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Surface and bulk properties of thick amorphous iron alloys

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The microstructure and mechanical properties, such as hardness and abrasive resistance, for the amorphous $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ samples in the form of plate and rod have been investigated. We have stated that the samples obtained by a suction-casting method were fully amorphous. Moreover, from Mössbauer spectroscopy studies we have found that the amorphous rod is more homogenous than the plate. It is due to different quenching rates in the layers located near the surface and inside the samples. Hardness on the side surface of the plate or rod are almost the same in different measured points. However, hardness in the cross-section of the rod exhibits the maximum value near its surface. It is worth noticing that hardness of the amorphous samples is about twofold larger than for crystalline ingots. Wear resistance of the outer layer is smaller than for layers located near the centre of the sample.

Keywords: bulk amorphous alloys, hardness, wear resistance, Mössbauer spectroscopy.

1. Introduction

Bulk amorphous alloys are a new group of materials and consist of more than three elements and additionally atomic radii of main components should differ by more than 12% and exhibit the negative heat of mixing [1–3]. Besides good magnetic properties, the bulk amorphous alloys show outstanding mechanical properties such as hardness and strength [4, 5]. It is well known that bulk amorphous materials are prepared at lower quenching rate than the classical alloys [6, 7]. It enables the structure relaxations during the sample preparation. Moreover, it is worth noticing that the quenching rate inside the sample is lower than on the surface. The properties of the bulk amorphous alloys are closely associated with their microstructure [8, 9] and depend on the location of a layer.

In this paper, we present microstructure and mechanical properties studies of the bulk $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ alloys.

2. Experimental procedure

Ingots of the $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ alloy, with mass of 10 g, were obtained by arc melting of high purity components in an argon atmosphere. In order to receive the homogenous alloy, the ingots were remolded four times. The samples in the form of plates of 0.8 mm × 10 mm × 3 mm dimension were prepared by a suction casting method in a protective argon atmosphere [6]. The amorphicity of the samples after solidification were testified at room temperature by Mössbauer spectroscopy and X-ray diffractometry. Additionally, the structure of the samples after etching in 1% aquatic solution of HF was investigated using an optical microscope. A Vickers hardness tester FutureTech 740 working under the load of 300 G was used for measurements of hardness [10]. However, the abrasive wear resistance was studied by kulotester [5]. The mechanical properties were measured in the different parts of the samples.

3. Results and discussion

Figure 1 shows the X-ray diffraction patterns of the bulk $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ amorphous alloy obtained in the forms of the rod and plate.

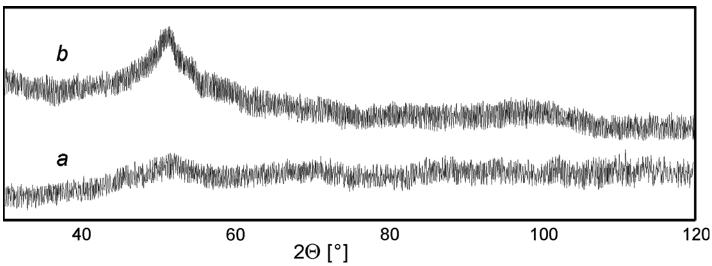

Fig. 1. X-ray diffraction patterns for powdered amorphous $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ alloys in the form of the plate (*a*) and rod (*b*).

The broad haloes in the diffraction patterns are seen for the both powdered rod and plate, which is characteristic of amorphous alloys.

The transmission Mössbauer spectra and corresponding hyperfine magnetic field distributions for the samples of the $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ alloy are presented in Fig. 2.

It is seen that the Mössbauer spectra consist of broad and overlapped lines, which confirms amorphicity of the investigated samples. Moreover, the hyperfine field distribution obtained from the Mössbauer spectrum of the rod is more asymmetric than that for the plate. It seems to be connected with the large difference between quenching rates on the surface and inside the rod. It is known that the amorphous state

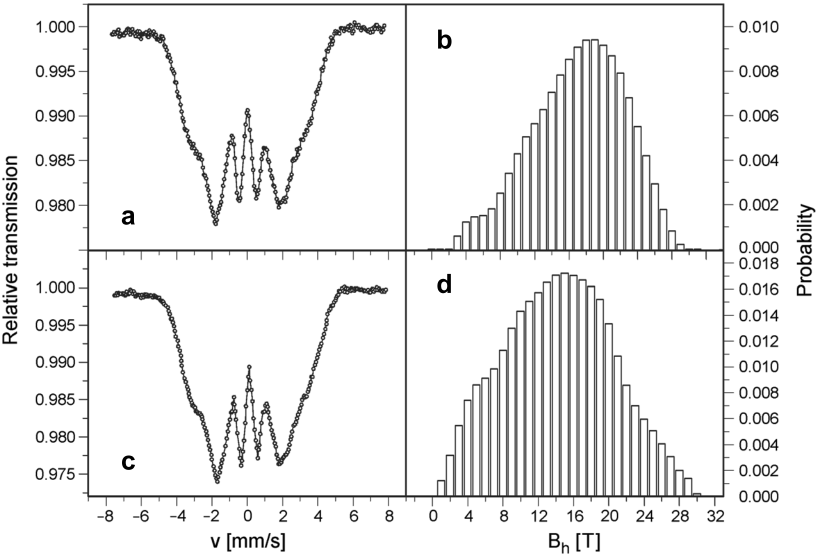

Fig. 2. Mössbauer spectra (**a**, **c**) and corresponding hyperfine field distributions (**b**, **d**) of the powdered $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ alloy: rod (**a**, **b**), plate (**c**, **d**)

is metastable and the lower quenching rate inside the rod enables the structure relaxations which may involve the decomposition of the amorphous sample.

