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STUDY OF SUPERPLASTIC PHENOMENON IN Fe_3Al INTERMETALLIC ALLOY

MOŻLIWOŚCI NADPLASTYCZNEGO ODKSZTAŁCANIA STOPÓW NA OSNOWIE FAZY MIĘDZYMETALICZNEJ Fe_3Al

This paper deals with a study of superplastic phenomenon in Fe_3Al intermetallic alloy. The investigated alloy was prepared by melting and casting in an induction furnace in argon atmosphere. The ingots were hammered at 1100°C and warm rolled at the temperature ranging from 650 to 750°C. The hot and warm deformed rods were then recrystallized at the temperature ranging from 600 to 900°C. As a result of this treatment, fine- or coarse-grained microstructure was obtained. Elevated temperature tensile tests were conducted in the air at 850, 900 and 1000°C. The testing was accomplished at constant velocities ranging from 1.67×10^{-4} to 1.67×10^{-2} s^{-1} in a universal testing machine. The superplastic deformation was observed in both fine- and coarse-grained specimens.
Keywords: intermetallic phases, superplasticity

W pracy przedstawiono wyniki badań zjawiska nadplastyczności w stopie na osnowie fazy międzymetalicznej Fe_3Al. Badany stop otrzymano na drodze topienia i odlewania w piecu indukcyjnym w atmosferze argonu. Otrzymane wlewki poddano procesowi młotkowania w temperaturze 1100°C i walcowania na ciepło w zakresie temperatury od 650 do 750°C. Odkształcone na gorąco i ciepło pręty poddano następnie procesowi rekrystalizacji w zakresie temperatury od 600 do 900°C. W wyniku przeprowadzonej obróbki uzyskano drobnoziarnistą lub grubokrystaliczną mikrostrukturę. Próby rozciągania w podwyższonej temperaturze przeprowadzono w powietrzu w temperaturze 850, 900 i 1000°C. Badania realizowano przy stałej prędkości odkształcenia w zakresie od 1.67×10^{-4} to 1.67×10^{-2} s^{-1} przy użyciu uniwersalnej maszyny wytrzymałościowej. W próbkach o mikrostrukturze drobnoziarnistej i grubokrystalicznej obserwowano zjawisko płynięcia nadplastycznego.

1. Introduction

Most metals and alloys undergo different technological processes-plastic working and machining. The processes are usually labour, energy and material-consuming and,

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as a result, expensive. In some cases, it is possible to reduce the production costs of machine elements and subassemblies and devices by the use of superplastic phenomenon.

Fe_3Al intermetallic alloys are characterized by low density, high corrosion resistance in oxidation medium, excellent sulphur resistance and good abrasive wear. Lately, Fe_3Al intermetallic alloys have become very important as construction materials in the energy and chemical industries. However, lack of plasticity at room temperature makes them impossible to be used as of full value construction material. A number of research is being done to improve plasticity of Fe_3Al intermetallic alloys at room temperature. However, despite applying numerous methods of production and heat and plastic treatment, the maximum fullering does not exceed 11% [1-3]. Therefore, the possibility of plastic forming of Fe_3Al intermetallic alloys seems to quite interesting.

Superplasticity is metal and alloys formability, usually at the temperature not exceeding 0,4 T_t, as a result of small stresses depending, to a great extent, on the speed of plasticity [4]. There are two kind of plasticity in Fe_3Al intermetallic alloy:
a) fine-grained- in alloys with the grain size below 10 μm (Ni_3Al, Ni_3Si, TiAl) [5];
b) coarse-grained in alloys with the grain size above 100-600 μm (FeAl, Fe_3Al) [6-11].

