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TEMPERATURE MEASUREMENT DURING THE TENSILE TEST OF 12013 STEEL WITH ALTERNATING MAGNETIC FIELD APPLICATION

MĚŘENÍ TEPLOTY V PRŮBĚHU TAHOVÉHO TESTU OCELI 12013 S APLIKACÍ STŘÍDAVÉHO MAGNETICKÉHO POLE

Anotace

Článek popisuje metodiku měření teploty v průběhu tahového testu. Teplota byla měřena termočlánky s krátkou dobou odezvy. Sběr dat z experimentů probíhal v reálném čase. Pro měření teploty byla užita měřící ústředna, která se skládala z PC s operačním systémem Windows 98, měřící kartou ICP-DAS 1800H, zakončovacím panelem ICP-DAS DB 8225/2 a termočlánky typu K s kompenzačním vedením. Při měření teploty v průběhu tahových testů s aplikací střídavého magnetického pole docházelo k zkreslení dat šumem, který byl vyvolán právě tímto polem. Proto bylo nutné navrhnout a odzkoušet metody filtrace dat.

Abstract

This paper describes manner and equipment for the temperature measurement during tensile test. The temperature changes were measured with thermocouples. Experimental data has been collected to PC during experiments (in real time). For high-speed temperature measuring, was chosen the thermocouples with a quick time response. For the temperature measuring have been used a measuring set, which consists of personal computer with Windows 98 operating system, data acquisition card ICP-DAS 1800H, daughter board ICP-DAS DB 8225/2 and thermocouples type K with extension grade. During the tensile test with alternating magnetic field application the temperature measuring data were with noise. The data noises were caused with the alternating magnetic field that is why there data were filtered. The situation has been described.

Introduction

During plastic deformation the flow stress is influenced with a strain rate, attained strain and with the temperature. It is needed to determine an evolution of the temperature during tensile test. About 95-98% from strain energy is changed into heat - adiabatic heating. This process is strain rate – dependent. We wanted to use the measuring set for temperature measurement during tensile test in magnetic field application [1]. Main aims were:

- measuring the temperature change, which is caused with the magnetic field
- average flow stress curves with magnetic field and without

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Experiment and results

Steel 12013

Steel 12013 is ferritic steel with small quantity of pearlite. The steel 12013 has guaranteed magnetic properties. Chemical composition of the studied steel 12013 is in Table. 1.

Table. 1 Chemical composition of steel 12013.

element	C	Mn	Si	P	S	Cr	Ni	Cu	Al	V	Nb	Zr	N
weight %	0,028	0,415	0,037	0,020	0,020	0,007	0,037	0,064	0,002	0,014	0,015	0,030	0,050

The microstructure is composed with ferrite and very small quantity of pearlite.

Temperature measuring

During tensile test the temperature was measured as function of time. These measurements were practised with five thermocouples. Thermocouples were welded on five segments of the sample (Fig. 1). Testing length L1 of the sample was divided into five segments, every segment were 10 mm long. On the right and left side from the centre of every segments, guidelines were plotted (Fig. 1). Their distances between guidelines were 2 mm (Fig. 1).

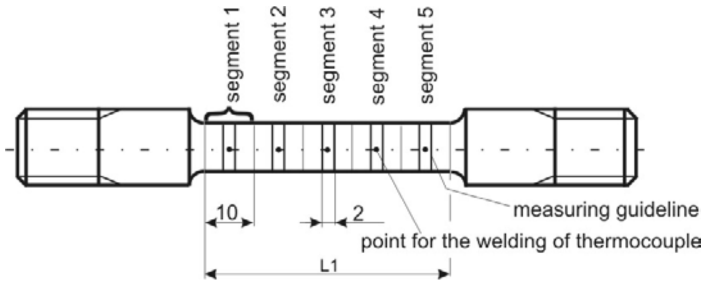

Fig. 1

The logarithmic plastic strains around thermocouples were determined from changes measuring guidelines distance. We supposed that maximum measured temperatures for separate thermocouples relate to maximum obtained strains in surroundings these thermocouples. In this way was performed transfer from the measuring temperature as function of time to measuring temperature as function of logarithmic strain.

During the tensile test with alternating magnetic field application the temperature measurement data were distorted with noise (Fig. 2). Because generated voltage, which causes data noise is alternately and measuring thermoelectric voltage thermocouple is direct-current voltage and then could be connected to thermocouple parallel capacity with acceptable sizes [2]. This parallel capacity operates as filter for the data noises. The filtered measuring data with parallel capacity are on Fig. 3. For transparence in Fig. 2 and Fig. 3 are plotted measuring data only for one thermocouple.

