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Research Article

THE SURFACE STRUCTURAL AND MECHANICAL PROPERTIES OF THE AMORPHOUS $CO_{22}Y_{54}AL_{24}$ RIBBON

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ABSTRACT
The aim of this study was to manufacture amorphous $Co_{22}Y_{54}Al_{24}$ alloy in a form of thin ribbons and to investigate their properties. The investigated ribbons were prepared by rapid solidification of molten metal on a rotating copper cylinder (melt-spinning). In order to obtain the material with amorphous structure, the cooling rate of the liquid alloy should vary in a range from 10^4 to 10^6 K/s. The microstructure studies were performed using X-ray diffractometery. The mechanical properties were investigated by metallographic studies, micro-hardness and tribological resistance tests moreover the surface roughness profile were analyzed. All studies were performed for two sides of tapes, since the differences in ribbons surface, related with manufacturing process, are clearly visible. The surface from the bottom (drum side) was glossy and from the top side it was shiny.

Keywords: amorphous alloy, melt-spinning, ribbons.

INTRODUCTION

The amorphous alloys manifest significantly better properties then their crystalline counterparts i.e. higher yield strength and plasticity, hardness and corrosion resistance. It is obvious that the manufacturing method and the chemical composition decide on the microstructure, which is shaping the parameters describing this kind of alloys [1, 2].

The most well-known method for producing amorphous alloys is unidirectional rapid cooling of liquid alloy on-to a rotating copper wheel [3, 4]. Applications of this method allow to obtain the materials in a form of ribbons of a few tens of millimetres. These alloys are produced at high cooling speeds in the range from 10^4 to 10^6 K/s [5].

MATERIALS AND METHODS

For measurements amorphous ribbons were used, obtained by continuous casting of liquid alloy on to the rotating copper wheel. The obtained ribbons are shown in Figure 1.

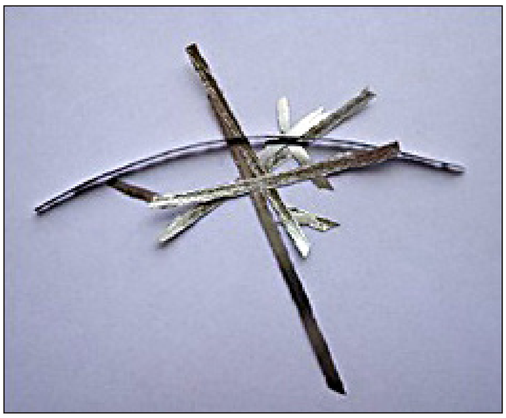

Fig. 1. The amorphous $Co_{22}Y_{54}Al_{24}$ alloy in the form of ribbons

The ingots of pre-alloy were prepared using electric arc and were several time remelted in order to obtain homogenous distribution of alloying elements. $Co_{22}Y_{54}Al_{24}$ alloy was prepared from high purity elements. Both ingots and ribbons were prepared in protective argon atmosphere.

X-ray diffraction patterns were measured using the Bruker X-ray diffractometer with CoK_{α} (λ = 0.17889 nm) radiation source, 3 s time and 0.02° angle step.

In next step, $Co_{22}Y_{54}Al_{24}$ amorphous ribbons were subjected to series of mechanical measurements i.e.: microharness, wear resistance, metallographic observations, surface roughness measurements.

The microharness studies were performed using Knoop method for HK 0.0025 impression load (245.2 mN) and 6 s time period (five stamps for each side of the ribbon).

The abrasion was determined on the basis of measurements of surface wear areas created after 1 and 2 hours of friction between zirconium ball and both surfaces of the sample. These measurements were performed on „KULOTESTER" fully automated set up.

Surface roughness was investigated on the basis of measurements performed on Hommel T1000 profilometer on 4.80 mm length of tape.

RESULTS AND DISCUSSION

The X-ray diffraction pattern for the investigated ribbon is presented in Figure 2.

Observed diffraction pattern have a typical shape as for the material in which Bragg conditions are not met, i.e. exhibit lack of periodicity in the arrangement of atoms and angular correlations between them [2, 6]. In case of the presence of short range interactions between atoms (characteristic for the amorphous state), there is no possibility that the X-ray beam will interfere with other beams reflected from planes that form the structure in the crystalline material [6]. Therefore, the images consist only of a broad diffraction peak.

The application possibilities of this type of metallic materials is determined mainly by good mechanical properties i.e. micro-hardness and wear resistance. The results of microhardness measurement are summarized in Table 1.

Table 1. Knoop micro-hardness measurement by load 245.2 mN for $Co_{22}Y_{54}Al_{24}$

No.	Microhardness HK0,0025	
	matt side	shinny side
1	376.2	325.3
2	384.2	327.2
3	387.2	335.3
4	426.2	343.3
5	432.0	347.2
mean	401.16	335.66

Basing on the data collected in Table I it can be concluded that the mat side of ribbon was characterised by higher average value of microhardness of more than 60 HK. This difference in microhardness for top and bottom side can be related with differences in cooling speed of liquid metal in contact with copper drum and protective gas. This, in turn, results in different atoms' concentrations and lesser stress for side cooled with slower cooling speed (matt side).

The results of abrasion resistance, namely, wear areas resulting from the rotation of the zirconium ball on the strip surface in the assumed time are shown in Figure 3.

Wear areas of the matt (top) side of sample are slightly smaller then, these obtained for shiny side (bottom). This means that the surface characterized by higher microhardness has reduced abrasion resistance. The data calculated on the basis of the wear area measurements are collected in Table 2.

