Hydraulic grips, optimization, dynamic forces, gripping force, jaw.

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IMPROVING mathematical models establishment of a full-doped STALEYIZ desired properties

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The basic design principles of chemical compositions of steels with specified properties.

Model, property, steel alloying.

Problem. So far not developed a unified theory that would mathematically summarized the diversity of the processes occurring in the alloy you type dopants. Experiments in the industry associated with significant energy and material costs because of domestic and foreign scholars in the field of complex doping evolved towards a reliable calculation of determining the chemical composition of steel depending on the conditions of production technologies, strengthening and operation details. Thus, the link between the concentration of alloying elements and the structure of the alloy properties.

Analysis of recent research. Studies in recent years have revealed the influence of the nature of the compositions of alloying elements on the internal structure and, consequently, the entire set of properties for steel gears. It was established that the simultaneous achievement of high strength and ductility properties is possible by integrated steel alloying. Complex doping also more appropriate from an economic point of view as rational planning several alloying elements contribute to the mutual influence of the structure and properties of the alloy [1], which can significantly reduce the cost of alloying elements.

To develop efficient methods of doping and modyfikuyuvannya authors [2] The phase composition of the alloy is divided into five levels - macro, micro, sub, meso and atomic. The introduction of alloying elements makes it possible to influence each of these levels. This marked one of the basic principles of choice of doping - namely, increasing the proportion of covalent bonding increases the strength of the alloy, while a metal bond increases its flexibility.

Effect of alloying elements are distributed by type of structural components to which they affect [3]:

- The size of a grain α-phase;
- The size and shape of the carbide phase and karbonitrydnoyi;
- The content of residual austenite;
- Non-metallic inclusions.

Also please note that α-phase, in cementing the steel has in the initial state ferrite-pearlitic structure undergoes during chemical and thermal processing changes the chemical composition (carbon content of steel increases of 0.10 ... 0.25% to 0,8 ... 1,0%), α → γ transformation and martensitic transformation during heat treatment.

Carbide phase should also divided into insoluble during high temperatures and cementation to that formed during the leave.

In respect of non-metallic inclusions, they can be regarded as void. Therefore they should promote maximum distance in metallurgical processes using doping or to their dispersion and hlobulyaryzatsiyi by modification. This generalizing to create computational model requires specification of complex mechanisms of the effect of doping on the structural components, and as a result, the properties of steel.

The purpose of research. The main objective of our work was to obtain steel that would be after thermochemical treatment was sufficient level of contact fatigue strength and thus ensure minimum susceptibility to warping during hardening heat treatment.

Results. Based on the analysis of the developments in this area for cementing steel with a given set of properties required maximum crushing its microstructure. This is mathematically difficult to reliably estimate the dependence of the internal structure of steel alloying, because in the literature are usually qualitative characteristics influence the concentration of alloying elements on the size and shape of the phase components of the alloy. Therefore, in our opinion, cited problem rationally divided on the impact of doping on the structure of complex steel structure and equilibrium state after thermal or chemical-thermal treatment. Bearing in mind the fact that complex alloying differently affects the characteristics zahartovuvannosti and prohartovuvannosti steels. That complex-alloyed steel, having the same properties to the heat treatment may receive varying degrees of consolidation during hardening, while ensuring a sufficient supply of specific job destruction.

As for cementing steel to be chemical-thermal treatment, which is associated with exposure to high temperatures for a long time, in their design should limit the propensity to austenitic grain growth during heating and aging. Based on the fact that the natural austenite grain with which we are dealing with cementation, directly affects the size and properties of martensite formed after heat treatment, it is this structural

characteristic can be intermediaries delicate relationship between the concentration of alloying elements and the structure of the alloy.

As to the establishment of mathematical computer models that correlate the number of characteristics of structural components with properties of the alloy, there are several theories that are based on generally accepted depending Hall-Patch [4], which binds the grain size of yield strength steel:

$$\sigma_{в} = \sigma_{i} + \kappa_{y} d^{-1/2}. \quad (1)$$

However, this equation takes into account the properties of the alloy, in some initial state, which describes the member of (1) - σi.

