THERMAL AND MECHANICAL CYCLING OF Ni – Ti SHAPE MEMORY ALLOYS

Otakar BLAHOŽ, Miroslav KURSA

Authors: ***Otakar Blahož, MSc. Eng., Miroslav Kursa, Professor, PhD.***
Workplace: ***FMMI, VŠB – Technical University of Ostrava***
Address: ***17. listopadu 15, 708 33 Ostrava-Poruba, Czech Republic***
Email: ***otakar.blahoz@vsb.cz, miroslav.kursa@vsb.cz***

Abstract

This article deals with a effect of a thermomechanical cycling on characteristic of Ni – Ti alloys. Special attribute of these alloys is shape memory effect and significant characteristic of this phenomenon is austenite to martensite transformation, which is characterized by exact temperature. This temperature can be shift in specific interval in dependence on thermal and/or mechanical load.

Key words

thermomechanical cycling, Ni – Ti alloys, transformation temperature

Introduction

Applications in modern industry often using materials with special properties. Ones of these materials are alloys based on Ni and Ti. Characteristic and very exploited property of these alloys is shape memory effect (SME), which enable apply these materials in many branches of current industy, e.g. in electrotecnical, optical, aeronautical or biomedical. When we using Ni - Ti alloys in these sophisticated applications, we very often need to know how is this material going under various types of strain, for example, under the thermal and mechanical cycling.

Theoretical principles

Shape memory alloys (SMA) belong to group od intermetalics-based alloys crystallising in base crystalograpic phaze CsCl (B2). High-temperature austenitic phase is in cooling process transformating on low-temperature structure named martensitic phaze by difussionless transformation. We can obtain permanent deformation of martensit by using sufficient strain. During heating above specific temperature martensite phase is transformated back to austenite structure by the effect of thermoelastic reversibility of martensite and spontaneously change of shape is obsereved at the same time [1, 2].

Experiment

For testing samples was developed and designed a special device, what can cycling wire samples under thermal and mechanical load at the same time. Scheme of testing machine you cas see at fig. 1. It is a lever mechanism joined with a dynamometer, combined with electric resistance heater and cooling device. Testing machine enable cycling wire samples in range from – 30 °C to + 200 °C and from 0 to 3000 N.

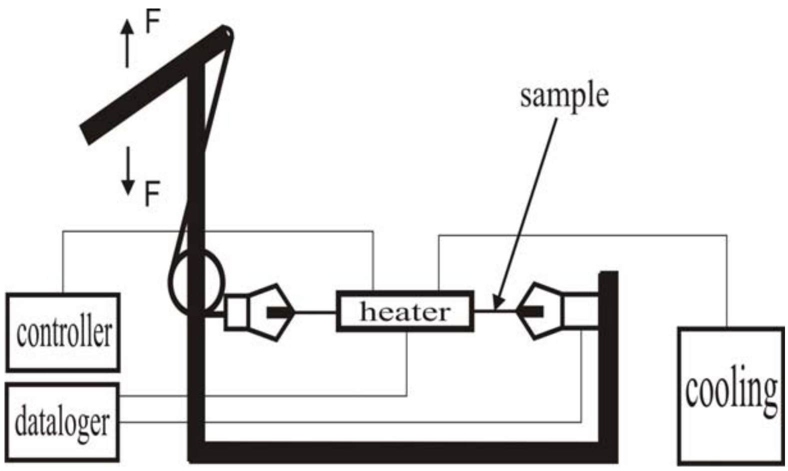

Fig. 1 *Scheme of testing device for thermomechanical cycling*

A part od iniciation tests of the machine was a measuring of temperature profile of the heater during various levels of heating and there was defined area of the specimen, which is influenced by desire temperature. Example of load and thermal cycles are shown in fig. 2.

