NEW AMORPHOUS $Fe_{85-x}Me_xB_{15}$ - ALLOYS WITH FAVOURABLE COMBINATION OF INVAR AND ELASTIC PROPERTIES

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Series of $Fe_{85-x}Me_xB_{15}$ (Me = Co, Ni, Mn, Cr; x = 0 to 20 at.%) have been rapidly quenched from the melt by PFC method. The compositional variations of the coefficient of thermal expansion α_l, of the Curie point T_c and of the elasticity modulus E, depending on the alloying element Me used, have been studied. It has been found that some of these amorphous alloys possess a favourable combination of Invar and elastic properties and could be used as an alternative of the conventional 36 Ni Invar alloys.

INTRODUCTION

The most important field of application of Invar precision alloys is the instrument-building where the major demands to the materials used are connected with their coefficient of thermal expansion α_l. It should be within $1 - 5x10^{-6}K^{-1}$ in the temperature range 20-200°C in order to guarantee a high precision of measuring instruments. Invar alloys should possess high enough strength and toughness as well. Amorphous alloys exhibit in general high hardness, high strength, toughness and corrosion resistance. From these characteristic properties high resistance to fatigue and wear are expected (1). It is known (2) that some ferromagnetic Fe-based amorphous alloys possess Invar thermal behaviour up to temperatures of 300°C, which is comparable with the behaviour of most widely used conventional 36 Ni Invar alloys. The aim of this study was to examine the possibility for development of new compositions of amorphous Invar alloys with favourable combination of Invar and elastic properties on the basis of $Fe_{85}B_{15}$ amorphous alloys by using Co, Ni, Mn or Cr additions.

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EXPERIMENTS AND EXPERIMENTAL RESULTS

Master alloys were prepared from the pure metals under argon atmosphere in silica glass crucibles. From the ingots obtained amorphous metallic ribbons 6 mm wide by approximately 0.03 mm thick were prepared by Planar Flow Casting method for rapid quenching from the melt.

The thermal expansion of the specimens was monitored with the aid of a PERKIN ELMER TMS 2 thermomechanical analyzer by heating rate of 20 K/min. Typical thermal expansion curve of $Fe_{80}Mn_5B_{15}$ amorphous alloy is shown in Fig.1. The measuring accuracy for length and temperature changes was $\pm 0.5 \times 10^{-5}$ mm and ± 1K respectively. For the calculations of the thermal expansion coefficient of the alloys studied two different definitions were used:

a/ technical definition:

$$\alpha_l = \Delta l / l_o \Delta T \quad (1)$$

where $\Delta l = l(T) - l_o$, l_o is the specimen length at the initial tepmerature T_o ($T_o = 50^oC$), l is the specimen length at temperature T, and $\Delta T = T - T_o$. The values of α_l, for different temperature ranges, are given in Table 1.

b/ scientific or differential definition:

$$\alpha_l^d = \Delta l' / l \, \Delta T' \quad (2)$$

where $\Delta l'$ is the length change in a narrow temperature range $\Delta T'$ of 5 or 10 K, α_l^d being assigned to the temperature in the middle of $\Delta T'$. The temperature dependence of α_l^d for the $Fe_{85-x}Mn_xB_{15}$ amorphous alloys studied is shown in Fig.2.

The Young's modulus E of the amorphous alloys was measured with the aid of a high precision pulse-echo system from:

$$E = \rho V^2 \quad (3)$$

where ρ is the alloy density and V is the velocity of propagation of 40 kHz extensional ultrasonic waves as described elsewhere (3). Young's modulus data are given in Table 1. In the same Table for comparison the α_l and E - values of the conventional 36 Ni Invar alloy, as well as of two russian amorphous Invar alloys, 93 FeCrB-A and 86 FeCrB-A, are given.

CONCLUSIONS

New compositions of amorphous Invar alloys with favourable combination of Invar and elastic properties are developed. Amorphous alloys of $Fe_{80}Co_5B_{15}$, $Fe_{80}Ni_5B_{15}$, $Fe_{75}Cr_{10}B_{15}$ and $Fe_{75}Mn_{10}B_{15}$ compositions

TABLE 1. Experimental data for $\alpha_l \times 10^6$, K^{-1} and E for the alloys studied. * - data from (4)