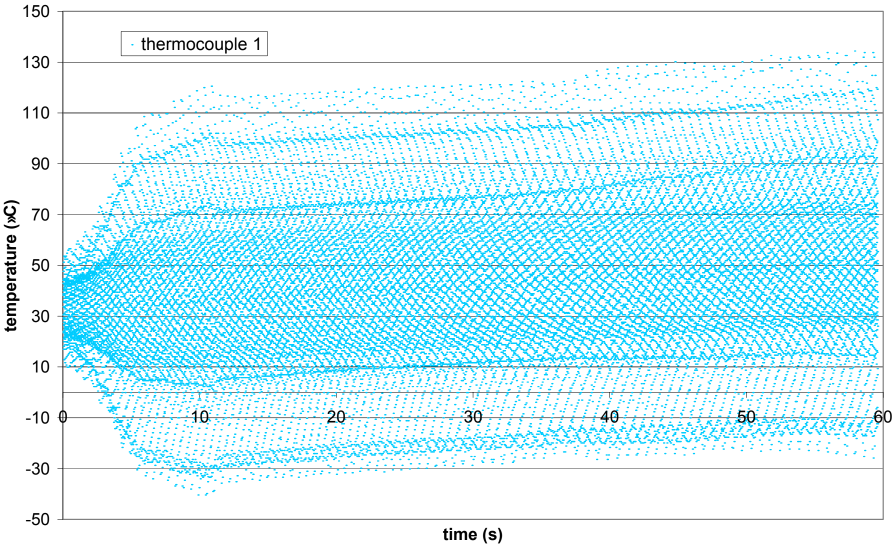

Fig. 2 Distorted measuring data with noise

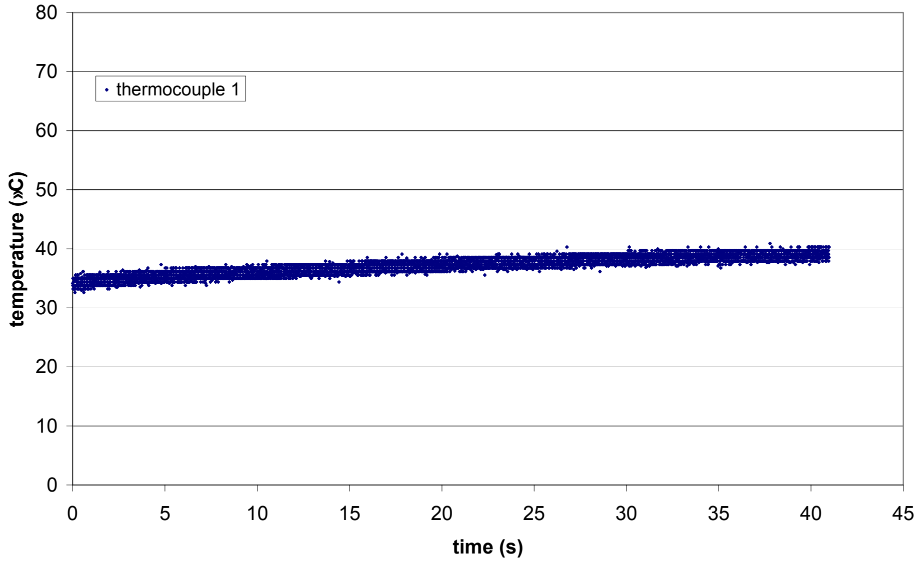

Fig. 3 The filtered measuring data with parallel capacity application

Tensile test

The strain rate was $0{,}005 s^{-1}$ for start the tensile test. The sample was loaded in alternating magnetic field – intensity of magnetic field for start of the tensile test was 470 kA/m. Magnetic intensity was measured with transverse Hall probe. The tensile tests were making also without magnetic field application for confrontation. Average flow stress curves as function logarithmic strain were determined for identical conditions of the experiment (with application magnetic field or without). Average total strains at fracture, the value of the homogenous plastic strains were determined for identical conditions of the experiment too. The partial measurement errors χ_i were calculated too. Then we compared influences of magnetic fields with measurement errors which are determined by Gauss quadratic law accumulation errors.

Fig. 4 The sample with welded thermocouples placed in coils, ready for tensile test.

