



Behavior of the High-temperature Background of Internal Friction by Martensite Phase Transformation in Fe-20% Ni

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Abstract.

The aim of the present study is to investigate the behavior of the high temperature background of internal friction in phase martensite transformations. The energy of activation against the internal friction background is close to that of the martensite transform, calculated on the maximum rate of the solid phase reaction. This confirms the dislocation mechanism of initiation and growth of the martensitic phase. There is a wide distribution of relaxation times, defining the energy of activation against the internal friction, which at the respective temperature defines the course of the martensite transformation process

Keywords: high temperature background, internal friction, martensite phase transformation, TRIP-steels, XRD.

1. Introduction

This paper presents studies of the relationship between the temperature dependence of the internal friction background and the structural states accompanying the processes of martensitic phase transformations in a high nickel alloy.

2. Material and methods

The Fe-20% Ni alloy is produced /cast, rolled and annealed/ in IMSETHC-BAS. The temperature dependencies of the dynamic relaxation spectra /internal friction/ were investigated with a computerized apparatus for the study of internal friction in metals and alloys built on the principle of the equilibrium pendulum of Ke. The investigations were conducted at working frequency of 1-3 Hz with heating and cooling in the temperature interval 20 – 1100 °C at heating rates of 10 and 20 deg/min. Data is processed with Origin.

3. Experimental results and discussion

Other studies of the same alloy [1-2] showed that at room temperature it has a martensite phase composition. Under heating, according to the state diagrams, the martensite is transformed into austenite. With cyclic heating and cooling in Fe-20% Ni the right and reverse reaction of the martensite $\alpha \Rightarrow \gamma$ -conversion occurs. These phase reactions are reflected as maximums on the temperature dependence of internal friction of the alloy – fig.1. Characteristic of the right reaction $\alpha \leftrightarrow \gamma$ is that the conversion occurs in the vicinity or in the high-temperature background of internal friction, where the mobility of the dislocation structure is greatest.

According to the literature, the investigated alloy has low stacking faults energy, the order of 50 erg / cm², which guarantees the martensitic γ - α transformation. In this sense, the dislocation structure of the high-alloy alloy is easily movable and consists of wide-spaced partial dislocations surrounding large areas with stacking faults [3-5].

Several models describing the relationship between the internal friction value and the phase conversion parameters show [6-8] that the height of the internal friction peak is proportional to the rate of phase conversion and the rate of heating.

The numerical integration of the experimentally obtained maxima represents the kinetics of the martensitic reaction under non-isothermal conditions.

The investigation shown in fig. 2 is an attempt to obtain information about the initial stage of development of the martensite transformation process. Then the primary role is played by the dislocation mechanisms of origin and growth of the new phase, and the internal friction method is sensitive to dislocation mobility. That is why the samples are heated only to the temperatures typical of the initial stage of the martensitic reaction before reaching the maximum of the conversion rate as shown in the figure.

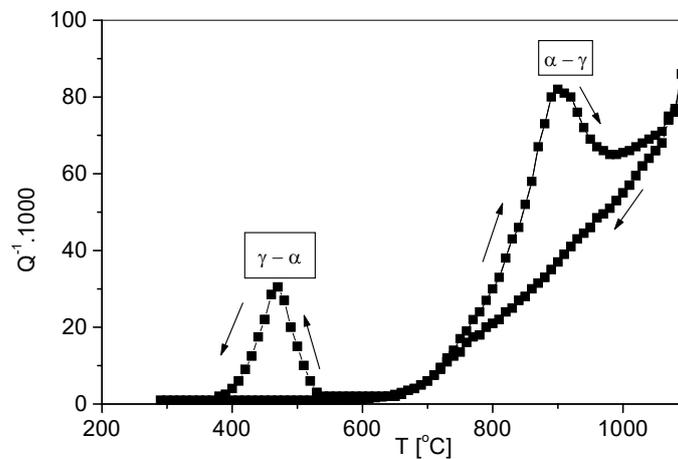


Fig.1. Temperature dependence of internal friction on heating and cooling – 10 deg/min [1]

