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Tomasz Śleboda*

THE INFLUENCE OF STRAIN RATE ON MICROSTRUCTURE AND MECHANICAL BEHAVIOR OF P/M FEAL

1. INTRODUCTION

Iron aluminides are widely investigated for potential structural and non-structural applications [1, 2] because of their low density and good oxidation and corrosion resistance [3–6]. Moreover, FeAl alloys are nonmagnetic, and possess a relatively high electrical resistivity making them potentially attractive for heating element applications. Various powder metallurgy (P/M) methods can be used to produce these materials, with advantages over casting techniques. Fully dense FeAl products have already been successfully fabricated by both extrusion [7–12] and cold rolling [13, 14] of alloy powders. The room temperature mechanical properties of these alloys, particularly the combination of ductility and strength, are known to be sensitive to the processing-induced microstructure [15]. In this respect, powder metallurgy methods are very promising, since much finer microstructures can be produced.

This research is primarily focused on evaluating the influence of thermomechanical processing parameters on the microstructural evolution and mechanical behavior of these materials with special emphasis on processing strain rate.

2. EXPERIMENTAL PROCEDURE

In this research –325 mesh water atomized FeAl alloy powder was used. The powder was examined under a JEOL Scanning Electron Microscope (Fig. 1).

The powder was consolidated to full density by hot pressing under an argon atmosphere at the temperature of 1100^{o}C. The density of the compacts was determined according to Archimedes method. The chemical composition of the FeAl powder is shown in Table 1.

* Ph.D.: Faculty of Metals Engineering and Industrial Computer Sciences, AGH University of Science and Technology, Kraków, Poland; sleboda@agh.edu.pl, tsleboda@metal.agh.edu.pl

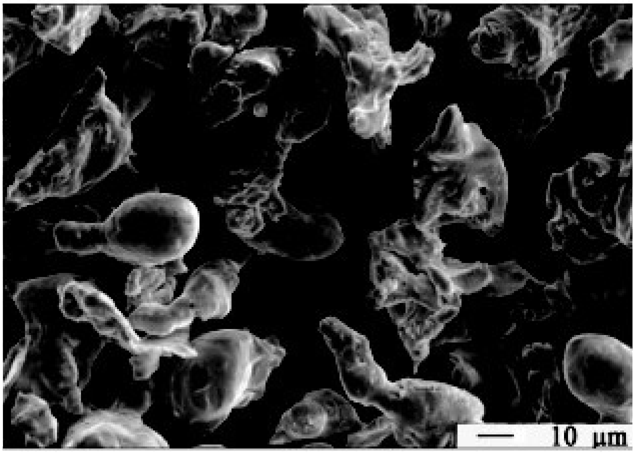

Fig. 1. *FeAl alloy powder used in this research*

Table 1. Chemical composition (wt. %) of the iron aluminide alloy powder used in the investigation

Powder	Fe	Al	Zr	Mo	Si	B	C	O
FeAl alloy	Bal.	24.77	0.1	0.40	0.04	0.005	0.016	0.283

Cylindrical specimens with an approximate height of 12 mm and a diameter of 8 mm were machined from the compacts and used for compression tests at 800°C and 900°C, at strain rates of 0.1 s^{-1} and 10 s^{-1}. A servo-hydraulic Gleeble testing machine was used for thermomechanical processing. The load vs. stroke data obtained from the experiments were converted into true stress – true strain curves. After processing, the microstructure of each deformed specimen was examined using optical microscopy. Average grain sizes of all samples were calculated using the linear intercept method according to PN-84/H-04507.01 standard. The mean intercept length was considered as an average grain size.

3. DISCUSSION

The microstructure of FeAl powder compacts, used as a starting materials for thermomechanical processing, is shown on Figure 2.

The microstructure of the water atomized (Fig. 2) powder compacts consists of polyhedral shaped grains with an average size of 8 µm. The nature of this microstructure, reflecting only the powder particle shape and size distributions, shows that hot compacting in this case resulted solely in densification without any further microstructural evolution.