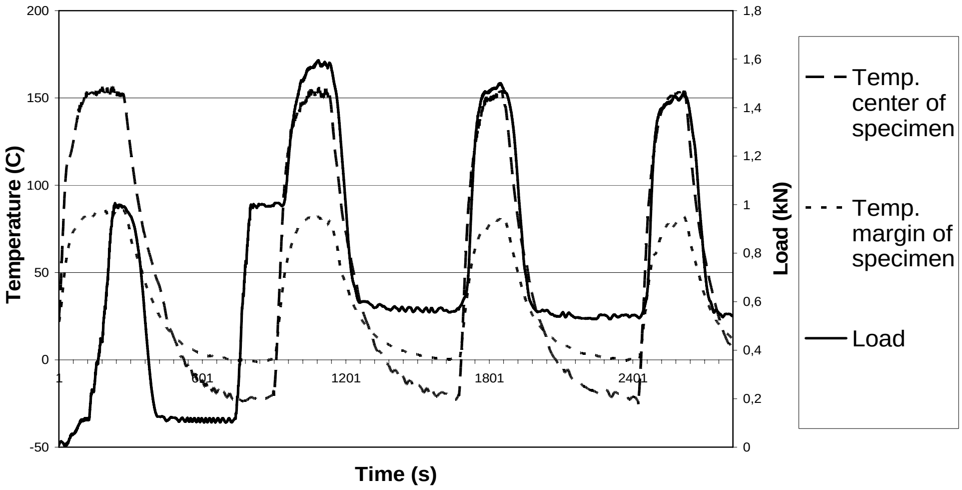

Fig. 2 *Part of a testing program with curves of load and temperatures on different position on specimen*

Samples for cycling tests were prepared from binary alloy Ni – Ti (average composition 51,81 at. % Ni, 48,20 at. % Ti). Alloy was prepared from electrolytic Ni and Ti by plasma melting, then was homogenized in vacuum induction furnace and forged into a wire shape with 300 mm lenght and 2.3 mm diameter.

For experimental verification of thermomechanical cycling effect on material were used 5, 25 and 100 cycles with 200 MPa initial loading and heating and cooling. In these cycles was lowest testing temperatures lower than M_f of the material and the highest testing temperature higher than its A_f [3]. In our case the lowest temperature was 15 ºC and the highest was 115 ºC. Persist in limit temperatures was about one minute for getting homogenous temperature field in whole volume of the sample.

Results

There are several methods to check how thermomechanical cycling affect transformation characteristic in studied materials. One of these is DSC (Differential Scanning Calorimetry) which is very often use in studying phase transformations. It is thermoanalytical method where the difference in the amount of heat required to increase the temperature of a sample and reference are measured as a function of temperature. The result of a DSC experiment is a heating or cooling curve of heat flux versus temperature or versus time [4]. In fig. 3 you can see DSC curve within cooling process, where the onset point on the right end of curve means temperature of martensite start and point on the other side of peak means martensite finish temperature. Other graph shows DSC curve while heating process. Onset point in the left side of graph means austenite start temperature and endset point on the right part of graph shows austenite finish temperature. Ms, Mf, As and Af temperatures for 5 and 100 cycles are displayed in similar DSC graphs.

