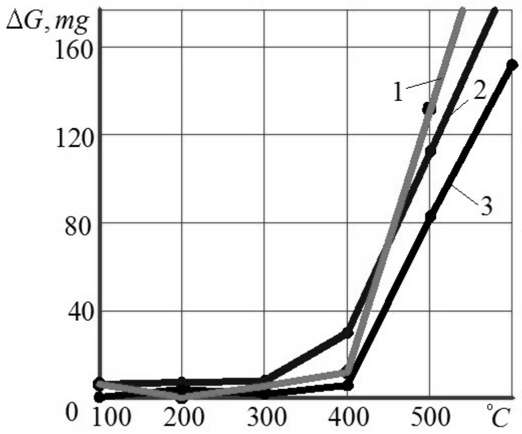

Fig. 2 – Dependence of mass losses in hydrosis of tempered steels from the temperature of release: 1 – steel 40; 2 – steel U12A; 3 – steel 40XN [5]

Thus, the analysis of literature data and studies carried out by us show that the cavitation and erosion, hydrocarbon wear resistance of carbon structural steels is determined, first of all, by their structure.

Thermocyclic treatment (TCT) allows to obtain a fine-grained structure on carbon steels and pig-iron and, thus, to change their physical and chemical properties in the desired direction [19]. However, the analysis of literary sources indicates that in some cases, the "schematic" application of TCT for specific conditions for improving the reliability and durability of parts does not take into account the conditions of their work such as, cyclical loads, changes in temperature fields, aggressiveness of the corrosive environment, the type of wear, etc. However, for each case, optimal regimes and types of TCT, which are determined, first of all, by the material, the heating and cooling rate, the number of thermal cycles, should be used.

The authors studied the influence of TCT on the steel 45 structure in order to further use of thermocycled samples to study the patterns of change in their electrochemical parameters, strength and durability characteristics.

The hardness of steels after the pendulum TCT remains virtually unchanged compared to their hardness after normalization. After the average temperature of TCT, the hardness of steel 45 increases somewhat. Thus, the Brinel hardness (HB) increases from 175 to 188 units after the average temperature of TCT, that is, approximately 7 %. Similarly, insignificant increase of hardness in the case of mid-temperature TCT was also obtained for steel 40X, which amounted to 230 HB after TCT and 215 HB after normalization.

The analysis of the mechanical characteristics of structural steels after TCT indicates that for steels 45 and 40X the gap strength is reduced, but at the same time the characteristics of plasticity increase: the yield line σ_T, the relative elongation δ and the relative narrowing of the section ψ. There is also a convergence of strength characteristics σ_V and σ_T, which is a positive factor in terms of the strength of metals (Table 1).

Table 1

Mechanical characteristics of steels after TCT

Steel	Pendulum TCT					Medium temperature TCT				
	σ_V	σ_T	δ	ψ	$a_H \times 10^4$	σ_V	σ_T	δ	ψ	$a_H \times 10^4$
	MPa		%		J/m^2	MPa		%		J/m^2
45	592/524	357/364	20,4/25,6	45,6/58	68/132	592/586	537/377	20,4/24,0	45,6/57,8	68/163
15X	550/573	375/402	27/31	57/62	73/147	550/580	375/408	27/34	57/64	73/212
40X	865/802	515/520	10,6/13,7	44/69	81/254	865/816	515/529	10,6/12,5	44/78	81/314

Numerator - normalization; denominator - thermocycle treatment.

The most structurally sensitive characteristic was the impact strength of the destruction of a_H, which is significantly increased as a result of swing (from 1.9 to 3.14) and medium temperature (from 2.4 to 3.87 times) TSP. The analysis of the data obtained (Fig. 3) indicates that the optimal number of cycles for the swinging processing steel 45 n_{opt} = 5 ... 6 and n_{opt} = 7 ... 9 for steels 15X and 40X at the rotational and mid-temperature TCT. It was for the stabilized value of the impact strength found for each steel net, and then the other mechanical characteristics given in Table. 1. Properly similar approach is recommended in papers [19, 20].