Microstructures of the hot processed samples were observed at the center of longitudinally sectioned specimens (perpendicular to the axis of compression). Figures 3 and 4 below show respectively the microstructures of fully dense water atomized powder materials, deformed to a total true strain of 1 at 800°C and at 900°C, at a strain rate of 0.1 s^{-1} (a) and 10 s^{-1} (b).

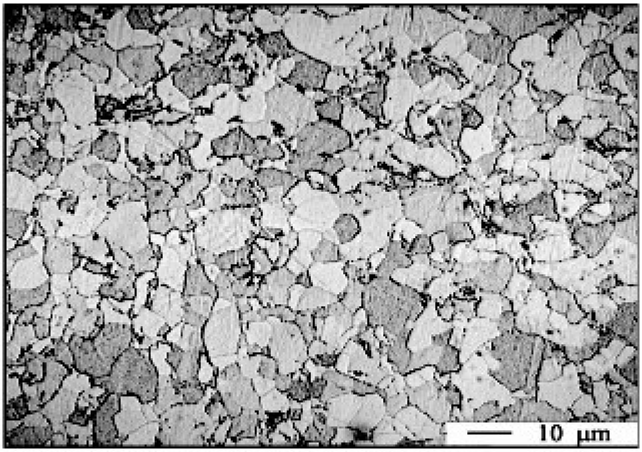

Fig. 2. *The microstructure of hot pressed water atomized FeAl alloy powder. Etched with Keller's solution*

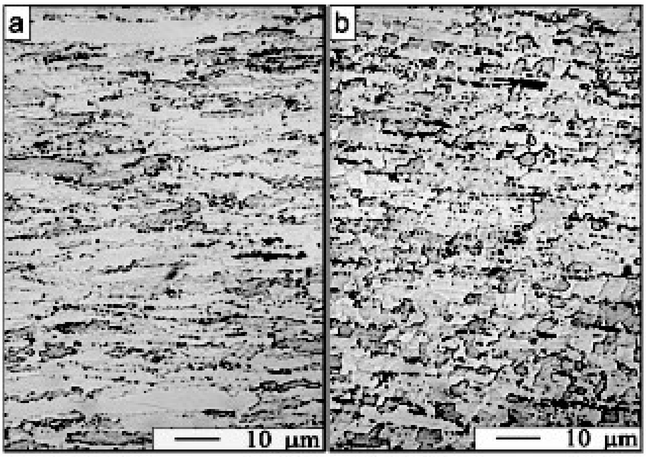

Fig. 3. *Microstructures of water atomized powder sample deformed in compression at 800^{o}C to a true strain of 1 at a strain rate of: 0.1 s^{-1} (a) and 10 s^{-1} (b). Etched with Keller's solution*

As can be seen in Figure 3a above, the microstructure of water atomized powder material sample, deformed at the temperature of 800^{o}C at lower strain rate (0.1 s^{-1}), consists of elongated grains, characteristic of highly deformed and unrecrystallized material. Hot compression at a strain rate of 10 s^{-1} caused refinement of the structure at a deformation temperature of 800^{o}C (Fig. 3b). The resultant average grain size in the sample deformed at 800^{o}C and at a strain rate of 10 s^{-1} was of 5 μm. Also, highly irregular nature of the water atomized particle shapes results in considerable amount of oxides existing in the structure of the processed material. These oxides restrict grain growth in this material at elevated and high temperatures what increases the stability of its structure, what was shown elsewhere [15].