The structure of the samples influences their mechanical properties. In Figure 3 the optical micrograph of the plate surface and the rod cross-section with Vickers indents are presented.

The data of Vickers hardness measured at the surface of the plate and rod, and in the cross-section of the rod along the line marked in Fig. 3 are collected in Tab. 1.

It is seen that Vickers hardness measured on the side surface of the plate or rod is practically the same and does not change from point to point, which confirms the homogeneity of the alloy. However, the hardness in the cross-section is higher near the surface than in the centre of the rod. This behavior is connected with

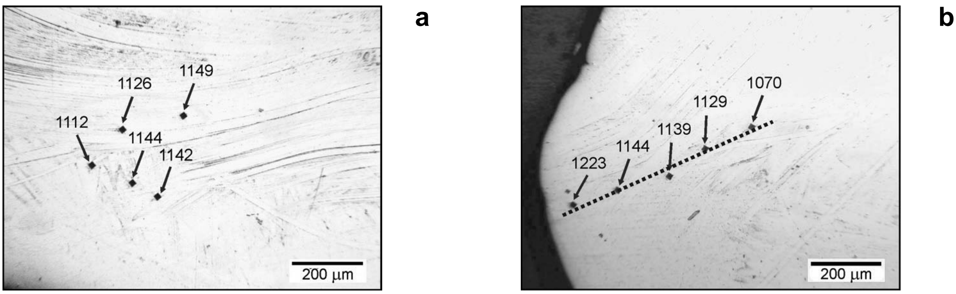

Fig. 3. Optical micrograph of the plate surface (**a**), and rod cross-section (**b**) for the $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ alloy. The Vickers indents for the rod were made starting from the sample surface to its centre.

T a b l e 1. Vickers hardness data for the $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ alloy in the form of 0.8 thick plate, rod 2 mm in diameter as well as for crystalline ingots.

State	Amorphous			Crystalline
Part of the sample	Surface		Cross-section	Cross-section
Shape sample	Rod	Plate	Rod	Ingot
	1154	1122	1223	553
	1160	1126	1144	546
$HV_{0.2}$	1138	1144	1139	551
	1144	1149	1129	560
	1139	1142	1070	558

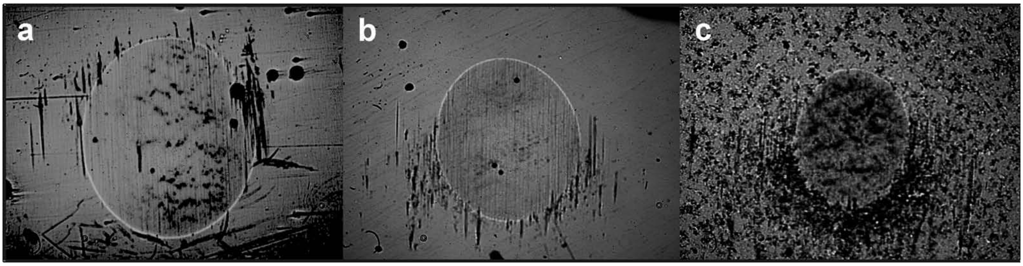

Fig. 4. Optical micrographs of the side surface of the $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ plate after wear resistance test for 1 h; after removing of 10 μm thick layer (**a**) and then 15 μm (**b**) by mechanical and chemical polishing, and for the ingot (**c**).

different quenching rate of layers during solidification which was confirmed by Mössbauer spectroscopy (Fig. 2**b**). For comparison, the hardness values for ingots of the investigated alloy measured at different points are also shown.

It is worth noticing that hardness obtained for the crystalline ingot is about twofold lower than that for the amorphous samples.

In Figure 4 the optical micrographs of the $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ plate surface subjected to the wear resistance test are shown.

We can see that wear resistance is bigger in the centre of the plate than on its surface. The values of the wear resistance are presented in Tab. 2.

Taking into account the results presented in Tabs. 1 and 2, we may conclude that the mechanical properties are highly influenced by the structure of the alloy which changes from layer to layer.

T a b l e 2. Values of wear resistance on the side surface of the amorphous $Fe_{60}Co_5Zr_8Mo_5W_2B_{20}$ plate 0.8 mm thick and for the ingot.

	Amorphous plate		Crystalline ingots
Thickness of the removing layer [μm]	10	15	10
Wiped area [μm^2]	342495	256238	107310

4. Conclusions

Based on the results presented we can formulate the followng conclusions:

1. The different quenching rate on the surface and inside the sample leads to inhomogeneity of the alloy.
2. Microhardness measured on the surface of the sample is higher than in the centre.
3. The layers inside the samples are more wear resistant than those at the surface.

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