The second part of ($\kappa_y d^{-1/2}$) Describes the degree of hardening by alloying and heat treatment, what shows that the decisive influence on the properties of the alloy has a grain size (d).

The model developed by Zener and Hillertom [4], takes into account the value Yeshbi-Orovana that links the critical stress (τ) The distance between nedeformuyemymy particles (L) And their size (r) And makes it possible to quantify the degree of hardening of the alloy due to the influence of so-called second phase (deformed particles carbides and carbonitrides) to consolidate effective grain size. This mathematical model includes the Burgers vector (b), Which further complicates the calculations.

$$\tau = \frac{kb}{L}\ln(r/b). \quad (2)$$

For low carbon steels, which includes strengthening technology operations - carburizing, quenching and low tempering, the main structural component is released martensite and carbide phases and karbonitrydna which are insoluble at cementation. Summarizing the listed mechanisms for strengthening steel by doping, given the influence of dislocations, Pickering [4] concluded that in calculating the strength of tempered martensite have a decisive influence martensitic grain size and the distance between the carbide phase particles and their size, and the mathematical dependence is as follows appearance:

$$\sigma_{0,2} = 550 + 1{,}23 \cdot 10^{-1} d^{-1} + 4{,}1 \cdot 10^{-2} L^{-1}. \quad (3)$$

Analyzing this model, we can conclude separation in the above equation ways of strengthening steel three components. The first one is a constant, which corresponds to the strength of the base composition, and the latter two members equations describe the degree of consolidation in accordance alloy by grinding grains and by reducing the distance between the particles of carbide phase. That again we have distribution impacts by doping according to their nature and determination of the coefficients of the components of equation (3), which essentially

determine the extent and strengthening of steel in concrete above case. This significant effect on strength (more than 10% of total steel properties) carbide phase will be if the distance between the particles does not exceed 100 mm. In order to improve computer models in the works of local scientists Vinokur BB and others [5], the influence of alloying elements divided into calculation strengthen the α-phase due to distortion of the crystal lattice and strengthen steel and carbide particles nedeformuyemymy karbonitrydnoyi phases. By selecting the appropriate composition of alloying elements, which enables grinding grain α-phase to achieve the required level of mechanical and technological properties of alloy steel turnover growth boundaries (τ) by strengthening the carbide phase can be calculated based on the equation:

$$\tau = \frac{2aGb}{L}. \quad (4)$$

An important value in this equation is the distance between the particles (L). Analyzing and summarizing considered mathematical models that describe the impact of structure on the properties of the alloy, it can be concluded that for optimal results, the solution of the problem in general terms is reduced to a mathematical expression for the distribution of members, each corresponding to a certain degree of consolidation phase alloy component and installation relationship between parts of the equation. Drawing attention to the fact that all equations as core includes parameters such as grain size α-phase concentration, size and distance between the particles of carbide phase, as one of the criteria is recommended austenitic grain size natural. Because it is austenitic structure determines the properties of martensite and can be intermediate between chemical composition and properties of steel. In addition, the method of determining the natural austenitic grain is mature enough. With regard to the definition of the second criterion, which depends on the characteristics of the carbide phase, then we have the mathematical relationship, which connects the distance between the particles nondeformed solid phase of its concentration and size. It is described by the following equation:

$$L_{k,d} = d \times \sqrt[3]{\frac{\pi \cdot 100}{6\kappa}} - d, \quad (5)$$

where Lk, d - distance between the particles; d - particle size; k - the concentration of particles.

This expression makes it possible to link a concentration of alloying elements (in this case, titanium and niobium) through its effect on the value of strengthening steel. It is necessary to know the distribution of elements between structural components of the alloy. For a visual display depending strengthening alloy of these characteristics are

graphic particles depending on the distance between the carbide phase changes depending on the size and concentration in the steel.