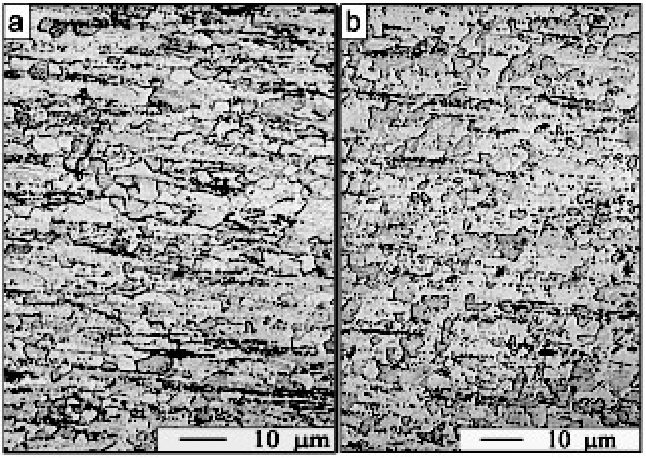

Fig. 4. *Microstructures of water atomized powder sample deformed in compression at 900°C to a true strain of 1 at a strain rate of: 0.1 s^{-1} (a) and 10 s^{-1} (b). Etched with Keller's solution*

From Figure 4 above one can see that compression at 900°C results in dynamic recrystallization of the material deformed at both strain rates. Moreover, hot compression at the temperature of 900°C caused comparable level of the grain refinement (an average grain size of 4 μm) in the materials deformed at both 0.1 s^{-1} and 10 s^{-1} (Fig. 4).

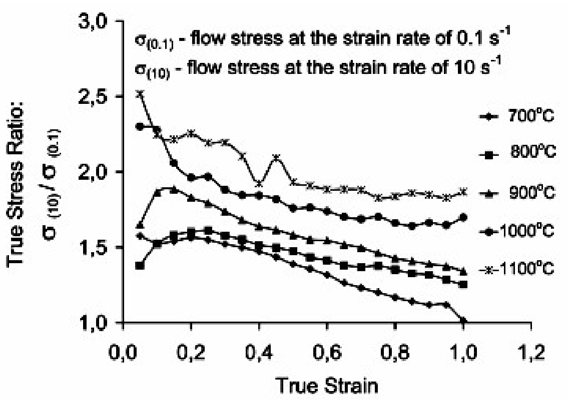

Fig. 5. *True stress at 10 s^{-1} strain rate – true stress at 0.1 s^{-1} strain rate ratio at given processing temperature*

Figure 5 presents an example of the influence of the processing strain rate on the flow stress at a given deformation temperature. Here the comparison of the flow stress–strain curves for two strain rates i.e. 0.1s^{-1} and 10 s^{-1} is shown.

A decrease of the strain rate sensitivity of the material with an increase of the strain at most of the processing temperatures can be noticed. In the case of deformation at lower strains (< 0.5 true strain), an influence of the strain rate on the flow stress is comparable.

Moreover, for deformation at higher strains (> 0.5 true strain), the research showed a stable strain rate sensitivity for the materials processed at the temperatures higher than 900°C. These observations could be directly employed in the design of deformation schedules for the industrial processing of FeAl alloys.

4. CONCLUSIONS

The following conclusions can be derived from the present research:

1. P/M samples deformed at the strain rate of 0.1 s^{-1} did not recrystallize at 800°C. Compression at a strain rate of 10 s^{-1} caused refinement of the structure at both 800°C and 900°C.
2. The sample deformed at 800°C, with a strain rate of 0.1s^{-1}, consists of elongated grains, characteristic of highly deformed and unrecrystallized material. Hot compression at a strain rate of 10 s^{-1} caused refinement of the structure at a deformation temperature of 800°C. Dynamic recrystallization at both strain rates is observed for deformation at 900°C.
3. Strain rate sensitivity of investigated material, considered here by means of an influence of the processing strain rate on the flow stress at a given deformation temperature, decreased with an increase of the strain at most of the processing temperatures can be noticed.
4. Processing at higher strains (> 0.5 true strain) showed a stable strain rate sensitivity for the materials deformed at the temperatures higher than 900°C, what can directly be employed in the design of deformation schedules for the industrial processing of P/M FeAl alloys.

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