Influence of material plasticity change on the evolved heat quantity of constructional steel subjected ECAP

by E.S. Lukin, A.M. Ivanov

Institute of physical and technical problems of the North SB RAS, Yakutsk, Russia

Abstract

Results of steel Fe360 storage energy investigation are presented. Temperature measurements during the specimen deformation were performed using IR camera. Evolved heat evaluation based on the solving of heat conduct equation. Comparison of experimentional results of evolved heat evaluation for Fe360 steel in initial state and Fe360 steel after hardening are presented.

Keywords: thermography, infra-red, storage energy, evolved heat, plastic strain.

1. Introduction

On the basis of the first law of thermodynamics, the storage energy dE_S is determined as the difference between the work of plastic deformation dA_P and the evolved heat dQ [1, 2]:

$$dE_S = dA_P - dQ \quad (1)$$

Results of storage energy evaluation during the Fe360 steel plastic strain are presented in this report. Method of storage energy evaluation based on solving of the one-dimensional heat conduct equation simultaneously with the use of infrared radiation measurement data. Temperature measurements during the specimen deformation were performed using the infrared thermography system TKVr-IFP/“SVIT” equipped with a computer. Work of plastic deformation obtained from deformation diagram. Detailed setup of this method is presented in previous papers [3, 4].

2. Materials and instruments

The chemical composition of the Fe360 steel was *0.15 wt % C*, *0.2 wt % Si*, 0.*52 wt % Mn*, *0.17 wt % Cr*, *0.13 wt % Ni*, and *0.25 wt % Cu*. The standard sheet specimens from the steel Fe360 were subjected to static tensile test. Dimensions of the tested specimens were 0.05 m - length, 0.0055 m - width, and 0.0025 m - thickness. Tensile tests were performed on the “UTS–20k” testing machine with a constant strain rate. The yield strength and the ultimate strength of steel Fe360 were 330 MPa and 500 MPa, respectively.

2.1. Hardening of Fe360 steel

In the present work, hardening of Fe360 steel was obtained by intensive plastic deformation (IPD). One of the effective methods of IPD realized is the equal channel angular pressing (ECAP) [5]. This method permit to obtain materials with ultra grain size structure and high mechanical characteristics. For example, the yield

strength and the ultimate strength of steel Fe360 after ECAP consists are 825 MPa and 835 MPa, respectively. At the same time, plasticity of Fe360 steel after ECAP is less then in initial state.

3. Results and discussion

Experimentional results for the Fe360 steel in initial state seen that the amount of evolved heat makes up to 30 % of work of plastic deformation. Another side, the evolved heat for the Fe360 steel after ECAP consists 10 % of work of plastic deformation. The great part of cold working is stored by material. Comparison of that steel in initial state and after ECAP shown that the evolved heat is depends by plasticity of material. In the work by E.A. Pieczyska, S.P. Gadaj and W.K. Nowacki was seen, that the amount of evolved heat for the annealed stainless steel makes 60-70 % of the work of plastic deformation [6]. Data obtained by G.I. Taylor, H. Quinney for the copper seen that heat consists 80-90 % of cold working [1].

Thus, reduction of steel plasticity subjected ECAP be accompanied by decreases quality of evolved heat. And another side, materials with high plasticity released more heat.

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REFERENCES

[1] G.I. Taylor, H. Quinney. The latent energy remaining in a metal after cold working, *Proc. Roy. Soc.*, vol. CXLIII, A (1934) 307-326.

[2] W. Oliferuk. Investigation of metal deformation using thermography, Proceedings of Eurotherm Seminar, QIRT'98, Lodz, Poland (1998) 134-139.

[3] A.M. Ivanov, E.S. Lukin, B.G. Vainer. Evaluation of storage energy of the constructional steel during plastic deformation, Book of Abstr. of 8th conf. on QIRT, Padova, Italy (2006) 10-11.

[4] A.M. Ivanov, E.S. Lukin. Plastic strain and fracture study of a subjected severe plastic deformation Fe360 steel, Mat. by Int. VIII Rus.-China Symp., vol.1, Khabarovsk, Pacific National University (2007) 129-133.

[5] R.Z. Valiev, I.V. Alexandrov. Nano structural materials obtained through method of intensive plastic deformation. Moscow, Logos (2000).

[6] E.A. Pieczyska, S.P. Gadaj, W.K. Nowacki. Rate of energy storage during consecutive deformation of steel, Proc. of Eurotherm Seminar No.64 QIRT'5, Reims, France, (2000) 260-264.