2. Materials and methodology of the study

The study of superplastic phenomenon was carried out in an alloy with the following chemical constitution: Fe-28Al-5Cr-0.08Zr-0.04B (% at.). The alloy was obtained by melting and steel mould casting in an induction vacuum furnace. As a result, ingots of 25 mm diameter and 1500 mm long were obtained. The ingots were homogenized for 5 hours at 1100°C and then hot hammered at 1100°C till the diameter of ∅ 7,8 mm (reduction approx. 70%) of the rods was reached. The rods were used to prepare two groups of specimens. First, the rods were warm rolled at 650-700°C and 1 mm thick tapes/strips were obtained (reduction about 90%). Next, the material was used to prepare flat strength specimens with the dimensions of 25×12×1 mm. The specimens were cut out from the tape/strip with a diamond saw and then mechanically ground and polished. The second group of specimens was made by hot hammering of the rods at 1100°C and holding at the temperature of 1100°C for 15 min. The rods of 7.8 mm diameter were obtained. Then, fivefold cylindrical specimens with 3.5 mm diameter and measuring length of 17.5 mm were made. Next, the rods were held at the temperature ranging from 650 to 900°C for 30 min. and five hours.

Microsections for metallographic studies were prepared by mechanical grinding and polishing in diamond suspension. The specimens were etched in $50CH_3COOH + 33HNO_3 + 17\ HCL$.

The study of microstructure, fracture and misorientation of grain boundaries were carried out using scanning microscope PHILIPS XL 30 (LaB_6) equipped with detectors SE, BSE, EDAX, EBSP and automatic image analyser. Optic microscopy was conducted with a matallographic microscope Neophot II.

The study of superplastic phenomenon in a tensile test was carried out in a testing machine Instron 8802 equipped with a high temperature furnace Instron SF 868 E. As a result, the tests were carried out at the temperature of 1000°C with 1°C accuracy. The deformation temperature was controlled by Ni-CrNi thermocouple being in three spheres of the furnace and by control system CU 868 E. Temperature difference in the furnace during the tensile test didn't exceed 1°C. The specimens were placed in the furnace, then brought up to the desired temperature and held at it for 20 min. Deformation was carried out without protective atmosphere at the temperature ranging from 850°C to 1000°C, and the deformation speed ranging from $1{,}67 \times 10^{-4}$ to $1{,}67 \times 10^{-2} s^{-1}$. Coefficient m calculations, defining the sensitivity of flow stress vs the speed of deformation, were made using Backofen method.

3. Results

As a result of the applied technologies of heat and plastic treatment, fine-grained and coarse- grained alloys were obtained. Illustration 1 shows examples of microstructure of Fe_3Al alloy after heat and plastic treatment:

a) fine-grained — grain diameter about 50 µm with some not recrystalised areas, after hammering at 1100°C, then warm rolling at 650-700°C and holding at the recrystalisation temperature of 750°C for 30 min.
b) coarse-grained — grain diameter about 200-250 µm with, after hot hammering of rods with diameter up to 7.8 mm at 1100°C, and holding at the temperature of 1100°C for 15 min.

Figure 2 shows examples of tensile curves of Fe_3Al alloy with fine- and coarse-grained structure. It has been stated that the highest unit elongation (163%) for fine-grained alloys was obtained at the deformation speed of $1{,}67 \times 10^{-4} s^{-1}$ at 950°C (fig. 2). It is