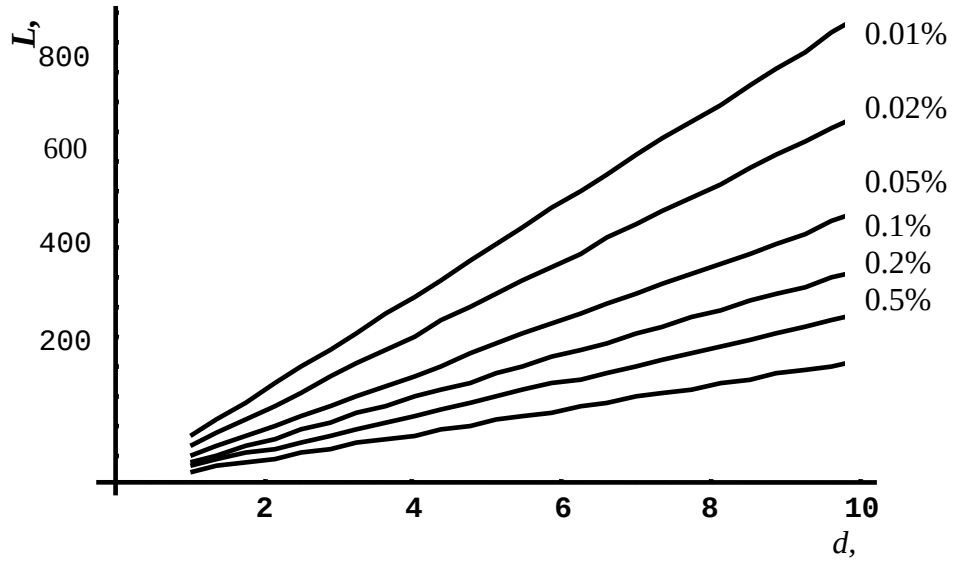

Fig. 1. Dependence of the distance between the carbide phase particles of size at different concentrations.

The graph (Fig. 1) see linear change of distance between the particles, depending on the size of the particles. This dependence shows that grinding carbide phase reduces the distance between the particles and, consequently, increases the hardened alloy. This grinding particles to 1 micron ... 3 significantly reduces the distance between the particles at a concentration of carbide phase within 0.1 ... 0.2% of the total alloy. This makes it possible for several tens of percent increase strength steel. The following tracker, which is described by equation (5), makes it possible to simplify the model proposed in the Pickering (3) by replacing in equation cock, taking into account the distance between the particles of carbide phase, the expression of which structure will include a factor (Lk, d), connecting particle size of this phase of its concentration in steel. To determine this factor should be applied Us derived formula (5). This will significantly simplify and increase the reliability calculations, not only by reducing the number of arguments in equation (3), and also because the method of determining the distance between the particles of carbide phase, especially at low concentrations and its small size, it is difficult and has insufficient degree of probability of the results. A complex character is dependent on the distance between the particles concentration of alloying elements. Fig. 2 shows the functional dependence of L = *f* (k) for the size of the carbide phaseparticles 1, 3, 5, 10 microns.