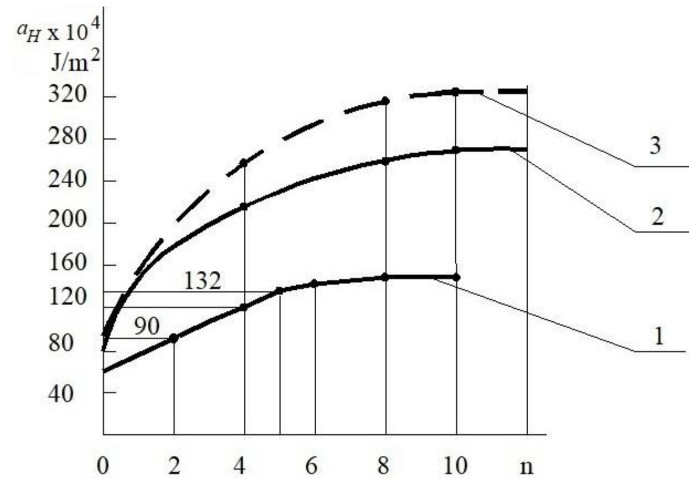

Fig. 3 – Change in impact strength from the number of thermocycles n:
1 – steel 45 at the pendulum TEC;
2 – steel 40X with a pendulum TEC;
3 – 40X steel with medium-temperature TCT

The polarization curves (Fig. 4) were photocopied in a potent dynamical mode at a constant rate of scan of the sample potential, which was a working electrode. To obtain quantitative indicators of the rate of occurrence of corrosion processes on the basis of the Tafel equation, using the mathematical method of finding the curvature of polarization curves and the computer analysis on the basis of this, and based on the method described in [21], found currents of corrosion at normalization and at TCT of steels.

Comparison of polarization curves (PCs) shows that, along with the displacement of the established potential φ_{vst} into the positive region for samples after TCT, in comparison with normalized, there is an extension of the passive zone. Thus, the passive area of samples of steel 45 after TCT is from – 0.0 to 0.2 V in a solution of sodium chloride, without yielding thus the corrosion resistance of normalized steel 45 in hard water. In addition, in the anode and in the cathode regions of the polarization curves, the angle Tof their inclination to the abscissa axis for thermocycled samples is slightly lower than for the normalized ones. The latter indicates a decrease in the rate of corrosion processes in the investigated media.

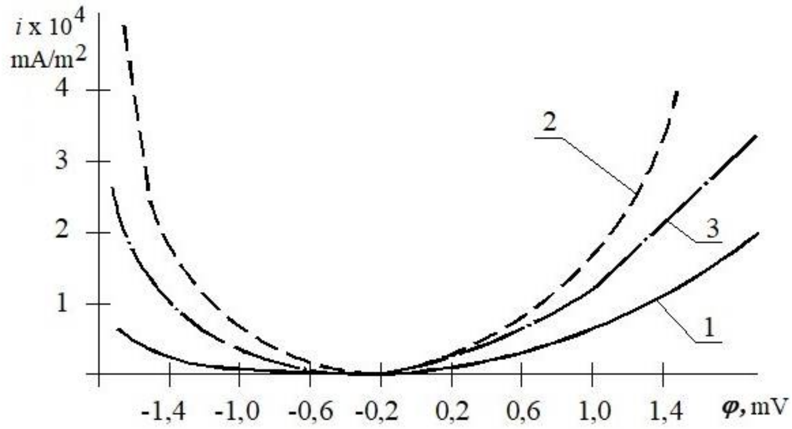

Fig.4 – Polarization curves of steel 45:
1 – in hard water after normalization;
2 – in 3 % NaCl solution after normalization;
3 – in 3 % NaCl solution after mid-temperature TCT

Found, according to our method of corrosion currents, confirm this conclusion. They decreased for thermocycled steel samples 45 compared to normalized at 1.23 and 1.52 times, respectively, when tested in severe water and solutions of sodium chloride.