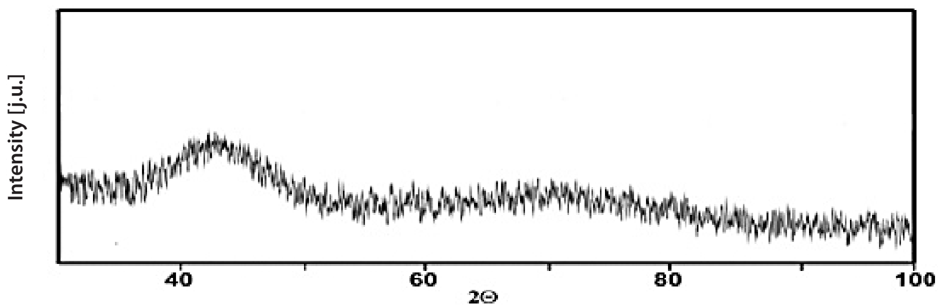

Fig. 2. The X-ray diffraction patterns obtained for amorphous alloy strip $Co_{22}Y_{54}Al_{24}$

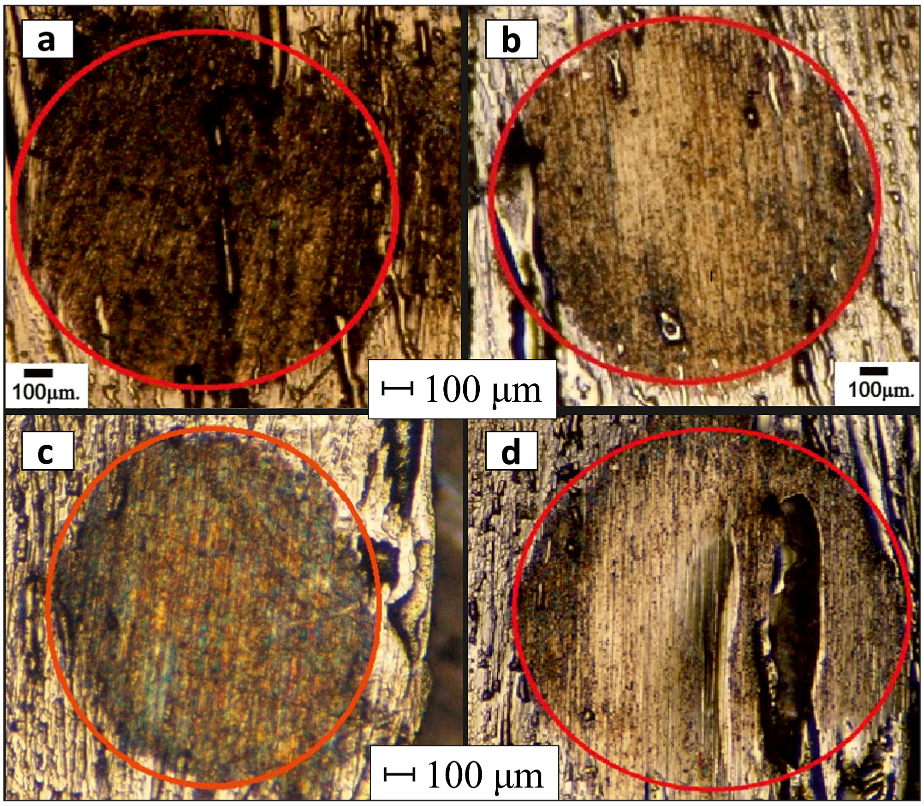

Fig. 3. Wipe the shiny surface of the tape after 1h (a), after 2h (b) and the matte side after 1h (c), after 2h (d)

Table 2. Results of the abrasion resistance of samples taken $Co_{22}Y_{54}Al_{24}$ alloy strip from the matte and glossy

Material	Time / Wear area [mm²]	
	1 h	2 h
Matt side	14417.33	14677.34
Glossy side	12523.80	15134.24

Table 3. Roughness measurement for $Co_{22}Y_{54}Al_{24}$

Parameter	Roughness [µm]	
	matt side	glossy side
Rt	3.44	14.60
Ra	2.894	1.128

Samples in a form of $Co_{22}Y_{54}Al_{24}$ ribbons were also studied in terms of profile roughness analysis (both side of the tape). The results of *Ra* (arithmetic mean deviation of the roughness profile) and *Rt* (maximum elevation-hollow) parameters are given in Table 3.

Analyzing the results obtained from the surface roughness measurement can be concluded that much higher values of *Rt* and *Ra* was found in top side of the sample. Taking into account that the matte side is formed from the copper wheel side during the manufacturing process, when the molten alloy is taken from the so called lake (located in the gas cushion), there comes to retracting only small volumes of gas under the surface of the chilled ribbon. The arithmetic mean of the absolute value of all profile deviations from the mean (parameter *Ra*) is more than two times greater for mat side. A similar relationship was found for the second parameter *Rt*.

CONCLUSION

The melt-spinning method allow to obtain alloy in a form of amorphous ribbons. Basing on the X-ray diffraction results it was found, that the structure of the investigated ribbons is amorphous. The properties determining the functional parameters were different depending on the sides of the ribbon. The matt side of the ribbon was characterized by higher (> 15%) the average microhardness than the glossy side. From the wear resistance studies can be concluded that the higher cooling rate during the preparation of the samples affects the deterioration wear resistance. The matte side of the sample have higher roughness than the glossy side.

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