DECOMPOSITION KINETICS DURING DIRECT PHASE TRANSFORMATION IN Y_{2}Fe_{17} MAGNETIC ALLOY

Shilina M.A.

Professor – Assoc. Prof., PhD. Rybalka S.B.
Bryansk State Technical University, Bryansk

kinetic@bk.ru

Kinetics of decomposition of Y_{2}Fe_{17} alloy during hydrogen-induced direct phase transformation, i.e. decomposition on YH_{2} hydride phase and α-Fe phase of iron of initial phase of Y_{2}Fe_{17} magnetic alloy in hydrogen atmosphere has been studied. It has been established that, as the temperature increase from 610 to 750°C, a direct phase transformation significantly accelerates. Activation energy of transformation process determined from kinetic data varying from 163 up to 242 kJ/mol that it is correspond to the values of activation energy of the iron atoms diffusion in R–T type alloys. It is shown that phase transformations kinetics in the investigated interval of temperatures is controllable by diffusion of iron atoms to growing new α-Fe phase centers.

At present the intermetallic compounds of R_{2}M_{17} (R=Sm, Y, Dy, Ho, Gd) type have attracted much attention because of their interesting magnetic properties [1,2]. In particular, R_{2}M_{17} compounds demonstrate very interesting magnetic phenomenon during their interaction with interstitial atoms (H, N, C, B) [3-5]. For instance, the new perspective technology well known as a HDDR-process (Hydrogenation-Decomposition-Desorption-Recombination) in R_{2}M_{17} type alloys (Sm_{2}Fe_{17}, Sm_{2}Co_{17}, Nd_{2}Fe_{14}B etc.) alloys for permanent magnets allows improve their structure and magnetic properties by hydrogen-induced reversible phase transformations [6].

The most significant aspect of the HDDR process is that there is a dramatic change in the microstructure from an initial grain size of typically ~150µm to a very fine, uniform grain size of about 0.1-0.3µm [6].

In particular, at HDDR-treatment the Y_{2}Fe_{17} alloy undergoes the direct hydrogen-induced phase transformation at temperatures above 500°C with
decomposition of initial alloy on hydride YH₂ phase and α-phase of Fe that can be described by the following scheme:

\[ \text{Y}_2\text{Fe}_{17} + \text{H}_2 \rightarrow \text{YH}_2 + \alpha\text{-Fe} \]  

(1)

Then, the reverse phase transformation takes place during hydrogen evacuation at higher temperatures with recombination decomposed phases into initial Y₂Fe₁₇ matrix phase and can be described by the following reaction:

\[ \text{YH}_2 + \alpha\text{-Fe} \rightarrow \text{Y}_2\text{Fe}_{17} + 2\text{H}_2 \uparrow \rightarrow \text{Y}_2\text{Fe}_{17} \]  

(2)

And finally, after the completion of recombination stage the treated alloy as a rule consist of the nanocrystalline phase of Y₂Fe₁₇.

It is obvious that the clear outstanding of kinetic features of the above hydrogen-induced phase transformations will allow in follows to control microstructure and magnetic properties of this alloy. For Y₂Fe₁₇ alloy above-mentioned kinetic peculiarities have been not known yet until present and therefore, the main goal of present work was to investigate the features of kinetics of the hydrogen-induced direct phase transformation (1) in Y₂Fe₁₇ alloy at temperatures range of 610-750°C in hydrogen pressure of 0.1 MPa. Samples of Y₂Fe₁₇ alloy were prepared by arc melting in an argon atmosphere of high purity. All kinetic experiments by investigations of kinetics of direct hydrogen-induced phase transformation has been carried out on special hydrogen-vacuum equipment using a special magnetometric Sadikov’s method.

Thus, heating of an alloy Y₂Fe₁₇ in hydrogen atmosphere results in development of direct phase transformation leading to alloy decomposition with formation of a hydride YH₂ phase and phase α-Fe (see the equation (1)) which was established by X-ray diffraction experiment.

The results of research of kinetics of hydrogen-induced direct phase transformation in Y₂Fe₁₇ alloy are generalized in Fig. 1 in form of kinetic curves.

As can be seen from Fig. 1, with increasing of transformation temperature in narrow interval (140°C) from 610°C up to 750°C the direct phase transformation lead to very strong acceleration of transformation in some order of magnitude. Because of this, it is necessary also to note, that at all temperatures there is a noticeable incubation period of a phase transformation (from 0.33×10⁴ s at 640°C
to 0.015×10⁴ s at 760°C). As can be seen in Figures 1, the shape of the kinetic curves with a gradual slowdown of the transformation rate with decrease temperature and also dependence of the incubation period on the temperature let us suggest [7] that phase transformations develop by the mechanism of nucleation and growth.

Further, as well known from classic kinetic theory of phase transformations in condensed state [7], in particular in accordance with Becker-Döering model of nucleation kinetics [8-9] if plots dependence \(\ln t\) on \(1/T\), where \(t\) is the transformation time, which it is necessary for reaching of some degree of transformation \(\alpha\) and \(T\) is the transformation temperature, we can determine an effective energy of phase transformation process. For this goal experimental data from Fig. 1 were re-plotted in co-ordinates \(\ln t\) versus \(1/T\) which are shown in Fig. 2. The slopes of the straight lines give us the values of the effective activation energies for hydrogen induced direct phase transformation in Y₂Fe₁₇ alloy. The obtained values of an activation energy determined for some degrees of transformation varying from 163 up to 242 kJ/mol. Thus, above obtained values of an activation energy correspond to the values of an activation energy of the iron atoms diffusion in R–T alloys (where R is a rare-earth metal, T – a transition metal) ~250 kJ/mol [10], whereas activation energy for hydrogen atoms diffusion in R–T alloys is 45 kJ/mol [10].

Thus, can be believed that the above investigated direct hydrogen-induced phase transformations in Y₂Fe₁₇ alloy are controllable by diffusion of iron atoms to growing \(\alpha\)-Fe phase centers.

REFERENCES

