Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava
číslo 2, rok 2005, ročník LI, řada strojní
článek č. 1473

Jiří KULHÁNEK[*], Petr TOMČÍK[**]

MEASUREMENT OF QUICK TEMPERATURE PROCESS UPON A TEST OF METAL MATERIALS

MĚŘENÍ RYCHLÝCH TEPLOTNÍCH PROCESŮ PŘI MATERIÁLOVÝCH TESTECH

Abstract

This contribution is specialized in quick temperature measurement on metal material upon the cold tensile test.

Because of short duration of cold tensile test (about ten seconds); it is important to acquire temperature data quite frequently (at least 50 Hz for one thermocouple). The typical data acquisition cards for thermocouples are possible to scan about 10 temperature samples at second, some advantage types are possible to scan at about 400Hz (but for expensive card). Because of that, we used a quite cheap, universal AD acquisition card, with integrated high gain for thermocouples.

In this contribution will be discussed the maximal speed of the temperature measurement with multiplexed AD inputs.

Abstrakt

Příspěvek se zabývá rychlým měřením teploty při testování materiálu trhací zkouškou za studena. Z důvodu krátkého trvání zkoušky (okolo 10 sekund) je důležité získat údaje o teplotě s poměrně vysokou frekvencí (alespoň 50 Hz na jeden termočlánek). Levné měřicí karty s termočlánkovými vstupy jsou schopny získávat obvykle údaje s frekvencí 1÷10 Hz. Pokročilejší měřicí karty pro termočlánky poskytují vzorkování např. 400 Hz, ale jsou dosti drahé. Z tohoto důvodu jsme pro měření teploty použili levnou a rychlou univerzální AD měřicí kartu se zesílením pro termočlánkové vstupy. V příspěvku je popsána maximální možná rychlost měření teploty s multiplexovanými AD vstupy.

1 INTRODUCTION

This contribution is aimed on quick measurement of temperature. The temperature measurement was done upon the bursting test of metal material. The temperature evolution upon bursting test is quite quick – the test takes about ten second, and the maximum temperature is attained at same time. Because of quite fast temperature evolution, we wanted to take samples at rate about 100 Hz. Typical temperature measurement equipment can't achieve so high sampling rates. Because of that, we decided to use a universal data acquisition card with AD converter and high amplification (suitable for thermocouples).

[*] Ing., Ph.D., Department of control systems, Faculty of mechanical engineering, VŠB Technical university of Ostrava, 17. listopadu 15, Ostrava, tel. (+420) 59 732 3585, e-mail Jiri.Kulhanek@vsb.cz
[**] Ing., Ph.D., CPIT, VŠB Technical university of Ostrava, 17. listopadu 15, Ostrava, tel. (+420) 59 732 4299, e-mail Petr.Tomcik@vsb.cz

2 CASE DESCRIPTION

In the laboratory we have hydraulic pressing machine ZD 40 with a computer controller. The pressing machine is using for the bursting tests of metal materials. We have some measuring set for high speed temperature measuring too.

At the present time we are solving two technological applications on the measuring set:

1. Temperature measurement during cold tensile test. During plastic deformation the flow stress is influenced with a strain rate, attained strain and with the temperature. We wanted to determine an evolution of the temperature during tensile test. About 95-98% from this energy is changed into heating - adiabatic heating. The adiabatic heating causes decrease of the flow stress. This process is strain rate – dependent. We wont used the measuring set for temperature measurement in during tensile test in magnetic field. It brings information about heating, which is caused with magnetic field.

2. The temperature-time profile during the quench (cooling curve). A change in the curvature and form of the curves occurs at a critical temperature, indicating an evolution of heat due to a phase change, namely austenite-to-pearlite. The beginning and end temperatures of such changes in the cooling curves increased with decrease in cooling rate. The temperature-time profile can be used for construction of diagrams of anisothermal decay of austenite. In the future we want connect of inductive distance sensor for measuring dilatometric displacement. It provides more accurately construction of diagrams of anisothermal decay of austenite, because phase changes cause volume anomalies.

