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Yspыtanyya, kabyna, visibility.

The problem of feasibility of designing forms tractor cab using ergonomic performance visibility from operator station and obtaining experimental data by computer simulation in three-dimensional space chiaroscuro method.

Testing, cabin, visibility.

UDC 630.56.7

ESTIMATING CRITERIA OF PARTS WARPING DURING HEAT TREATMENT

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The causes of parts warping during heat treatment were found. Estimating criteria for that value was constructed.

Steel, doping, cementation, technology, warping, internal pressure.

Problem. Modern technology sets increasing requirements towards mechanical properties of the structural materials and serial and wholesale engineering demands for high level of their adaptability. Complicated specialization of modern gear details requires inclusion of stamp operations, cutting treatment, welding, surface hardening, final lapping in the manufacturing process. Hence, all these additional operations should comply with higher technological standards

Recent research analysis. The choice of cementing steel compositions with optimal physical, mechanical and technological characteristics is getting complicated due to lack of information regarding

structure effect on those characteristics. In addition, the information is inconsistent and mainly qualitative. It's not enough data regarding mutual links between different properties of cementing steels. So, these properties are not predictable that significantly expands their choice or design.

Our objectives were not only the quality but also the quantitative estimation of such technological characteristic as steels warping susceptibility under the thermochemical treatment. We goaled to create the single characteristic which determines steel deformation susceptibility under the quenching.

The choice of steel type is determined by the exploitation conditions as well as by the equipment technological capabilitie. In [1-3] performed a comprehensive analysis of steels used for heavy-loaded gears. Analyzing this papers, it might be concluded that the choice of material basically determines the appropriate strengthen technology. Thermochemical treatment is meant to be the most promising strengthen gears technology.

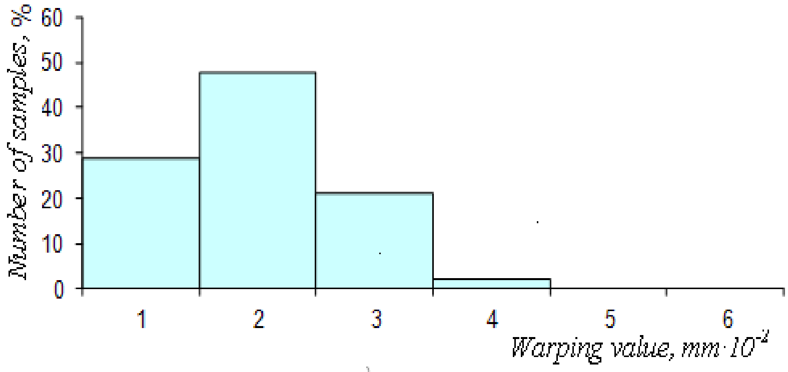
Research objectives. The main goal of our investigation was creating of the same estimating criteria for steels warping susceptibility under the thermochemical treatment.

Results. The change of the geometric parameters that occurs during the thermochemical treatment is essential for economic performance of manufacturing. Removing warping requires additional lapping operations such as restoring of initial holes, sanding and lapping of working profiles. Moreover, poor cutting machinability of high hardness materials implies necessary operations for protection from carbon saturation during grouting surfaces of parts that are processed after thermochemical treatment. For that usually electrolytic copper plating processes or application of protective antytsementatsiynyh pastes are used. These operations are labor and energy consuming and require expensive and scarce materials.