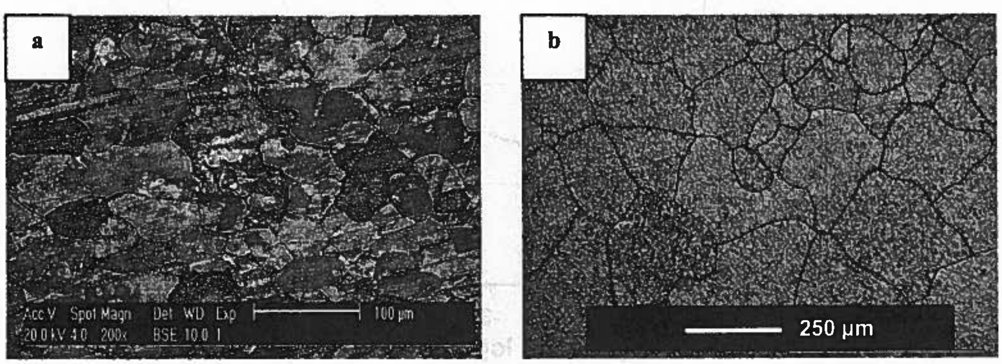

Fig. 1. Alloy microstructure in Fe_3Al after different heat and palstic treatment
a) Hot hammering at 1100°C and warm rolling at 650- 700°C and additionally holding at the temperature of 750°C for 30 min. b) hot hammering at 1100°C and holding at the temperature of 1100°C for 15 min.

worth mentioning that unit elongation for analogical specimens at room temperature didn't exceed (11%).. The study of superplastic phenomenon for a coarse-grained alloy has shown that the highest unit elongation (153%) was obtained at the deformation speed of $3,5 \times 10^{-4} s^{-1}$ at 950°C (fig. 2)

The results of coefficient m calculations, defining the sensitivity of flow stress vs the speed of deformation, has confirmed the presence of the superplastic phenomenon in Fe_3Al alloy. The coefficient m for fine-grained specimens at 950°C is m=0.356 (fig. 3). The value of the coefficient m is similar to the values obtained for Fe_3Al alloy, FeAl where coarse-grained superplasticity was observed [6-11].

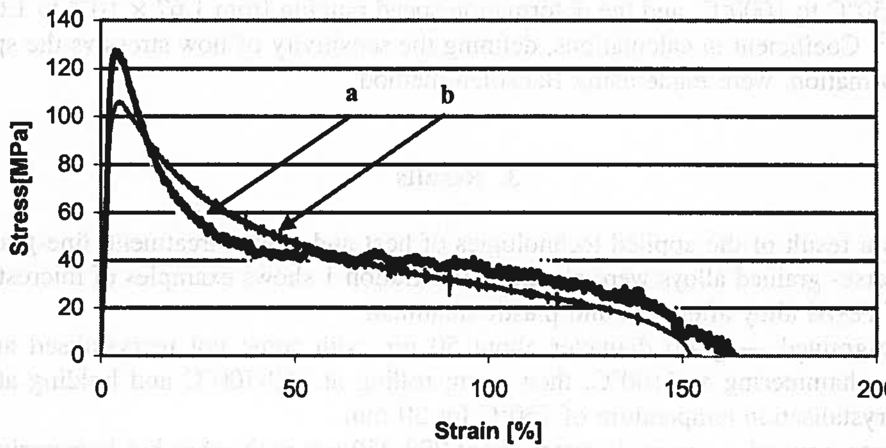

Fig. 2. Tensile curves of Fe_3Al alloy at 950°C in the air atmosphere.: (a) fine-grained alloy stretched at $1.67 \times 10^{-4} s^{-1}$, (b) coarse-grained alloy stretched at $3.5 \times 10^{-4} s^{-1}$

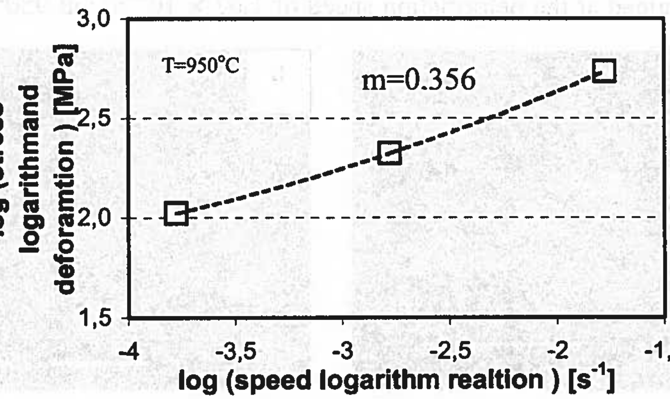

Fig. 3. Flow stress logarithmand deformation speed logarithm realtion for a specimen deformed at 950°C 1.67×10^{-4} to $1.67 \times 10^{-2} s^{-1}$ with deformation speeds

Fig. 4 shows examples of specimens for studying superplastic phenomenon before and after deformation together with the obtained deformations.