Me C_{Me}, at. %	50-100°C	50-150°C	50-200°C	50-250°C	50-300°C	E, GPa
Co 5	3.9	4.3	4.5	5.2	4.9	166
Co 10	6.3	6.4	7.1	6.8	6.6	124
Co 15	9.3	9.8	9.9	9.8	9.5	118
Co 20	11.9	12.0	11.1	10.1	9.1	136
Ni 5	4.5	4.8	5.2	5.4	5.4	120
Ni 10	7.4	7.5	7.5	7.5	7.5	148
Ni 15	8.8	9.9	9.8	9.8	9.5	139
Ni 20	10.3	11.6	12.1	12.1	11.9	167
Mn 5	1.8	1.8	1.5	2.5	3.9	122
Mn 10	5.5	5.9	7.1	9.0	10.3	133
Mn 15	7.0	7.6	9.0	10.7	11.4	110
Mn 20	14.8	17.4	18.8	20.4	20.4	119
Cr 10	4.4	5.8	7.5	9.8	11.1	126
Cr 20	14.0	16.8	18.0	18.5	18.4	185
$Fe_{85}B_{15}$	5.4	5.3	4.7	4.5	4.2	122
36Ni*	1.3	-	2.2	-	4.4	147
86FeCrB-A*	5.7	8.9	10.2	11.0	11.6	-
93FeCrB-A*	0.5	1.9	2.2	3.0	4.7	-

possess low ($3.0 \times 10^{-6} K^{-1} < \alpha_l < 7.0 \times 10^{-6} K^{-1}$) coefficients of thermal expansion. Amorphous alloy of $Fe_{80}Mn_5B_{15}$ composition could be distinguished as a high performance amorphous Invar alloy possessing very low ($\alpha_l < 3 \times 10^{-6} K^{-1}$ up to 250°C) coefficient of thermal expansion together with relatively high Young's modulus of elasticity of approximately 122 GPa.

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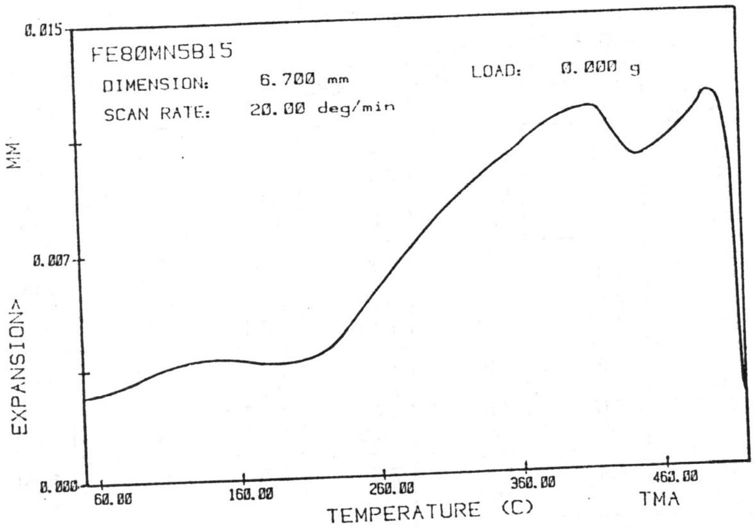

Fig.1. Thermal expansion of $Fe_{80}Mn_5B_{15}$ amorphous alloy.

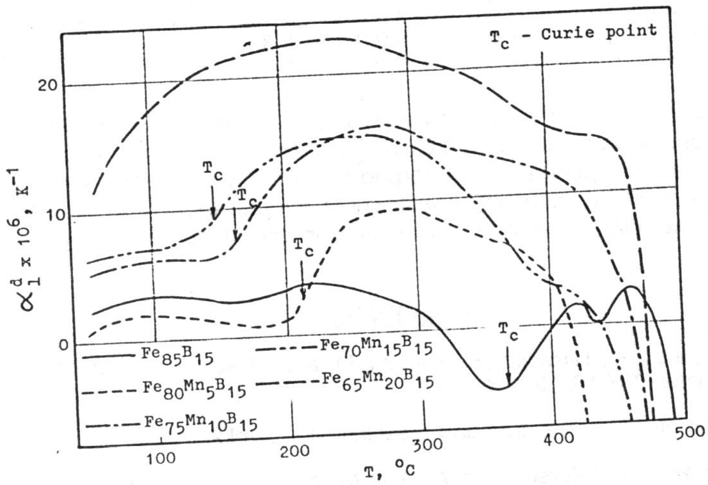

Fig.2. Temperature dependence of α_l^d of $Fe_{85-x}Mn_xB_{15}$ amorphous alloys.