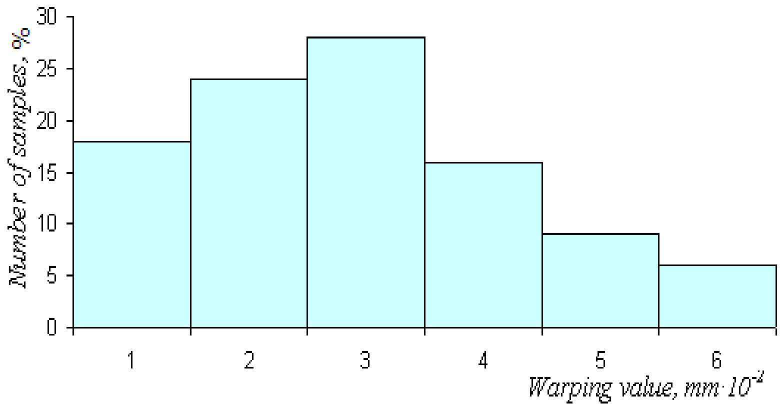
The issue of warping of details which require surface hardening is essentially up to date particularly due to significantly increasing requirements to metal capacity and manufacturing precisicion of gears [4, 5]. It is well known that the main cause of warping under the thermochemical treatment is hardening. Cooling during hardening leads to the appearance of a temperature gradient along the details crossing. Its value is determined by the heating temperature, the detail's size and shape, steel thermal conductivity, cooling capacity and circulation of quenching environment [6].

Indefinite change of temperature in the depth of the materials during cooling along with indefinite percolation of phase transitions and change in specified volume cause pressure. The pressures arising from non-simultaneous thermal deformation are called thermal.

Our work invoked the task of not only quality but also quantitative estimation of such technological characteristics as steel warping susceptibility under thermochemical treatment. The results of comparison of warping value for various steels details are presented in Fig. 1 histogram.



a)



b)

Fig. 1. Histogram of value of the details warping during the quenching: a) steel 15HHNBTCH; b) steel 12HN3A.

Hence, the creation of a similar characteristic determining steel deformation susceptibility during quenching is proposed. It is a coefficient that is determined from the ratio between the number of parts that fit the permissible warping value according to the technical documentation and the number of parts that do not fit the technical documentation permissible deviation (defective parts).

In this case, Riemann integral as Darboux sums limit is meant to be the above mentioned quantitative characteristic - (as curvilinear trapezoid area). Step graph of the function $\Im(x)$ takes a form: $\Im(x) = \sum_{i=1}^{m} \left(n_i \chi_{(a_i; a_{i+1})}(s) \right)$, Where $\chi_A(xx$ is an indicator function $\chi_A(xx = \begin{cases} 1, & x \in A \\ 0, & x \notin A \end{cases}$).

Let nj be the value of the function at the semi-closed interval $\left(a_j, a_{j+1}\right]$. Then deriving characteristics takes a form:

$$\Re(x)=\Re(\Im(x))=\frac{\int_x^b\left(\sum_{i=1}^{m}\left(n_i\chi_{(a_i;a_{i+1})}(s)\right)ds\right)}{\int_a^x\left(\sum_{i=1}^{m}\left(n_i\chi_{(a_i;a_{i+1})}(s)\right)ds\right)}=\frac{\sum\limits_{\substack{i=j+1\\ j:x\in(a_j,a_{j+1}]}}^{m}\left(n_i\Delta a_{i+1}+\frac{n_j(a_{j+1}-x)}{m-j}\right)}{\sum\limits_{\substack{i=1\\ j:x\in(a_j,a_{j+1}]}}^{j-1}\left(n_i\Delta a_{i+1}+\frac{n_j(x-a_j)}{m-j}\right)}.$$

where $\chi_A(x)=\begin{cases}1, & x\in A\\ 0, & x\notin A\end{cases}$, Is an indicator-function, nj - the function value at the semi-closed interval, $(a_j,a_{j+1}]$ $\Im(x)=\sum_{i=1}^{m}\left(n_i\chi_{(a_i;a_{i+1})}(s)\right)$ - The function built at experimental data.

For instance, calculate deformation susceptibility coefficient for steels and 12HN3A 15HHNBTCH.