The study of low cycle fatigue showed that the highest value of the endurance limit is in the alkaline medium, both for normalized and for thermocycled samples, and the lowest value in the acidic medium (apple juice (Fig. 5)). In this case, the value of endurance in alkaline medium exceeds the values of endurance indices in the air. The increase of low cyclic durability in alkaline medium compared with the durability in neutral, acidic environments and in the air is due to the formation of a hydroxide layer on the surface, which prevents the access of oxygen to the deformation zone and reduces the dismembering effect of oxides.

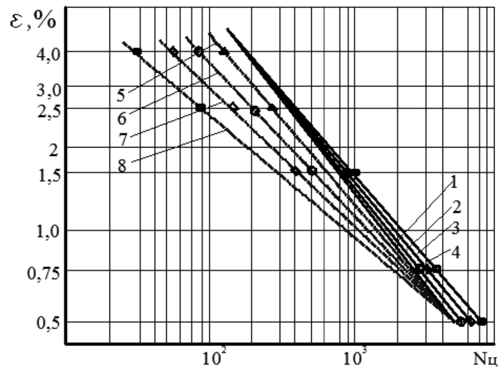

Fig. 5 – Low-cycle durability of steel 40X after pendular TCT (1 ... 4) and after normalization (5 ... 8) in the media:
1.5 – alkaline with pH12; 2.6 – in the air;
3.7 -- neutral (3 % NaCl solution with pH7);
4.8 – sour (apple juice with pH 6.5)

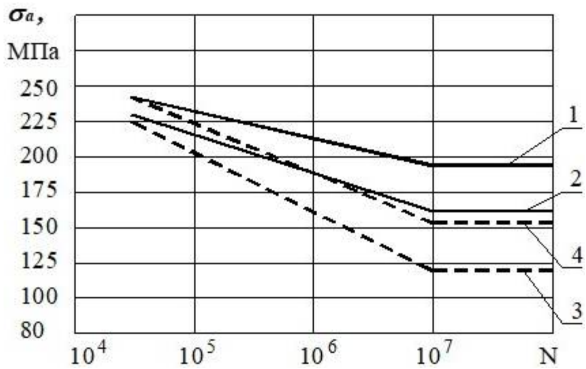

Fig. 6 – Multi-cycle endurance of steel 40X in the air:
1 – after average temperature TCT;
2 – after normalization and 3 % NaCl solution;
3 – after normalization;
4 – after mid-temperature TSP

Intense electrochemical processes of dissolving steels in an acid medium result in the formation of a large number of stress concentrators, which reduce the fatigue strength of both normalized and thermocycled samples (straight lines 4 and 8 in Fig. 5). In solutions of sodium chloride with a lower, compared with acidic medium, corrosion activity of low-cycle durability of steel increases. However, with increasing amplitude of cyclic deformation, the influence of aggressiveness of the medium on the durability is weakened and at ε 3.5 % for thermocycled and ε 3.0 % for normalized samples the equilibrium of their durability in the air and in the corrosive medium takes place [20, 21].

Taking into account the fatigue nature of wear, the multi-cyclic fatigue life of thermocycled specimens in corrosive-active media was investigated. The studies showed that multi-cyclic fatigue endurance of 40X steel after the average temperature of the TCT compared with normalization increased in air from σ-1 = 160 MPa to σ-1 = 187 MPa, that is 17 %, and in solutions of sodium chloride with σ-1 = 124 MPa up to σ-1 = 156 MPa, or

26 % (Fig. 6). The results obtained can be explained by the fact that corrosion resistance grows at TCT and this increase is higher than the higher corrosion activity of the medium. As a result, the number of "corrosive" centers of stress concentrators decreases. The great influence on fatigue endurance, possibly basic, has an increase in the characteristics of steel ductility after TCT, and especially the impact strength.