Results

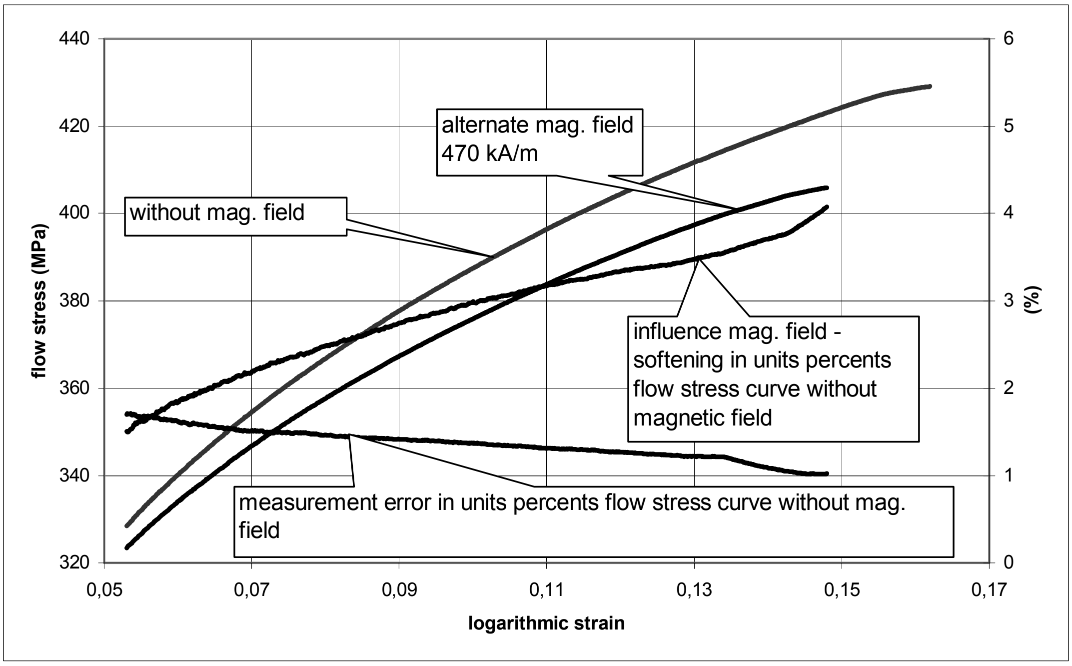

Fig. 5 Comparison average flow stress curves with magnetic field vs. without magnetic field, influence magnetic field vs. measurement error.

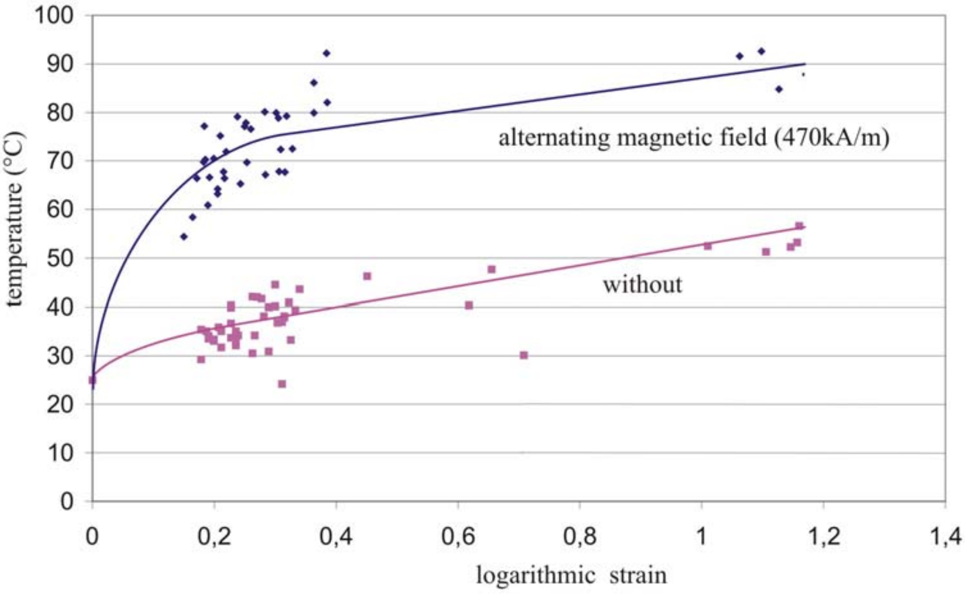

Fig. 6 Comparison of temperature change during tensile tests

Table. 2 Comparison of average total strain at fracture ε_f with magnetic field vs. without magnetic field, value of the homogenous plastic strains with magnetic field vs. without magnetic field, influence magnetic field vs. measurement error.

	alternate mag. field 470 kA/m	without mag. field	influence mag. field	measurement error
ε_f	0,3630	0,3928	-0,0298	0,0223
ε_{hom}	0,1480	0,1620	-0,0139	0,0109

Discussion and conclusions

The alternate magnetic field with magnetic intensity 470 kA/m for strain rate $0{,}005 s^{-1}$ evidently caused shift of the flow stress curve to less values of the mechanical stress. Influence of magnetic field is over measurement error (Fig. 5).

The temperature evolution during the tensile test, their comparison with application magnetic field and without is on Fig. 6.

In the case without magnetic field the temperature changes are caused with adiabatic heating. This is produced with the plastic strain process. With application the alternate magnetic field the temperature changes are caused with adiabatic heating and with induction heating. The induction heating is result of losses at alternate magnetization. The alternate magnetic field influenced the temperature rises about maximum 35°C.

If we make comparison average total strains at fracture with magnetic field vs. without magnetic field application, then we find that with application the magnetic field decrease average total strains at fracture (Table. 2). The explanation we can find in magnetostriction vibrations. The changes of the value of the homogenous plastic strains caused by magnetic field are on Table. 2. We considered that the decreasing of the total strains at fracture and of the homogenous plastic strains is connected with strain ageing. This strain ageing is caused with alternating magnetic field. The strain ageing process runs during tensile test [3, 4].

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