For steel 12HN3A it equals:

$$\Re(x)=\begin{cases}\dfrac{101-18x}{18x}, & x\in(0,\ 1]\\ \dfrac{107-24x}{24x-6}, & x\in(1,\ 2]\\ \dfrac{115-28x}{28x-14}, & x\in(2,\ 3]\\ \dfrac{79-16x}{16x+22}, & x\in(3,\ 4]\\ \dfrac{51-9x}{9x+50}, & x\in(4,\ 5]\\ \dfrac{36-6x}{6x+65}, & x\in(5,\ 6]\end{cases}\qquad x=\begin{cases}\dfrac{101}{18(R_0+1)}, & x\in(0,\ 1]\\ \dfrac{107+6R_0}{24(R_0+1)}, & x\in(1,\ 2]\\ \dfrac{115+14R_0}{28(R_0+1)}, & x\in(2,\ 3]\\ \dfrac{79-22R_0}{16(R_0+1)}, & x\in(3,\ 4]\\ \dfrac{51-50R_0}{9(R_0+1)}, & x\in(4,\ 5]\\ \dfrac{36-65R_0}{6(R_0+1)}, & x\in(5,\ 6]\end{cases}$$

$$R_0=0.03\Rightarrow x\geq 5{,}5097$$

For steel 12HN3A it equals:

$$\Re(x)=\begin{cases}\dfrac{29(1-x)+61}{29x}, & x\in(0,\ 1]\\ \dfrac{48(2-x)+23}{48(x-1)+29}, & x\in(1,\ 2]\\ \dfrac{21(3-x)+2}{21(x-2)+77}, & x\in(2,\ 3]\\ \dfrac{2(4-x)}{2(x-3)+98}, & x\in(3,\ 4]\end{cases}\qquad x=\begin{cases}\dfrac{90}{29(R_0+1)}, & x\in(0,\ 1]\\ \dfrac{119+19R_0}{48(R_0+1)}, & x\in(1,\ 2]\\ \dfrac{65-35R_0}{28(R_0+1)}, & x\in(2,\ 3]\\ \dfrac{2(1-23R_0)}{(R_0+1)}, & x\in(3,\ 4]\end{cases}$$

$$R_0=0.03\Rightarrow x\geq 2{,}956$$

In our particular case under permissible percentage ratio of quantitative characteristics of defective and non-defective details dropping to 3% -band, steel 15HHNBTCH with low warping susceptibility yields the value of allowance of 0.029 mm and steel 12HN3A does 0,055 mm. And in the case when the serial steel provides the same allowance as designed, the number of defective details will be 30%.

Thus the proposed coefficient enables quantify the steels warping susceptibility and provides a choice of chemical composition of steel given the required size of allowances and technological capabilities of manufacturing.

Determining of this coefficient is quite complicated process. For its simplification the comparison of the coefficient with other steel technological characteristics was implemented

In terms of causes of details warping during the quenching, the closest characteristic correlated with the deformation coefficient is the pressure value in the consolidated layer.

Dependencies of residual internal pressures distribution for steels with varying doping degrees were considered (Fig. 2).

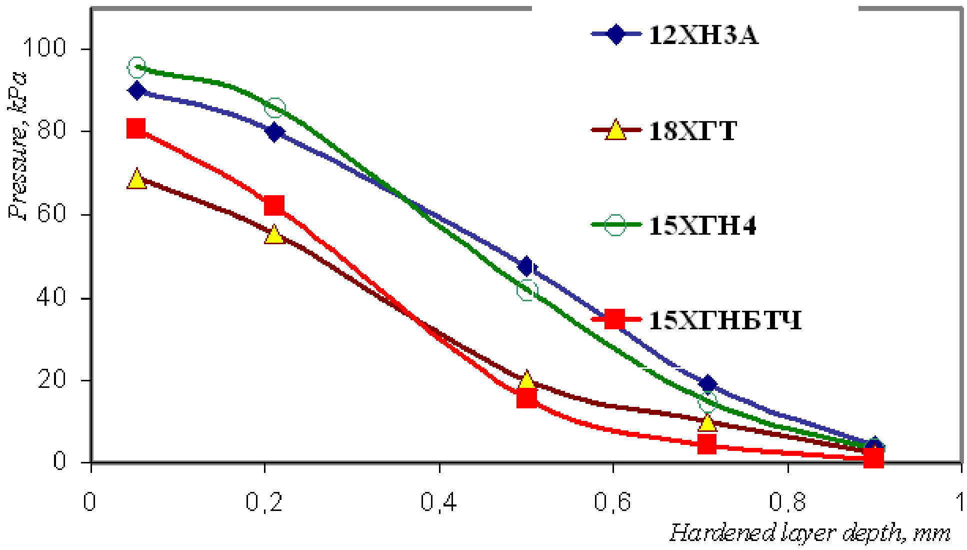


Fig. 2. Distribution of residual internal pressures in hardened layer.