When cyclic loading of samples in a liquid medium, in accordance with the hydrodynamic theory of the propagation of shock waves, shock wave phenomena largely determine the intensity and ratio of elastic and plastic deformation of surface metal layers. The influence of the medium thus manifests itself in the change in the surface energy of the metal, which makes it difficult or easier to discharge the dislocations in the surface layer.

At long load (multi-cycle endurance $\sigma_A << \sigma_T$) and at low cyclic endurance, especially at $\sigma_A > \sigma_T$, from the first cycles of loading of the dislocation form a cluster. Under the influence of the external stress σ_A and the forces of interaction with other dislocations, in the head of the cluster there are stresses exceeding the shear strength - there is a violation of continuity, the emergence of microcracks. Microcracks are formed in metal volumes, where the density of dislocations reaches a critical value [22]. The formation of microcracks facilitates the discharging of discharges to them, causing the leveling of the layer. The number of microcracks increases over time, which leads to more intensive stretching due to a decrease in the length of the run of dislocations. In this case, the displacement of dislocation clusters to microcracks can restore the activity of previously not working sources of dislocations, which causes an increase in the density of linear defects and a decrease in the rate of expansion [22].

Thus, the cyclic strength of metals is proportional to the energy intensity of their surface layers, which is determined by the energy expended on the deformation and cracking of the metal until the formation of the main crack fractures. For steels after TCT, the energy of the impact strength a_H is much larger and, accordingly, the duration of the strengthening layer of the surface layers is much longer, and the strengthening cycle itself - strengthening is also longer in time. That is why we have higher characteristics of endurance of samples after TCT when tested in air and in a medium of sodium chloride. At the same time, the multi-cycle endurance of samples in the air exceeds its value in the corrosive-active medium both during normalization and at their TCT. It is known that the deformation and destruction of materials under the simultaneous action of the medium, especially the corrosion - active medium, occurs at significantly lower mechanical stresses [16].

The analysis of the above data shows that thermocycled samples have higher corrosion resistance under static conditions (without cavitation) compared to normalized in hard water and in 3 % sodium chloride solution. Consequently, TCT can be an effective method for increasing the corrosion resistance of carbon structural steels. Also, the obtained data indicate that at 40 μm oscillation amplitudes, the thermocycled and normalized samples in a 3% solution of NaCl showed practically the same stability. When the amplitude of oscillations decreases (decreasing the rigidity of the microwardload) from 40 to 28 microns, the stability of the thermocycled samples increased by 1.35 times compared to normalized (3 % NaCl). In studies in hard water, thermocycled and normalized samples at amplitudes of oscillations of the vibrator 40 and 28 μm showed almost the same stability (Table 2).

Cavitation-erosion fracture in a corrosive environment is one of the subspecies of corrosion-mechanical wear (KMW) of metals and alloys [21]. Corrosion-mechanical deterioration of metals is considered as a process based on the fatal-electrochemical nature. In this case, electrochemical processes play the role of catalyst for fatigue failure. However, the role of the corrosive medium is quite significant and the contribution of corrosion to the overall intensity of surface fracture at the microstroke load depends on the correlation between the corrosion and mechanical factors of wear. Curve analysis: the intensity of wear (total mass loss) – the rigidity of the load (the amplitude of the MSV fluctuations), and corrosion losses – the stiffness of the load showed that they are similar to the curves of superficial fatigue. On these curves there are three distinctly delimited zones [22]:

1) zone of intense corrosion-fatigue fracture with the predominant influence of corrosion processes (elastic zone, amplitude, $a \leq 5$ microns);

2) the zone of multi-cycle surface corrosion-fatigue failure with significant impact of corrosion on the total mechanical and chemical wear (elastic zone, a = 5 ... 20 microns);

3) the zone of intense malocyclical destruction with a non-essential role of the corrosion factor (zone of predominantly plastic deformation, and > 20 microns).