2.1 Measuring set

For the high-speed temperature measuring, was chosen the thermocouples with a short response time. Typically the data acquisition cards (DAC) for thermocouples don't allow high speed data acquisition. Because of that, we chose the universal DAC with 330 kHz AD converter and high gain (1000x) suitable for thermocouples. Measuring set consists of following hardware (Fig. 1):

- Personal computer with Windows 98 operating system-
- Data acquisition card ICP-DAS 1800H-
- Daughter board ICP-DAS DB 8225/2.
- Set of thermocouples type K and extension wires.

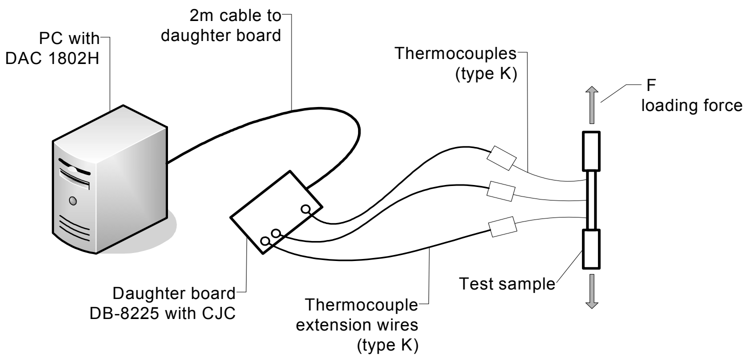

Fig. 1 Measuring set

With the DAC was supplied a basic communication software and drivers. For the measuring we have to create own measuring software with following features:

- Architecture is Visual Basic application with card developer supplied DLL functions.
- Interactive setting and reading of eight AD inputs in differential mode.
- Interactive setting type of data to voltage or temperature (thermocouples type K).
- Interactive setting of measuring frequency (with recommendation of freq. limits).
- Interactive setting of number of samples for digital filtration.
- Continuous data acquisition for selected channels, selected frequency and selected time.
- Output file format suitable for MS Excel import.

The thermocouples were welded to the surface of tested sample by special welding machine (Fig. 2)

Fig. 2 Thermocouple welding machine

The temperature measurement was done on metal sample (Fig. 3 and Fig. 4).

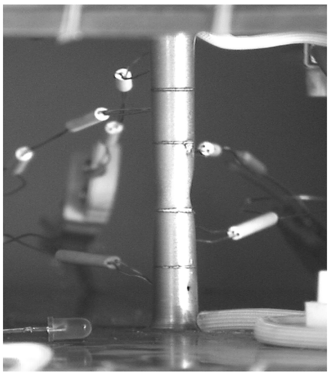

Fig. 3 Cold tensile test sample

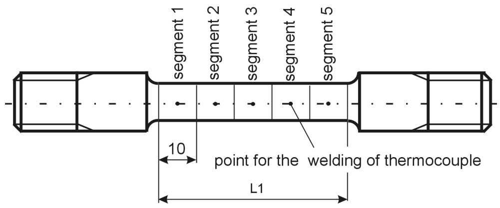

Fig. 4 The drawing of the sample

3 SAMPLE OF MEASURED DATA

Upon the cold tensile test we measure five temperature curves, for five segments of tested sample (Fig. 5).

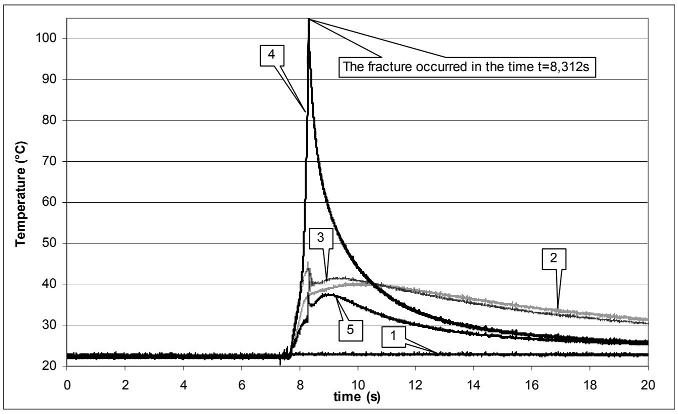

Fig. 5 Evolutions temperatures were measured with five thermocouples

4 PRECISION OF THE TEMPERATURE MEASUREMENT

The first task before measurement is a calibration of measuring set. In the case of temperature measurement we have used the calibration device, which is possible to simulate a thermocouple voltage for a specific thermocouple type and temperature.