The shape of curves derived implies that the complex-alloied steel has a sharp reduction of pressure, as the distance from the surface increases, comparing to the serial 12HN3A steel.

Based on the physical meaning of this value one could argue that the sum of all the pressures in the surface layer relates to the considered characteristic. It can be represented as a Riemann integral.

For the steel 12HN3A:

$$\mathbf{I_{12XH3A}} = \int_{0,1}^{0,9} \left(-953{,}12x^4 + 2343{,}8x^3 - 1910{,}3x^2 + 456{,}06x + 57{,}948\right) \cdot dx = 37.0398$$

For the steel 15HHNBTCH:

$$\mathbf{I_{15X\Gamma HБТЧ}} = \int_{0,1}^{0,9} \left(263.02x^4 - 527.08x^3 + 479.32x^2 - 314.73x + 107.08\right) dx = 20.7075$$

For the steel 18XGT:

$$\mathbf{I}_{18XГТ} = \int_{0,1}^{0,9} \left(-3208,3x^4 + 6672,9x^3 - 4562,3x^2 + 1046,8x - 2,2063\right) dx = 25,305$$

For the steel 15HHN:

$$\mathbf{I}_{15XГН} = \int_{0,1}^{0,9} \left(1296,9x^4 - 2579,2x^3 + 1736,6x^2 - 504,21x + 82,005\right) \cdot dx = 15,5048$$

Computer processing of the total value of the overall hardened layer pressures showed that for serial steel 12HN3A this coefficient is 1.5 times higher than for designed steel. However it's not reliable to recommend this characteristic for determining of steel warping susceptibility for two reasons. First, the value of residual internal pressures relates to pressures effecting the product (sample) deformation under the heat treatment only indirectly. And is not the cause but the consequence. Second, its determining is associated with considerable technical difficulties. At the same time, as a qualitative characteristics it confirms obtained results during the investigation of warping susceptibilities of steels with different alloying elements compositions.

The steel susceptibility to the austenitic grain growth under the heating is the most appropriate characteristic that relates to the deformation coefficient. The physical meaning of steel susceptibility to the austenitic grain growth under the heating explains the rapid change of function describing this process. After consideration of dependence graphs in Fig. 3 and approximation by polynomial trend line of the experimental data using we are able to specify the rate of change of approximated curves as the derivative $f(x)'$.

The mean of the function f (x) 'at the interval [a, b] is calculated from the equality $\int_a^b [f'(x)]dx = f'_{cp}(\theta) \cdot (b-a)$ Where $\theta \in [a.b]$. Where

$$f'_{cp}(x) = \frac{\int_a^b [f'(\theta)]dx}{(b-a)}.$$

The calculated values of this characteristic for investigated steels are:

for the steel 12HN3A:

$$\mathbf{V}_{12XH3A} = \frac{\int_{800}^{1100} \left[\frac{\partial}{\partial x}\left(7.9655\mathbf{x}^{0.8324}\right)\right] \mathbf{dx}}{\mathbf{1100 - 800}} = 2.10298;$$

for the steel 15HHNBTCH:

$$\mathbf{V}_{15XГНБТЧ} = \frac{\int_{800}^{1100} \left[\frac{\partial}{\partial x}\left(5.16\mathbf{x}^{0.53}\right)\right] \mathbf{dx}}{\mathbf{1100 - 800}} = 0.109308;$$

for the steel 18XGT:

$$\mathbf{V}_{18XГT} = \frac{\int_{800}^{1100}\left[\frac{\partial}{\partial x}\left(5.68\mathbf{x}^{0.72}\right)\right]\mathbf{dx}}{\mathbf{1100-800}} = 0.6006;$$

for the steel 15HHN:

$$\mathbf{V}_{15XГH} = \frac{\int_{800}^{1100}\left[\frac{\partial}{\partial x}(6.3709\mathbf{x}+3.36)\right]\mathbf{dx}}{\mathbf{1100-800}} = 6.3709.$$

