# Thermal Expansion Measurements on some Ni-Ti-Cu Alloys

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***Abstract.*** *Multicompound Ni-Ti-X alloys are presenting, depending of chemical composition and alloying elements (Cu, Al, Fe, Zn, Co), some parameters modification of them main characteristic, the shape memory effect. So, one can observe, from thermal expansion curves of some alloys (Ni-Ti-X/T1*), solid state transformations in 800-900°C temperature range. This phenomenon leads us to the conclusion that one complex $Ni_xCu_yTi_z$ compound just "disappears" from that temperature*

***Keywords:*** thermal expansion, solid state transformation, shape memory effect

## 1. INTRODUCTION

Dilatometer analysis is based on the fact that material's expansion depends proportional with the temperature as long as in the material there are not present internal changes (crystalline lattice distortion, phase transformations, allotropic transformations). Expansion curve linear deviation is marking the material internal changes, these changes being proportional with the transformations intensity. In this case, we can use the direct dilatometer analysis with a heating/cooling speed of 1-5°C/min.

A precise knowledge of the nature and extent of these size changes are of paramount importance for any engineering design. With the introduction of new materials, the need for means to determine this property has grown substantially.

## 2. USED APPARATUS

The dilatometer used is one of high temperature and is produced by Anter Corporation, the model being Unitherm 1161V. This class of dilatometers have maximum operating temperatures of 1650°C, and have a high purity alumina dilatometer tube/pushrod construction. It's ideal for research, softening point and sintering studies, and quality control testing.

The vertical version (Model 1161V) is a computerized unit that utilized a fully digital, absolute displacement transducer for sample length change measurement, with no periodic calibration requirements. As with every vertical system, thermal uniformity is not as good in a horizontal device, but we can limit sample size to be still within a nearly uniform thermal zone. Also, counterbalancing with dead weight is possible, so tracking pressure can be greatly reduced to a minimum needed for smooth and continuous movement. Type "S" thermocouples are used for furnace control and sample temperature measurement. It is, also, equipped with a vacuum inert gas or nitrogen atmosphere system. Built-in safety features include cooling water flow sensor, open thermocouple and dead computer protection, software selectable temperature and shrinkage limits. Optional program modules allow softening point determination and controlled rate sintering cycles.

Stored data is automatically processed by statistical methods. The analysis includes polynomial curve fitting, evaluation of the equation at user selectable points or intervals, and tabulation of results (percent expansion, average coefficient, thermal conductivity, specific heat) as a function of temperature. A variety of single or multiple curves for a group of tests can be generated and displayed. Optionally, data files may be downloaded to other computers, for further processing**.**

## 3. DEFINITIONS

*Linear Thermal Expansion* – The change in length of a material resulting from a temperature change. Linear thermal expansion is symbolically represented by $\Delta L/L_0$, where $\Delta L$ is the observed change in length ($\Delta L = L_1-L_0$), and $L_0$ and $L_1$ are the lengths of specimen at reference temperature $T_0$ and test temperature $T_1$. Linear thermal expansion is dimensionless, it is often expressed as a percentage, or in parts per million (such as µm/m) units.

*Mean Coefficient of Linear Thermal Expansion (CTE)* – The linear thermal expansion per change in temperature. The mean coefficient of linear thermal expansion, α, is defined as:

$$\alpha=1/L_0[(L_1-L_0)/(T_1-T_0)]=[1/L_0(\Delta L/\Delta T)] \qquad (1)$$

In industry, frequently the whole process is referred to as "CTE testing". The value must be accompanied by the values of the two temperatures.

*Instantaneous Coefficient of Linear Thermal Expansion (CTI)* – The slope of the linear thermal expansion curve at temperature T. Instantaneous coefficient of linear thermal expansion represented by:

$$\alpha_T=(1/L_0)dL/dT \qquad (2)$$

The value of the instantaneous coefficient must be accompanied by the temperature at which it is determined.

## 4. SELECTION OF MATERIALS

The expansion determinations were made on two samples from two different Ti-Ni-Cu alloys. Chemical composition of these alloys are presented in the Table 1

**Table 1- Chemical composition of Ti-Ni-Cu alloys**

| Sam-ple | Elements, [wt %] | | | | | |
|---|---|---|---|---|---|---|
| | Ni | Cu | Al | Fe | Zn | Co |
| 1 | 39.1 | 11.1 | 0.01 | 0.030 | 0.014 | 0.0084 |
| 2 | 35.9 | 10.4 | 0.03 | 0.220 | 0.014 | 0.0080 |

The alloys were selected in close proximity of the chemical composition of $Ti_xNi_yCu_z$ metallic compound ($Ti_2Ni$ at 38 wt% Ni and $Ti_2Cu$ at 39.9 wt% Cu) [1], as shown in Figure 1.

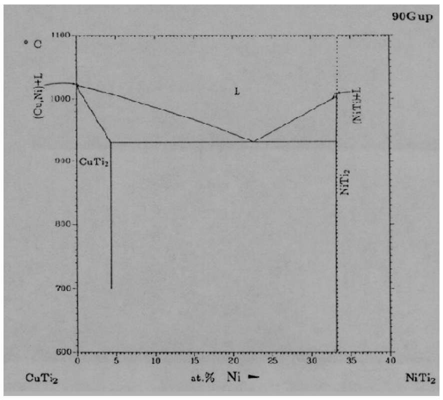



**Figure 1. Section through Cu-Ni-Ti ternary diagram at 1.0/1.0 at% conv. [1]**

From these Sections of diagrams results that some of metallic compounds are stable till $900^0$C, with different atomic percent of elements, shown in Figure 2 [1].