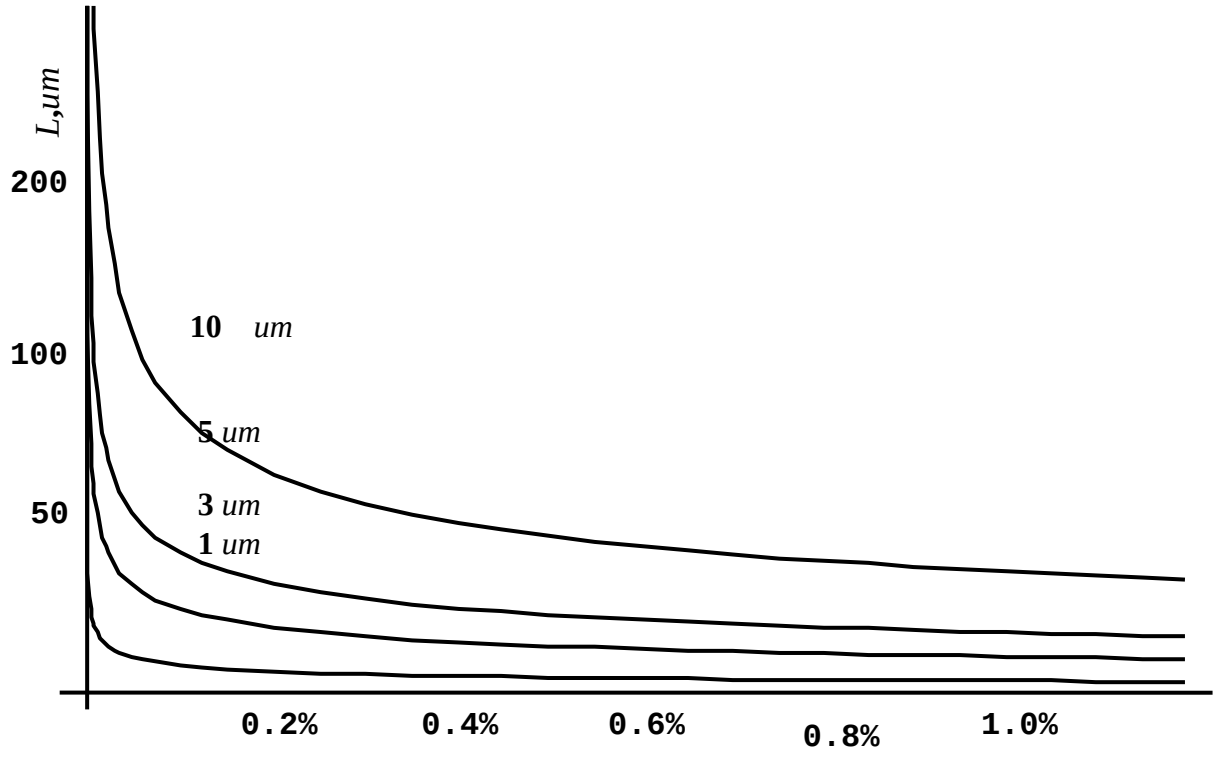

Fig. 2. Dependence of the distance between the carbide inclusions on their concentration (for sizes carbide phase respectively 1, 3, 5, 10 m).

The graph these curves are upward, according the following sequence. It can be seen that when the size of the carbide phase 5 and 10 microns, the distance between the particles will remain within 30 ... 100 mm even when the concentration of this phase to 0.5%, which is impractical. The noticeable strengthening alloy at the optimum concentration of carbide phase within 0.1 ... 0.2% observed in particle size to 2 ... 3 mm.

Noteworthy is the fact that the nature of the curve described by dependence: L = *f* (k) (Fig. 2), indicating the increased intensity increasing the distance between the particles at lower concentrations of less than 0.05 per cent to 0.15 ... size particles under 5 ... 1 micron. Intensive increase the distance between the particles, as mentioned earlier leads to the leveling effect of alloying elements in our case forming carbide phase (niobium and titanium).

The comparison of image analysis dependencies distance between the carbide phase particles of size and concentration made it possible to answer the question why in excess of a certain limit content of alloying elements decrease in mechanical properties of steel. This is because at low concentrations (within 0.1%) particle size of carbide phase remains minimal (1 ... 3 microns). In this case, it is the concentration of alloying elements reduces the distance between the particles, which causes hardening alloys.

Increase of alloying elements that form the carbide phase is resistant to high temperatures causes the increase in its size, which in turn increases the distance between the particles and leads to rozmitsnennya alloy.