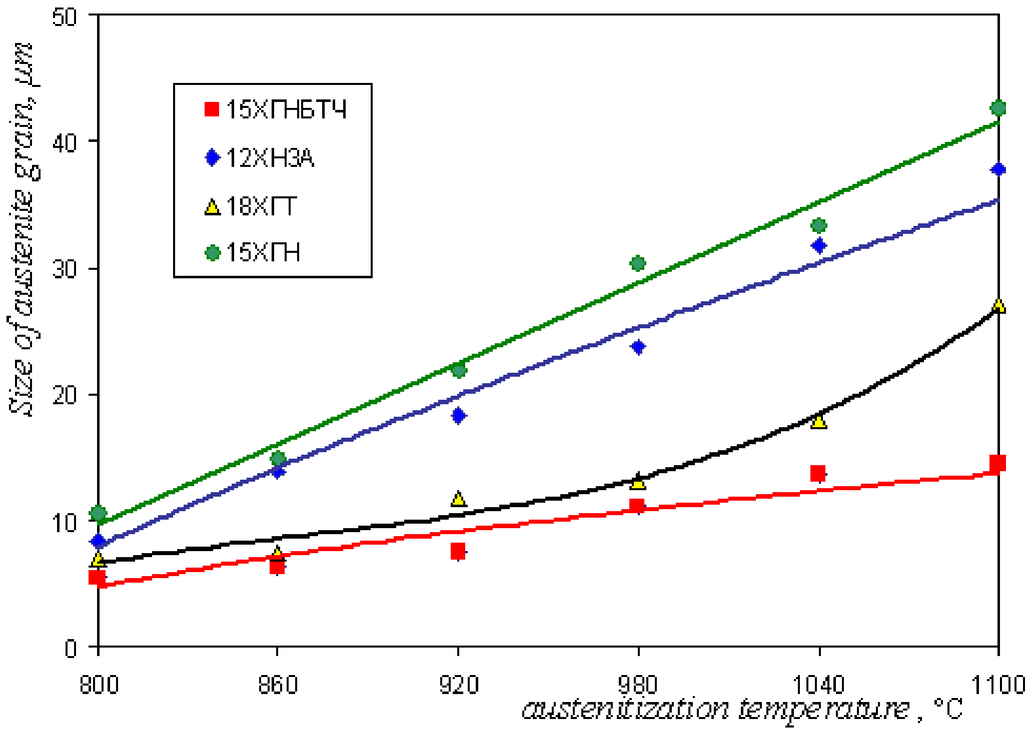


Fig. 2. Kinetics of austenitic grain growth.

After analysis of mathematical calculations of technological characteristics for the investigated steels and comparison them with derived steel warping susceptibility coefficient we can conclude that the steel susceptibility to the austenitic grain growth during exposure under the high temperatures is sufficiently correlated with the steel warping I coefficient.

Conclusions

1. Reduced steel warping susceptibility allows to increase the economic performance of production by reducing the amount of lapping operations.
2. It was found during the investigations that the level of steel warping under the thermochemical treatment is directly dependent on the dispersion degree of the initial austenitic structure.

3. For the cementing steels under the prolonged high temperatures exposure during hermochemical treatment it is necessary to minimize the alloy susceptibility to the austenitic grain growth. This is achieved by a complex alloying via elements such as titanium and niobium which form a high temperatures resistant carbide phase.

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The causes warping of parts during heat treatment. Criteria of evaluation of this magnitude.

Steel, doping, cementation, technology, warping, internal pressure.

Causes Ustanovlenы deformation of parts in the process termycheskoy processing. Razrabotanы Criteria otsenki эtoy velychynы.

Steel, alloying, tsementatsyya, tehnolohychnost, koroblenye, vnutrynnye voltage.