Proceeding from this, taken by us during research, modes of micro-impact load a = 28 and 40 microns belong to the zone of intensive low-cycle load with a negligible role of corrosion factor of destruction. It is precisely this that one can explain the practically identical results of wear resistance at a = 40 microns in hard water and in 3 % sodium chloride solution. The mechanical destruction factor in this case is much greater than the corrosion component of the fracture. The same can be said for a = 28 μm when tested in hard water. A slight increase in the corrosion resistance of thermocycled samples (in 1,23 times) with insignificant influence of corrosion factor of destruction completely equaled the insignificant effect of increasing corrosion resistance (in 1,23 times).

When wearing in a solution of sodium chloride at a = 28 microns, an increase in corrosion resistance in 1.52 times resulted in an increase in cavitation and erosion resistance of 1.35 times. This can be explained by the fact that the research mode was closer to the zone of multi-cycle surface corrosion-fading destruction (zone 2) and with more significant influence of the corrosion resistance of thermocycled samples received a more significant increase in overall wear resistance.

Table 2

Influence of pendular TCT on cavitating and erosion and corrosion resistance of steel 45

Environment	Amplitude a, μm	Number of hermocycles n	Corrosion current i, mA/cm^2	Mass loss, Δm, mg/cm^2
3% NaCl	0*	normalization	0,0079	-
-”-	0*	5	0,0052	-
hard water	0*	normalization	0,0037	-
-”-	0*	5	0,0030	-
3% NaCl	40	normalization	-	12,0
-”-	40	5	-	11,8
-”-	28	normalization	-	4,2
-”-	28	6	-	3,2
hard water	40	normalization	-	4,8
-”-	40	6	-	4,8
-”-	40	6	-	4,7
-”-	28	8	-	2,4
-”-	28	normalization	-	2,6
-”-	28	6	-	2,5

0* – without superimposed ultrasonic oscillations (static)

Grinding of grain, in particular by TCT methods, leads to an increase in the fatigue strength of metals. Thus, according to the data obtained by us (Fig. 6), the average temperature TCT of steel 40X increases the limit of endurance in the symmetric cycle of loads with σ_{-1} = 167 MPa to σ_{-1} = 216 MPa, that is, almost 30 %. Considering the fatigue-electrochemical mechanism of destruction of the surface metal layers, it would also have to be expected a more significant increase in cavitation stability of steel 45 after TCT. Obviously, the explanation of the results obtained by the reasons outlined above is not enough. It is necessary to look for them also in the relationship between the specificity of the micro-shock load and the resulting structure of the layers after the TCT.

It is known [7] that the area of the cells of the destruction of metal under cavitation is many times smaller than the size of the transverse size of the area of the grain and is proportional to the individual structural components having different strength characteristics, different ability to strengthen the phases. In accordance with this destruction, the surface layer of the metal passes initially in certain "weak" places, which for steel 45 are the boundaries of ferrite and carbide inclusions in the ferrite.

With the swirling method of thermocycling, the grain of perlite is crushed, and the ferrite remains unchanged. As a result, we obtain a structure in which the small interstices of perlite are surrounded by ferrite. Due to the micro-impact load, the destruction of the metal begins at the boundary of the ferrite component and subsequently develops in the direction of the ferrite. Thus perlite inclusions appear to be separated from the bulk of the metal, which leads to a significant weakening of the mechanical connection between the structural components. The next cuvette effect of the liquid medium is "washes out" the perlite grains, which is the reason for the intense wear of thermocycled specimens.

In the case of the application of a medium-temperature TCT throughout the cross-section, a structure of granular sorbitol-like perlite was obtained. However, it is known that steel with a grain perlite structure has less resistance to cavitation fracture than steel with a structure of plate perlite [5, 6]. In the plate form of the ferrite-cementite mixture, each phase is almost equally involved in the resistance of the micro-impact load. In the globular form, the surface of the carbide phase decreases and therefore the fraction of its participation in the resistance to destruction also decreases.

Consequently, studies have shown that the use of carbon monoxide steel structures is first and foremost in view of increasing their corrosion resistance, as well as increasing corrosion-mechanical wear resistance under loads with a predominant influence on the corrosion factor of fracture and, in part, with multi-cyclic surface corrosion-fatigue fracture with significant corrosion effects on the total mechanical and chemical deterioration.