Thus derived equation (5) makes it possible to link the concentration of the alloying element through the steel structure of its properties. That is, knowing the distribution of chemical elements between phases, we can determine the effect on the mechanical properties nondeformed phase.

To establish a final settlement on the basis of the proposed Pickering equation (3) requires more quantitative assessment of the impact of alloying elements to strengthen grain α-phase. However, as noted earlier, this feature can greatly vary depending on the heat treatment. Therefore, more appropriate to proceed with the evaluation criteria of strengthening grain α-phase mode after a standardized heat treatment, linking it with the austenitic grain size natural.

So far, the only settlement model, which establishes the quantitative relationship between the chemical composition of steel and

its properties is available [6]. Based on a comparative analysis of calculated data model Kondratyuka and others. [6], the data obtained by the study of complex-alloyed steels The high degree of correlation between the two.

The mechanical properties of steels were determined by ten samples to the point, because the experimental data with sufficient accuracy. With dilatometer curves adopted under optimal temperature of tempering. This made it possible to avoid inaccuracies that are made in the calculations that part of the equation that determines the degree of influence of overheating during heat treatment.

Especially for sure, almost completely, estimates coincide with the experimental, in determining the ultimate strength of the base steel composition 15HHN. A more complex set of alloying elements comprising the composition Ti + Nb, disagreement with experimental data calculation did not exceed a few percent, by doping titanium ta little more than 10 percent in the joint doping titanium and niobium.

Regarding the characteristics of viscosity constant, as noted by the authors of computational models, the correlation is somewhat lower, it is within 80-90%. This applies both basic and complex steel-alloy steel compositions developed by us.

These factors explain the nature of the reduction of mechanical properties of steel in excess of a certain limit alloying elements that can form insoluble carbide and karbonitrydnu phase.

Obtained from experimental studies Mathematical formulas are given the opportunity to clarify the calculation model [6], in the studied concentration range of alloying elements. In the equation for determining the strength of steel (6) of the specified concerning the impact of titanium and niobium, and supplemented by another member that determines the effect of cerium:

$$bB = 3058 + 443 \times C - 229 \times Mn + 267 \times Si + 412 \times Gr + 184 \times Mo + 22{,}7 \times Ni - - 235 \times Gr \times Si - 35{,}2 \times Mn \times Ni + 323 \times Gr \times V + 170 \times Mn2 - 68{,}3 \times Gr2 - 1113 \times V2 -- 28\,423 \times Ti2 + 545{,}5 \times Ti - 7442 \times Nb2 + 1985 \times Nb + 15050500 \bullet Ce\,3 - - 955\,628 \times Ce\,2 + 14\,913 \times Ce. \quad (6)$$

Specified equation to determine the impact strength is:

$$KSU = 85 + 69{,}4 \times Mn + 1{,}51 \times Gr - 167 \times Mo - 9{,}61 \times V - 195 \times C \times Mn + + 12{,}7 \times Mn \times Ni - 358 \times C2 - 10{,}2 \times Mn2 + 9{,}6 \times Si2 + 551 \times 368\,056 \times Mo2 + Ti3 - 90\,387 \times 5239 \times Ti2 + Ti + 39\,805 \times Nb3 - 20{,}701 \times Nb2 + 3289 \times Nb + + 19{,}474{,}700 \times Ce3 - 1631000 \times Ce\,2 + 31\,984 \times Ce. \quad (7)$$

Conclusions

An analysis of mathematical models calculating the chemical composition of steels with specified properties revealed that the main, the link between them is such structural factors: a) grain size α-phase; b) morphology of carbide phase tanemetalevyh inclusions.

For the calculation base characteristics of the structure should be considered natural austenitic grain size of steel and the distance between the particles so-called nedeformuyemoyi phase.

In order to improve the existing mathematical models of the dependence between the size, concentration and distance between inclusions and carbide phases karbonitrydnoyi.

For optimum concentrations of titanium, niobium and cerium refined mathematical model [6], which is still the only directly connects properties and chemical composition of the steel.

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