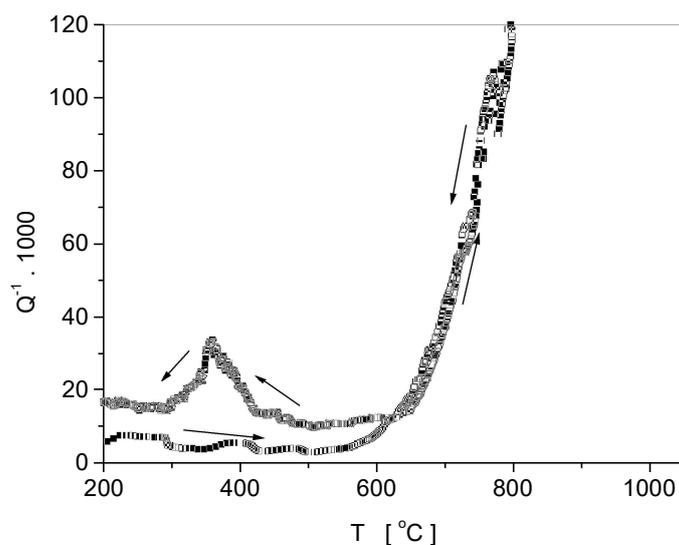


Fig.2. Temperature dependence of internal friction on heating and cooling – 10 deg/min [1]

Fig. 3 and 4 show experimental temperature dependencies of internal friction background after subtraction of relaxation maxima.

According to the Maxwell rheological model, refined by Weller [9] and Schaller [10], the temperature dependence of the internal friction background Q^{-1}_f is described by the dependence:

$$Q^{-1}_f = A \cdot \exp(-H/RT),$$

where – A is an empirical constant.

The equation refers to the ideal case of a rheological model characterized by a single relaxation time.

In reality, there is a distribution in relaxation times, in which the above equation is transformed into:

$$Q^{-1}_f = [A \cdot \exp(-H/RT)]^n,$$

where “n” is a constant describing the distribution of relaxation times of the process.

At $n = 1$, the above equations are identical.

To determine the energy of activation, the experimental data was approximated with the top function – Fig. 3-4, using the program product "Origin 6.0". The results are automatically plotted as shown in the figures. For clarity, the values obtained are shown in Table 1.

The experimental results are approximated and at a set value for one relaxation time $n=1$. The values of the energy of activation corresponding to one relaxation time, as well as the magnitude of its values for heating and cooling, are given in Table 2. The average energy value and the energy distribution are also shown in the table.

