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Computer simulation of microstructure transformation during the quenching

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Computer simulation of austenite decomposition during the steel quenching has been investigated. The method of prediction of quenched steel microstructure composition is based on hardenability curve of Jominy-specimen. The phase transformations have been estimated based on time, relevant for structure transformation measured on Jominy specimen.

The designed method of prediction austenite decomposition has been used in computer simulation of phase portion vs. hardness in quenched specimens of steel 34 Cr 5.

1. INTRODUCTION

Phase transformation modeling is one of the main challenges in modeling of heat treatment [1]. In practice numerous phase transformations calculations are based just on statistic correlation between chemical composition and final microstructure as result of quenching. The mechanism of phase transformations is not fully understood and interactive influence of different elements, austenitizing temperature, etc. usually are not taken in account. Cooling transformations diagrams CCT diagrams are irreplaceable in the clear presentation of structural transformation during the steel cooling in order to predict structural constitution and hardness after cooling. Moreover, preparing CCT diagrams is rather expensive. They are prepared for strictly determined elemental composition and austenitizing temperature and they could be used with accuracy only for simulation of steel quenching with same elemental composition, austenitizing temperature and history as were of steel for it the CCT diagram is made [2].

The inversion method of computer simulation of austenite decomposition and evaluation of quenched phase portion can be established based on *Jominy* test results.

2. ALGORITHM FOR PREDICTION OF MICROCONSTITUENTS PROPORTIONS

Structure composition after cooling is depended of an actual steel hardness:

$$HV=((\%\ \text{ferrite})HV_{(F)}+(\%\ \text{pearlite})HV_{(P)}+(\%\text{bainite})HV_{(B)}+(\%\text{martensite})HV_{(M)})/100 \quad (1)$$

and:

$$((\%\ \text{ferrite} + \%\ \text{pearlite}) + \%\ \text{bainite} + \%\ \text{martensite})/\ 100=1 \quad (2)$$

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By the equations (1) and (2) is not difficult to predict phase fractions. Both, hardness (HV) of cooling microstructure with 90 % or 50 % of martensite and of 10 % or 50 % of (ferrite + pearlite) and hardness of microstructure constituents separately, have to be known.

Results of austenite decomposition are depending on the chemical composition of steel, severity of cooling, austenitizing temperature and steel history. If other heat treatment parameters are constant, the austenite decomposition results in some location of a cooled specimen will depend only of the time $t_{8/5}$[2] [3]. Every one location of Jominy-sample has one characteristic time $t_{8/5}$.

It could be written for Jominy test that phase hardness depends of chemical composition (CC) and cooling rate parameter ($CRP = \log t_{8/5}^{d}$) that corresponds to actual distance (d) of Jominy specimen quenched end.

$$HV_{\mathrm{d}}^{\mathrm{M}} = f_{\mathrm{M}}(CC, CRP) = HV_{\max}^{\mathrm{M}} - K_{M} \log \frac{t_{8/5\mathrm{d}}^{\mathrm{M}}}{t_{8/5\max}^{\mathrm{M}}}; \tag{3}$$

$$HV_{\mathrm{d}}^{\mathrm{B}} = f_{\mathrm{B}}(CC, CRP) = HV_{\max}^{\mathrm{B}} - K_{\mathrm{B}} \log \frac{t_{8/5\mathrm{d}}^{\mathrm{B}}}{t_{8/5\max}^{\mathrm{B}}}; \tag{4}$$

$$HV_{\mathrm{d}}^{\mathrm{P+F}} = f_{\mathrm{P+F}}(CC, CRP) = HV_{\mathrm{N}}^{\mathrm{P+F}} + K_{\mathrm{P+F}} \log \frac{t_{8/5\mathrm{N}}^{\mathrm{P+F}}}{t_{8/5\mathrm{d}}^{\mathrm{P+F}}}; \tag{5}$$

where N is normalizing, B_{max} is lower bainite. Characteristic values of HV, K and $t_{8/5}$ in equations (3), (4) and (5) have to be evaluated by the Jominy test results and based on chemical composition of steel.

The regression relations between the cooling times from 800 to 500°C for characteristic percentages of cooling structures are established.

$$\log t_{8/5}^{\mathrm{M}\%} = f_{\mathrm{M}\%}(CC, T_{\mathrm{a}}, t); \tag{6}$$

$$\log t_{8/5}^{\mathrm{P+F}\%} = f_{\mathrm{P+F}\%}(CC, T, t_{\mathrm{a}}); \tag{7}$$

where T_a is austenitizing temperature in K and t_a is austenitizing time in h.