Because of scale of possible temperatures (up to 1100 °C) we have to test three different voltage ranges:

- ±0,005 voltage range, up to about 140°C
- ±0,01 voltage range, up to about 250°C
- ±0,05 voltage range, up to about 1100°C

The calibration test was made as follows, at first was set temperature on calibration device, next the output tension was measured by measuring set.

The differences between set and measured values are in Fig. 6.

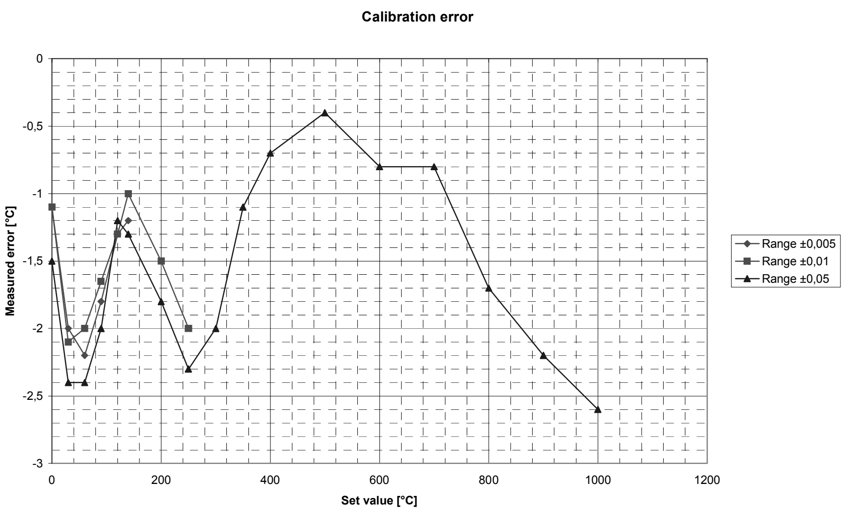

Fig. 6 Differences between calibration device and measured values

The temperature was measured for 100 samples and the average value was computed and recorded to the chart. It is interesting, that measured error curves are similar for different ranges of voltage. The measured error can be caused by interpolation in conversion from voltage to temperature. The interpolation equation was used. On the whole we can say that the calibration error is 3°C at maximum. It is very good value for high temperatures, but for temperature smaller than 200°C it is error larger than 1%.

The error curve can be smooth by new conversion equation. The error can be decreased by voltage shift on measurement card.

5 THE MULTIPLEXED ACCURACY

In our measuring set is quite cheap, universal data acquisition card ICP DAS 1800H. This A/D card has one A/D converter and multiplexer for 8 differentials or 16 single ended analogue inputs. For thermocouple measurement is blocked first channel for temperature of environment (the cold end of thermocouple). For thermocouples the inputs have to be in differential mode.

Between the multiplexer and A/D converter is some high amplifier, which amplifies input voltage for native input voltage of A/D converter.

Multiplexing of high amplified inputs is difficult, because of persistence of voltage in amplifier or multiplexer.

To find out, how much are measured values affected by multiplexer we made up new measuring task.

On the measuring set, we connect the calibration device to inputs 3, 5, 7 and the inputs 2, 4, 6 were connected to analogue ground. The results are in Fig. 7.

