Achievements in Mechanical and Materials Engineering

COMMENT Worldwide Congress on Materials and Manufacturing Engineering and Technology
16th - 19th May 2005 Gliwice-Wisla, Poland

COMMITTEE OF MATERIALS SCIENCE OF THE POLISH ACADEMY OF SCIENCES, KATOWICE, POLAND
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS OF THE SILESIAN UNIVERSITY OF TECHNOLOGY, GLIWICE, POLAND
ASSOCIATION OF THE ALUMNI OF THE SILESIAN UNIVERSITY OF TECHNOLOGY, MATERIALS ENGINEERING CIRCLE, GLIWICE, POLAND

13th INTERNATIONAL SCIENTIFIC CONFERENCE ON ACHIEVEMENTS IN MECHANICAL AND MATERIALS ENGINEERING

Simulation of hardness distribution in quenched steel specimen

B. Smoljan, N. Tomašić, D. Rubeša, S. Smokvina Hanza

Chair of Materials, Faculty of Engineering, University of Rijeka
Vukovarska 58, 51000 Rijeka, Croatia, email: smoljan@riteh.hr

Abstract: Hardness distribution in quenched steel specimen for two different steels with different hardenability has been investigated using 3D numerical simulation. Numerical simulation is consisted of computation of steel cooling curve and computation of hardness in specimen points.

Numerical calculations of hardness distribution in steel specimen for two different steels and comparison of calculated results have been performed in order to define appropriate steel for manufacturing of machine part.

Keywords: Numerical simulation, 3D modeling, Steel quenching

1. INTRODUCTION

Mathematical modelling of hardness distribution in quenched steel specimens is consisted of numerical simulation of specimen cooling, numerical simulation of specimen hardening and respectively prediction of mechanical properties. For the simulation of specimen cooling which is thermodynamical problem, it is necessary to establish the appropriate algorithm which describes cooling process and it is necessary to accept appropriate input data.

The accuracy of mathematical modelling of quenching directly depends on the correctness of input variables applied in the model. Experimentally acquired heat transfer data have advantages in specific conditions but numerical simulation of quenching with the application of calibrated heat transfer data is a generalized way of simulation and is largely applicable. Calibrated data are not as precise as experimentally acquired data but they are useful for large spectra of specimen dimensions [1].

Mechanical properties can be estimated according to prediction of structure composition. Structure composition can be defined by kinetic equations of prior structure transformation or can be estimated by using CCT diagrams. Structure transformation and hardness distribution can be also estimated based on time, relevant to structure transformation [2].

2. SIMULATION OF SPECIMEN COOLING

The temperature field change is an isotropic rigid body with heat conductivity λ, density ρ and specific heat capacity c, without heat sources, can be described by Fourier's law of heat conduction:

$$\frac{\delta(c\rho T)}{\delta t} = \mathrm{div}\lambda\ \mathrm{grad}T \tag{1}$$

Characteristic initial condition is:

$$-\lambda \frac{\delta T}{\delta n}\bigg|_s = \alpha(T_\mathrm{s} - T_\mathrm{f}) \tag{2}$$

The discretization equation for a 3D situation was established by using the control volume method [3, 4] and is equal:

$$T^1_{\mathrm{ijk}}\left[\sum_{m=1}^{2} b_{(\mathrm{i,i+n})\mathrm{jk}} + \sum_{m=1}^{2} b_{\mathrm{i(j,j+n)k}} + \sum_{\mathrm{m}=1}^{2} b_{\mathrm{ij(k,k+n)}} + b_{\mathrm{ijk}}\right] =$$
$$\sum_{m=1}^{2}\left(b_{(\mathrm{i,i+n})\mathrm{jk}} T^1_{(\mathrm{i,i+n})\mathrm{jk}} + b_{\mathrm{i(j,j+n)k}} T^1_{\mathrm{i(j,j+n)}} + b_{\mathrm{ij(k,k+n)}} T^1_{\mathrm{ij(k,k+n)}} + b_{\mathrm{ijk}} T^0_{\mathrm{ijk}}\right) \tag{3}$$
$$\mathrm{i} = 1,2,...\mathrm{i}_{\max};\quad \mathrm{j} = 1,2,...\mathrm{j}_{\max};\quad \mathrm{k} = 1,2,...\mathrm{k}_{\max}\quad \mathrm{n} = 3 - 2\mathrm{m}$$