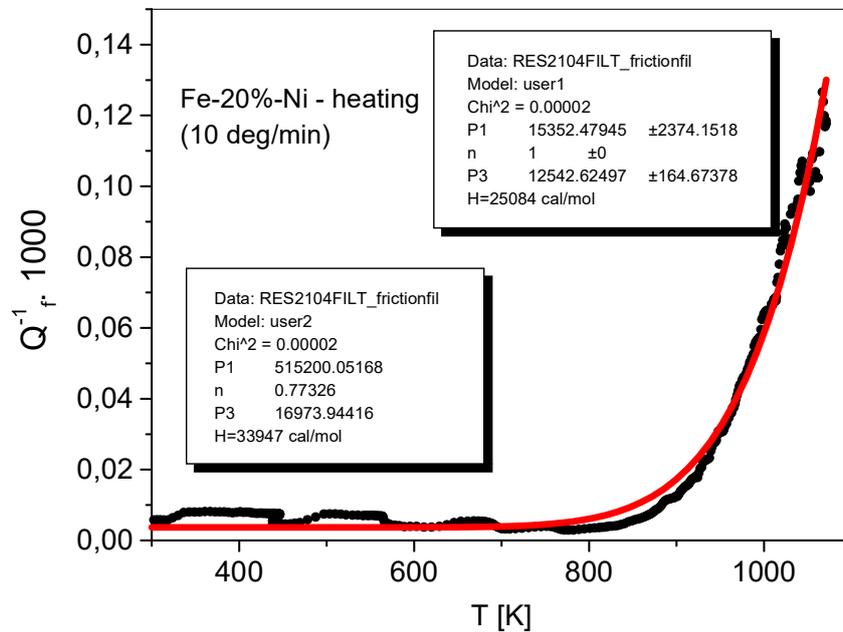


Fig.3. Temperature dependence of the internal friction background on heating

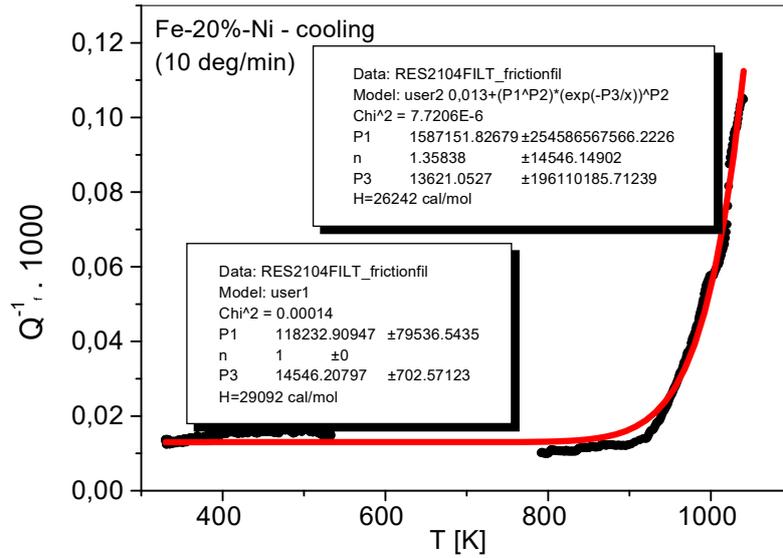


Fig.4. Thermal dependence of the internal friction background on cooling

Table 1. Activation energy values H [kcal/mol] and n

Conditions		H [kcal/mol]	n
10 degrees / min	Heating	33.9	0,77
10 degrees / min	Cooling	26.2	1.36
20 degrees / min	Heating	33.4	0,77
20 degrees / min	Cooling	27.4	1,138
Average values	Heating and cooling	30,33	1,0095

Table 2. Values and mean value of activation energy distribution H [kcal/mol] at n = 1

Conditions		H [kcal/mol]	ΔH [kcal/mol]
10 degrees / min	Heating	25.9	-8.0
10 degrees / min	Cooling	29.1	+2.9
20 degrees / min	Heating	25,4	-8.0
20 degrees / min	Cooling	29.4	+2.0
Average values	Heating and cooling	27,45	-5.55

The results showed that:

- The activation energy against the internal friction – Table 2 is close to that of the martensitic transformation, which confirms the dislocation mechanism of origin and growth of the martensitic phase.

- There is a wide distribution of relaxation times that determine the energy of activation against the background friction, which at the appropriate temperature defines the course of the martensite transformation process. The spread of this distribution is in the order of 10 [kcal / mol].
- The difference in activation energies against the internal friction with heating and cooling, determined by the thermal dependence of the energy of the defects in the arrangement, defines the parameters of the martensitic right and the reverse reaction.
- In the mechanism of germ formation in low-energy alloys of the defects in the arrangement defining the temperature dependence of the latter. It is known that it depends heavily on the temperature and changes jump from it. This fact also determines the existing high temperature hysteresis between the straight and reverse martensitic reactions observed in these alloys.

4. Conclusions

Studies have shown that there is a widespread distribution of relaxation times that determine the energy of activation against the internal friction, which at the corresponding temperature defines the course of the martensite transformation process. The spread of this distribution is in the order of 10 [kcal / mol] and for the full and accurate description of a martensitic reaction this fact needs to be taken into account.

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