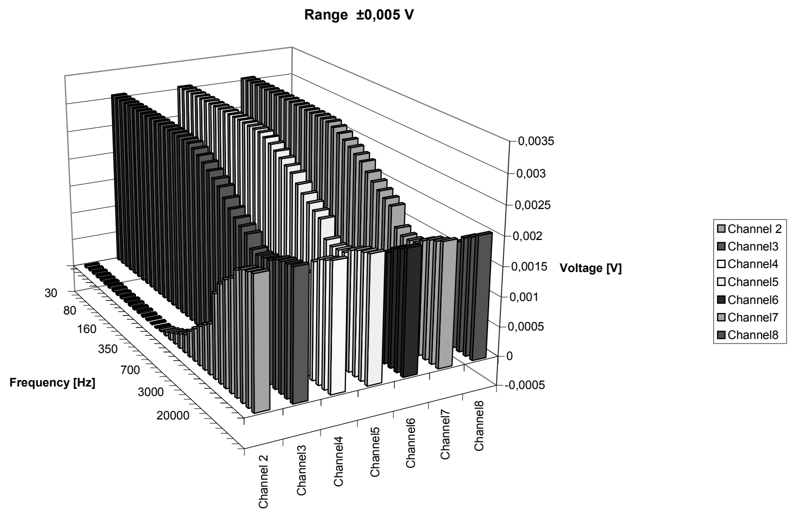

Fig. 7 The dependency of error on sample frequency

On the Fig. 7, we can see the measured values of input channels 2-8 for different frequencies. The frequency axis is not shown regularly (because is not linear), so the chart is only for illustration. For the frequency 30 Hz, the measurement is fine for all inputs. When the frequency rises, the multiplexed inputs are affected by theirs neighbours. At the high frequencies all inputs has the some, wrong value. The chart in Fig. 7 was measured for voltage range ±0,005 V.

The chart with correct frequency axis is in Fig. 8 – the axis is logarithmic.

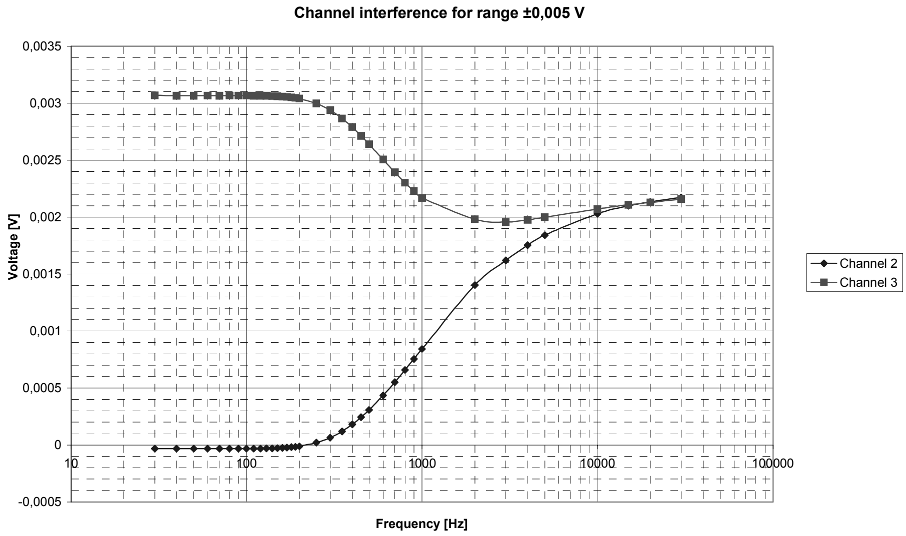

Fig. 8 The dependency of error on sample frequency for one channel

On the Fig. 8 is shown that the measured value is correct for frequencies from 30 Hz to at about 100 Hz. Values measured at higher frequencies, are affected by interference error. This type of error is dependent on frequency and amplification.

6 CONCLUSION

We verified that measurement of rapid temperature processes with our measurement set is correct. The limitations of frequency are 100 Hz for the high resolution and 1000 Hz for the most used temperature range. The results from calibration show that the conversion equation has minor errors, but for temperature ranges above 200 °C it is not important.

Project was realized with the financial support of the Grant Agency of the Czech Republic registration number 101/04/P104.

REFERENCES

[1] KULHÁNEK, J. 2005. Rychlé měření teploty pomocí univerzální A/D karty. In *WORKSHOP 2005*. Ostrava: FS VŠB-TU Ostrava, 12. 1. 2004, s. 240-243. ISBN 80-248-0521-9.

[2] TOMČÍK, P., KULHÁNEK, J., ŠVRČKOVÁ, R., TROJAN, R., HRUBÝ, J. Temperature measurement during cold tensile test. *Acta Metallurgica*, 2004, vol. X, No. 3, pp. 245-252, ISSN 1335-1532.

Reviewer: prof. Dr. RNDr. Lubomír Smutný, VŠB-Technical University of Ostrava