3. HARDNESS DISTRIBUTION IN QUENCHED STEEL SPECIMEN

Numerical calculations of hardness distribution in steel specimen for two different steels with different hardenability: 41Cr4 and 30CrNiMo4 (DIN) have been performed in order to define appropriate steel. Steel specimen is shown in Figure 1

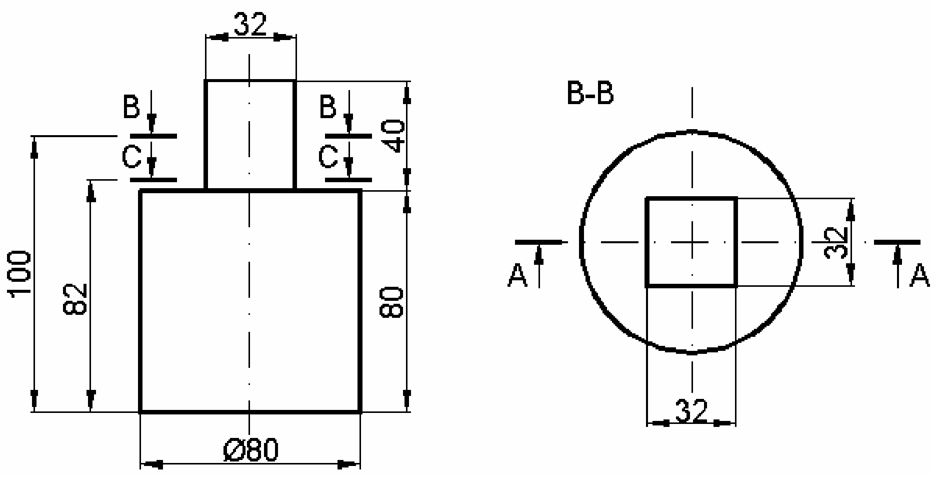

Figure 1. Steel specimen

The specimen was quenched in oil with Grossman's H-value H=0.45 with austenitization temperature 850°C. Correlation between coefficients of heat transfer and temperature is appointed with Crafts-Lamont's diagrams [7].

Hardness distribution on longitudinal view A-A, and transversal views B-B and C-C are shown in figures 2 and 3. Hardness values are expressed in HRC. Figures are accompanied with legend which shows relation between harness and adequate colour.

Hardness distribution in specimen made of steel 41 Cr 4 is shown in Figure 2 and in specimen made of steel 30 CrNiMo 4 is shown in Figure 3.

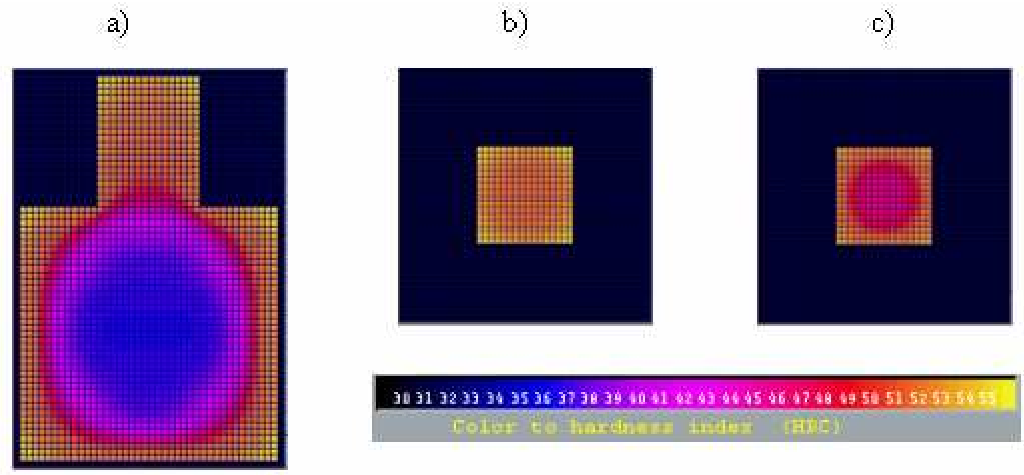

Figure 2. Hardness distribution on (a) view A-A, (b) view B-B and (c) view C-C for steel 41 Cr 4