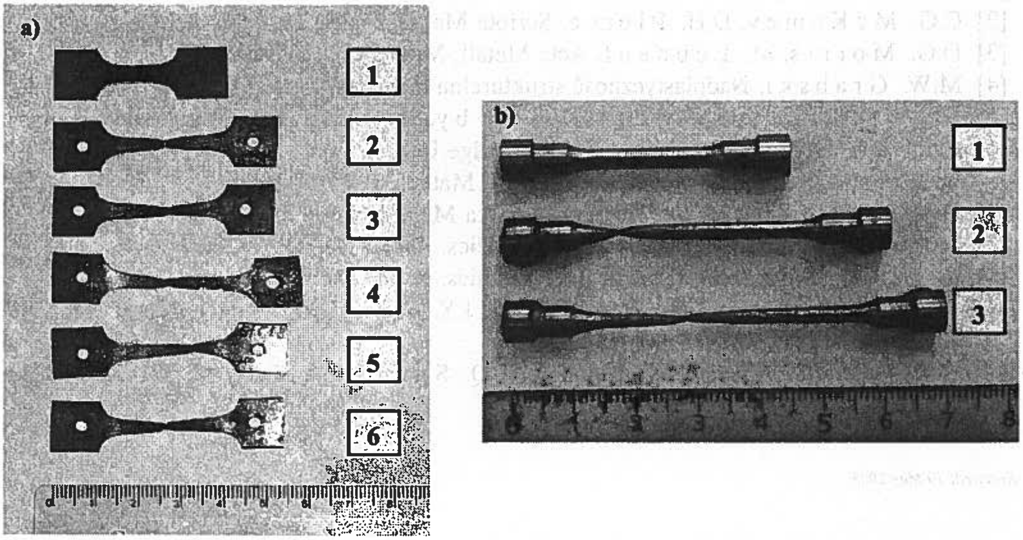

Fig. 4. a) Specimens for studying superplastic phenomenon before and after deformation at 950°C and 1000°C:

1) exit condition,
2) $\dot{\varepsilon} = 5.6 \times 10^{-4} s^{-1} T = 950°C$ A = 122%,
3) $\dot{\varepsilon} = 8.3 \times 10^{-4} s^{-1} T = 950°C$ A = 110%,
4) $\dot{\varepsilon} = 1.67 \times 10^{-4} s^{-1} T = 950°C$ A = 163%,
5) $\dot{\varepsilon} = 1.67 \times 10^{-4} s^{-1} T = 950°C$ A = 135%,
6) $\dot{\varepsilon} = 1.67 \times 10^{-4} s^{-1} T = 1000°C$ A = 128%

b) Specimens for studying superplastic phenomenon before and after deformation at 950°C: 1.67×10^{-4} s^{-1} and 3.5×10^{-4} s^{-1}:

1) exit condition,
2) T = 950°*C* *A* = 116%,
3) T = 1000°*C* *A* = 140%

4. Conclusions

Fe_3Al fine-and coarse-grained alloy after heat and plastic treatment shows superplastic flow tendency. All the specimens tended to form a neck.

The highest values of elongation in a tensile testing were obatined for fine-grained alloy (163%) and for coarse –grained alloy (153%). The fine-grained specimens were deformed at $1{,}67 \times 10^{-4} s^{-1}$ and coarse-grained specimens at $3{,}5 \times 10^{-4} s^{-1}$ at 950°C.

The value of m parametr for fine-grained alloy is 0,356 and 0,338 for coarse-grained alloy.

The results imply that further dealing with superpalstic phenomenon in Fe_3Al alloy with other parameters can enhance the effectiveness of superplastic flow process.

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