Conclusions

1. Cavitation stability of dodectoid carbon steels is determined mainly by the properties of two structural components - ferrite and perlite. Destruction begins with ferrites, and then extends to perlite grains. At the same time, the plate perlite has a higher resistance to plastic deformation than granular.

2. Cavitation wear resistance of zeutectoid steels is determined mainly by the properties of perlite. Increasing the cavitation resistance of zeutectoid steels is primarily due to the increased level of their mechanical characteristics. These steels after quenching and low release have significantly higher cavitation wear resistance than pre-eutectoid steels. In this case, both types of steels are characterized by low corrosion resistance, and according to the technological properties, the pre-eutectoid steels are significantly higher than the eutectoid ones, and therefore the use of the latter for the production of cavitation-resistant parts is considerably limited, and they are hardly used for the manufacture of components of complex shape.

3. Studies have shown that cavitation, hydrous wear resistance of structural carbon steels of perlite and martensitic classes is determined mainly by the nature of the structures that are obtained as a result of their thermal treatment. The highest cavitation and erosion wear resistance has the most homogeneous and strong structure of steel martensite. At the same time, cavitation wear resistance of martensite depends on its structure, carbon content and alloying elements of steel. With increasing carbon content, the hardness of martensite during hardening increases and at the same time cavitation wear resistance increases.

4. With the increase in the amount of carbon, the hydro-erosion resistance increases for both burnt and hardened steel. For annealed steel, increased erosion resistance is observed with an increase in carbon content from 0.6 % to 0.8 %. For tempered steel, the optimum carbon content is 0.4 ... 0.5 % and, with further increase in its content, wear resistance is practically unchanged.

5. At the release temperatures of 200 ^{o}C, the martensitic is retained and the steel is characterized by high resistance to micro-impact destruction. At the release temperatures of 400 ^{o}C, troosit appears in the structure of steels and the erosive strength is slightly reduced. At a release temperature of more than 400 ... 600 °C, the structure of the steel has a comorphoid structure, and at 600 °C, the part of the carbides coagulates and takes the spheroidal shape, which dramatically reduces wear resistance.

6. The conducted studies point to the prospect of the use of TCT carbon structural steels the first in terms of increasing their corrosion resistance, as well as increasing the corrosion-mechanical wear resistance in loads with a predominant influence of corrosion factor of fracture and, partly, with multi-cyclic surface corrosion-fatigue fracture with significant corrosion effects on the total mechanical and chemical deterioration.

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Скиба М.Є., Олександренко В.П., Стечишин М.С., Мартинюк А.В. **Кавітаційно-ерозійна зносостійкість вуглецевих конструкційних сталей.**

У роботі на основі аналізу літературних джерел та власних досліджень авторів систематизовані результати кавітаційно-ерозійної зносостійкості конструкційних сталей залежно від їх термічної обробки (структури) та виду середовища.

В основу аналізу зносостійкості при кавітаційно-ерозійному руйнуванні поверхонь покладено структурну будову сталей, та розглянуто механізми кавітаційного руйнування доевтектоїдних, заевтектоїдних і перлітних сталей.

Руйнування доевтектоїдних сталей розпочинається з фериту, а далі поширюється на зерна перліту. Зносостійкість зерен перліту пластинчастої форми вища ніж для перліту зернистої форми. Кавітаційна зносостійкість заевтектоїдних сталей визначається, в основному властивостями перліту. Механічні властивості якого залежать від дисперсності і форми частинок цементиту.

В перлітних сталях зменшення величини його зерна підвищує їх ерозійну стійкість, особливо при наявності в структурі сітки цементиту, а не сітки фериту.

Використовуючи різні види термічної і термоциклічної термообробки можна формувати відповідні структури і, відповідно, досягати підвищення кавітаційно-ерозійної зносостійкості.

Ключові слова: кавітаційне руйнування, конструкційні сталі, термічна і термоциклічна обробка, циклічна міцність.