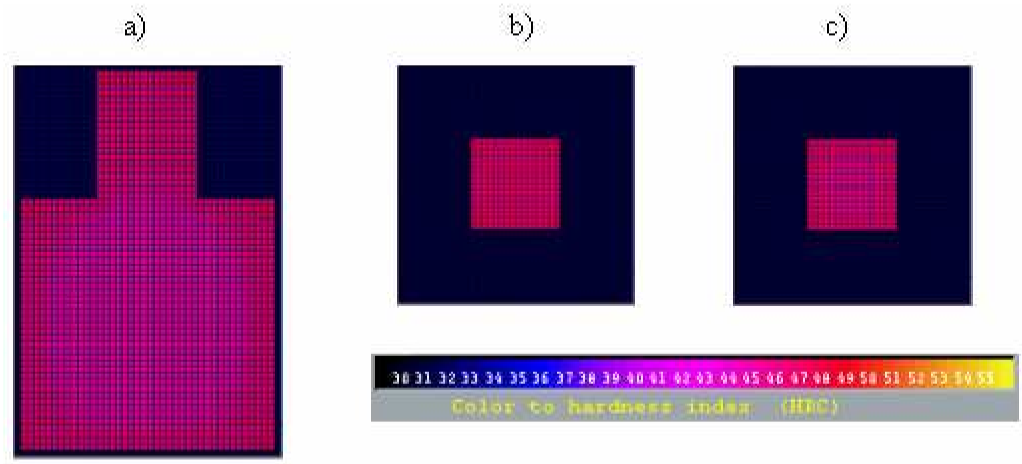

Figure 3. Hardness distribution on (a) view A-A, (b) view B-B and (c) view C-C for steel 30 CrNiMo 4

Specimen made of steel 41 Cr 4 is completely quenched in part with dimension of cross section of 32mm. In wider cylindrical part decreasing of hardness is visible in deeper layer of cross sections. Hardness decreasing is the most visible in location of changing the cross section dimension. The specimen made of this steel has the higher hardness values on the surface than steel 30 CrNiMo 4. But the steel 41 Cr 4 can not be recommended for application, because of the very strong decrease of hardness, especially, in location of cchanging of cross section dimension. Specimen made of steel 30CrNiMo4 is completely quenched.

4. CONCLUSION

3D mathematical model of hardness distribution in steel specimen is developed in order to define hardness distribution in steel specimen with complex geometry. Model is based on control volume method and consisted of numerical simulation of heat transfer during the cooling and of numerical simulation of specimen hardening. Input variables are estimated by inverse method. Heat transfer data estimated in such way are suitable for computer simulation of quenching of steel before selecting optimal material and processes.

Numerical simulation of hardness distribution after quenching in concrete specimens made of two steel with different hardenability, shows that specimen made of steel 30CrNiMo4 is completely quenched and that hardness in specimen made of steel 41Cr4 is decreasing in deeper layers due to lesser hardenability.

According to investigations of oil quenching of concrete specimens it can be concluded that the steel 30 CrNiMo 4 is better choice for manufacture of machine part.

REFERENCES

1. B. Smoljan, The Calibration of the Mathematical Model of Steel Quenching, Proc. of 5th World Seminar on Heat Treatment and Surface Engineering, Isfahan, Eds. M. Salehi,
2. ISSST and IFHT, Vol.1, 1995, pp. 709-715.
3. A. Rose et al., Atlas zur Wärmebehandlung der Stahle I, Verlag Stähleisen, Düseldorf, 1958.
4. S. Patankar, Numerical Heat Transfer and Fluid Flow, Mcgraw Hill Book Company, New York, 1980.
5. B. Smoljan, Contribution to Numerical Estimating the Hardness Penetration Depth on Steel Specimen, Strojarstvo, Vol. 36, No. ¾, 1994, pp.151-155.
6. B. Liščić et al., Heat Treatment – Practicum, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, 1992.
7. B. Liščić and G. Totten, Controllable Delayed Quenching, Proc. of Int. Heat Treating Conf., Schaumburg, 1994, pp. 253-262.
8. B. Smoljan, Numerical Simulation of As-Quenched Hardness in a Steel Specimen of
9. Complex Form, Comunications in Numerical Methods in Engineering, 1998, 14, pp. 277285.