Distances of quenched end of Jominy specimen with different microstructures fraction can be predicted by using the relation between cooling time and distance from the quenched end of Jominy specimen shown in Figure 1. Hardness of characteristic cooling structures with different percentages of microstructure constituents can be predicted by the conversion of Jominy distances results to hardness using the diagram of Jominy curve.

3. COMPUTER SIMULATION OF PHASE PORTION

The phase portion in specimen of steel 34 Cr 4 (DIN) was estimated by computer simulation. Elemental composition of investigated steel 34 Cr 4 was 0.36% C, 0.28% Si, 0.63% Mn, 1.15% Cr. Jominy test results of investigated steel 34 Cr 4 are shown on Figure 1. Austenitizing temperature was equal 850 °C.

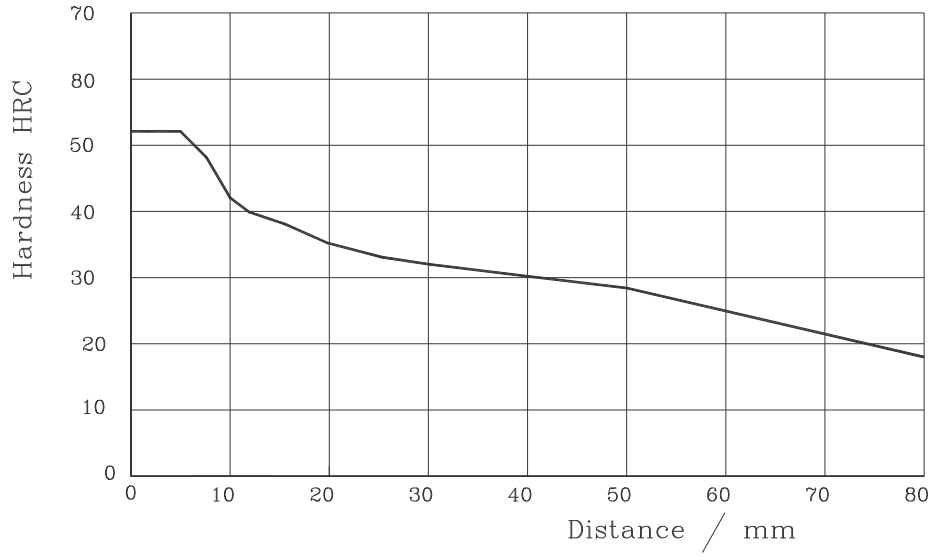

Figure 1. Jominy test result of steel 34 Cr 4

Diagram of structure portion for cylindrical specimen of steel C45 with Dia=100mm is shown on figure 2.

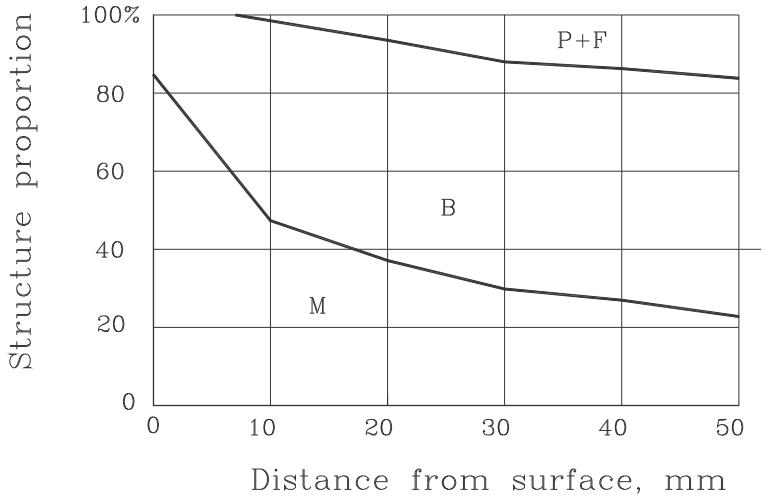

Figure 2.Simulated structure composition of cylindrical specimen of steel C45

4. CONCLUSION

The inversion method of computer simulation of austenite decomposition and evaluation of quenched phase portion was established.

The austenite decomposition results can be estimated based on time, relevant for structure transformation. The characteristic cooling time, relevant for structure transformation for most structural steels is the time of cooling from 800 to 500 °C (time $t_{8/5}$).

In the established mathematical model, the numerical measure of specimen cooling kinetic was time $t_{8/5.}$ For the calculation of microstructure composition, the hardness in specimen points, Jominy test results and chemical composition of steel must be known.

The established mathematical model was applied in computer simulation of microsructure transformation in Jominy and cylindrical specimens of steel. It can be concluded, that by proposed method microstructure composition in quenched steel specimen can by successfully calculated.

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