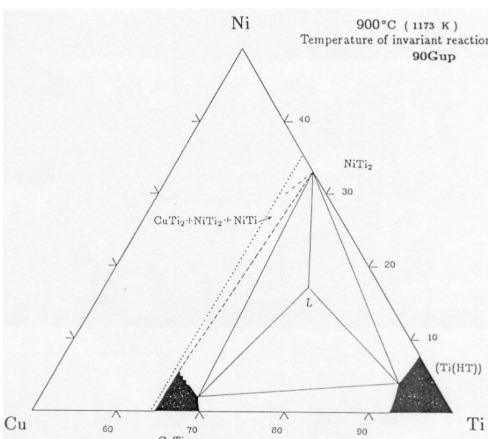



**Figure 2. Isothermal sections ($900^0$C), through ternary diagram Cu-Ni-Ti [1]**

## 5. EXPERIMENTAL DATA

The measurements were performed at "European Thermophysical Testing Laboratory" which is functioning in U.P.B. – "Matallic Materials Science, Physical Metallurgy Department".
The experimental conditions for the two samples used are presented in Table 2.

**Table 2. Experimental conditions**

| Sam -ple | Length, [mm] | Heat. rate, [$^0$C / min] | Temp., [$^0$C] | Expansion, [%] |
|---|---|---|---|---|
| 1 | 29.425 | 2 | 900 | 1.19 |
| 2 | 34.850 | 2 | 900 | 1.72 |

The test expansion graph shown in Figure 3, illustrates the real time plots AY which display the temperatures (set point, furnace, sample) versus time, as well as the samples length changes versus time, during the test. There are displayed simultaneous the following traces [2]:

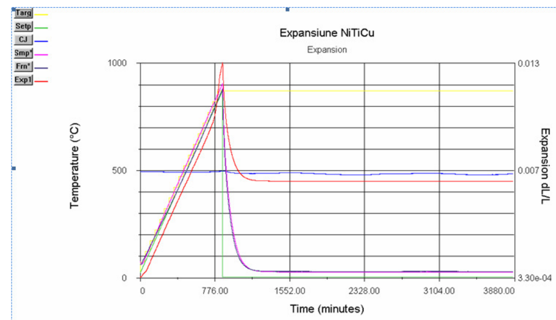
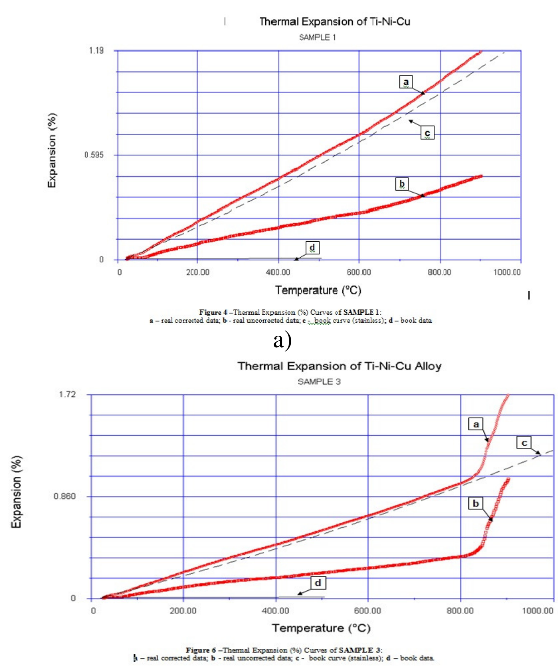



**Figure 3. The real time data for the process. [2]**

TARG - the final temperature of the present segment of the process; SEPT - the progress of the control set point; CJ - could junction temperature; SMP - sample temperature; EXP - sample expansion

## 6. RESULTS

The expansion test graphs from Figure 4 shows that for the sample 2 , the expansion curve relieves an inflexion point at about $810^0$C (Figure 4b), witch means that this alloy suffer a solid state transformation (eutectoid type) at this temperature and the other one alloy, with 39 wt% Ni, doesn't.




b)

**Figure 4 –Thermal Expansion (%) Curves of samples (a,b) a – real corrected data; b - real uncorrected data; c - book curve (stainless); d – book data**

In order to obtain a confirmation of this transformation and the temperature it was repeated the expansion test for this sample and the results are the same, as it is shown in Figure 5.

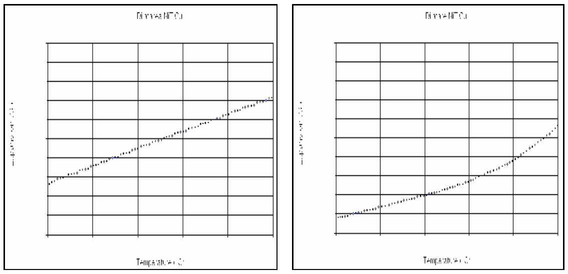


**Figure 5. Details of the two expansions curves from Figure 5, showing the inflexion point**

## 7. CONCLUSIONS

The Ti-Ni-Cu alloy with 35 wt% Ni, is situated on the phase diagram, in the domain of eutectoid transformation, which for this chemical composition is at about $810^0$C.

In comparison with Ti-Cu (eutectoid at $790^0$C) and Ti-Ni (eutectoid at $765^0$C), binary diagrams [3], in the case of Ti-Ni-Cu ternary alloy the eutectoid reaction is situated at $810^0$C.

The next researches will focus both on the eutectoid reaction temperature determination and metallic compounds identification and characterisation.

## 8.REFFRENCES

[1] The Phase Diagram Web – http://cyberbuzz.gatech.edu/asm_tms/phase_diagrams//

[2] Operating and service manual for Dilatometer System, Version 10.0, UNITHERM$^{TM}$, Model 1161V; Anter Corporation 2001.

[3] ASM Phase Diagrams Catalogue; J.L.Murray: 1987 → Cu-Ti; 1991 → Ni-Ti.