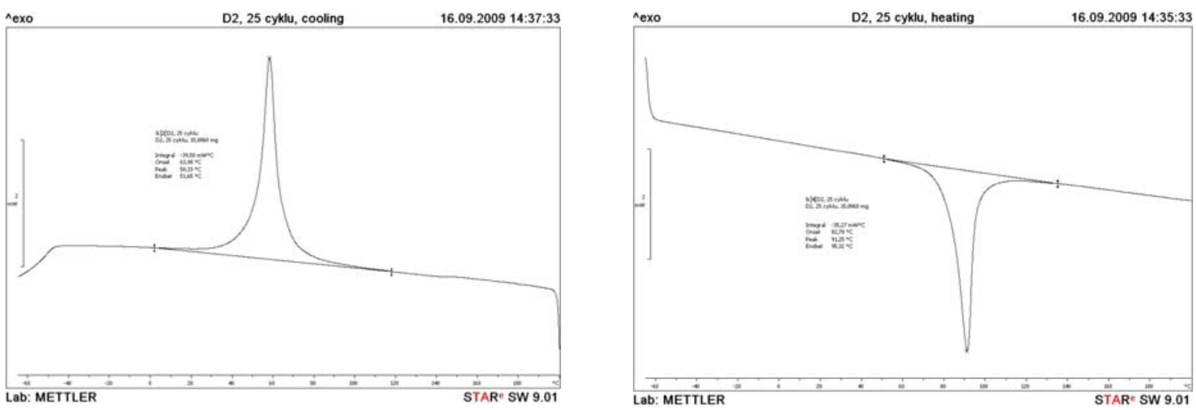

Fig. 3 *DSC cooling and heating curves for 25 cycles of studied Ni – Ti alloy*

Comparing of transformation temperatures measured by DSC show that increasing number of cycles under load decrease transformation temperature as it can be seen on fig. 4. Fall down of the Ms temperature is not a linear, but significant decline is observed in initial cycles. With a rising number of cycles is a decrease of Ms temperature not so distinctive. A graph on fig. 4 shows that sould be a temperature, which never can be reached by any number of cycles. Next step in our research would be recognize effect of various load to reach this temperature.

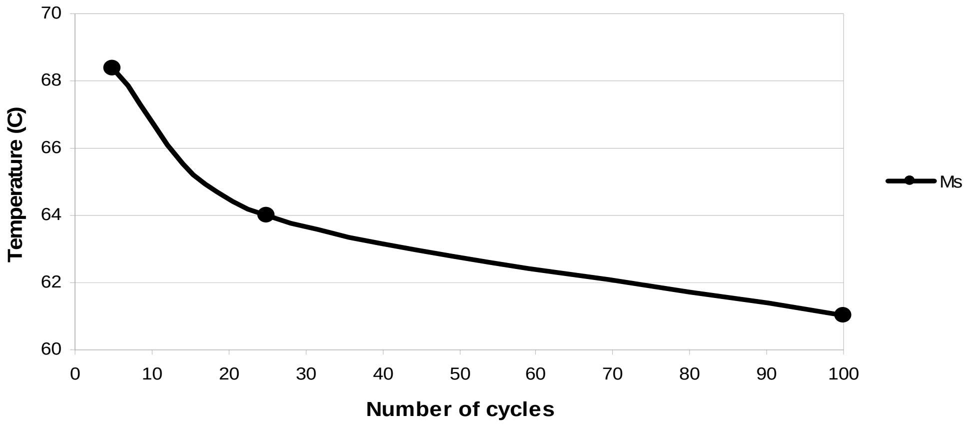

Fig. 4 *Curve of decreasing Ms versus number of cycles*

Summary

Aim of this research is analyze effect of thermal and mechanical cycling on changes of transition temperatures and others material characteristics in Ni – Ti alloys with shape memory effect. Following program in our research are preparing new types of alloys, e.g. Ni – Ti – Zr, Ni – Ti – Hf or Ni – Ti – Cu, specify their transition temperatures, then recognize, how composition of these alloys can influence cycling program and propose cycling processes for getting desired characteristic of shape memory material.

The presented work has been supported by the Ministry of Education of the Czech Republic under the projects No. GA106/09/1573 and MSM 6198910013

References:

[1] Kursa, M., Pacholek, P. Metalurgické charakteristiky tvarově paměťových materiálů na bázi Ni-Ti-Me. *In Metal 2002* [online] [cit. 2009-11-12]. Dostupné na internetu <: http://konference.tanger.cz/data/metal2002/sbornik/ > ISBN 80-85988-73-9.

[2] Stöckel, D. *Legierungen mit Formgedachtnis*. Böblingen : Expert-Verlag, 1988, p. 197

[3] Pacholek, P. *Návrh zařízení a řešení tepelně mechanického zpracování paměťových slitin.* Ostrava: VŠB – TU, 2005, s. 20 – 21.

[4] Pungor, Erno. A Practical Guide to Instrumental Analysis, Boca Raton CRC, Florida, 1995, p. 181–191. ISBN 0-8493-8681-0.