HARDENING OF RAPID SOLIDIFICATION Al-Fe-V-Si ALLOY EXPOSED AT ELEVATED TEMPERATURE①

Xu Yiheng, Long Chunguang, Li Songrui, Li Wenxian, Yang Shibao
Department of Materials Science and Engineering,
Central South University of Technology, Changsha 410083

ABSTRACT Rapidly solidified(RS) FVS0812 alloy powder was obtained by means of multi-stage RS powder-making device. The effect of elevated temperature (200~ 500 ℃) on the mechanical properties of the cold deformed specimens was investigated. The results showed that the strength increases significantly after being exposed at 200~ 500 ℃. This abnormal behaviour can be attributed to the clusters of the transition metal solute—iron in aluminum matrix, forming during the hot deformation or heat treatment.

Key words rapid solidification cluster Al alloy for elevated temperature applications

1 INTRODUCTION

The previous research work showed that RS Al-Fe-V-Si alloy is hopeful to replace Ti alloy for aerospace use[1]. Furthermore, contrary to expectation, the strength of the alloy increases significantly after an exposure at 200~ 500 ℃[2]. This study is undertaken to investigate the abnormal behaviour mentioned above and offer a reasonable explaination.

2 EXPERIMENTAL

Multi-stage rapid solidification powder-making device was applied to produce RS FVS0812 alloy powder. The powder of interest size was consolidated by means of CIP and then extruded at about 520 ℃. After that, the obtained plates were rolled to different sizes. The processing route is shown in Fig. 1. The number outside the block is the specimen number from $1^{\#}$ to $8^{\#}$.

Tensile testing was carried out on WD-10A materials testing machine at a strain rate of 2 mm/min. Hardness of the materials after heat treatment was measured by a microhardness meter using a 3 kg load.

Neophot 21 optical microscope and H-800 TEM were applied to observe the microstructure of the specimens. Specimens for TEM were electropolished at 12 V (dc) using a 2 to 1 methanol: nitric acid electrolyte.

3 RESULTS AND DISCUSSION

Table 1 contains the results of room temperature tensile tests on rolled FVS0812 plates. It shows clearly that even though dynamic recovery may occur in the $2^{\#}$ and $3^{\#}$ specimens during the hot deformation, their strength is higher than that of the cold rolled plates ($4^{\#}$, $8^{\#}$). Furthermore, RS FVS0812 alloy exhibits low work hardening, which is due to its fine grains[3] (about 150nm in diameter as shown in the Fig. 2).

Table 1 Tensile strength of rolled RS FVS0812 plates

No	$2^{\#}$	$3^{\#}$	$4^{\#}$	$8^{\#}$
σ_b/MPa	410	430	403	411

The micrograph of $3^{\#}$ and $8^{\#}$ specimens is shown in Fig. 2 and Fig. 3. No obvious difference is observed. In order to find out the reason for the difference in tensile strength, further ex-

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periments were carried out.

The change in hardness versus the exposure temperature for 1 h is illustrated in Fig. 4. The hardness of 1#, 2# and 3# specimens remains almost constant after being exposed at 200~ 500 ℃ for 1 h. However the hardness of the cold rolled specimens (4#, 8#) increases considerably from about 108 ℃ to 120 ℃ or so. Fig. 5 shows the change in the tensile strength of 1# and 8# specimens after holding at 300 ℃ for 20 or 60 min, where the trend of tensile strength being increased considerably by elevated temperature exposure is also observed. This indicates that an exposure at elevated temperature (during processing or heat treatment) leads to the increase in both hardness and strength. Therefore, the strength of the hot rolled specimens is much higher than that of the cold rolled specimens and the hardness of the cold rolled specimens (4#, 8#) increases after being exposed at elevated temperature. The reason for no appreciable change in the hardness and tensile strength of 1#, 2# and 3# is that they had already been

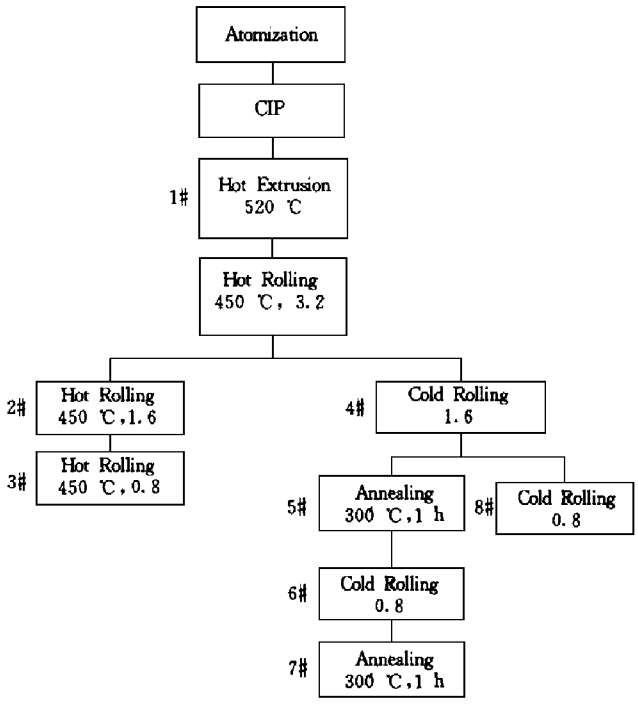

Fig. 1 Processing of RS FVS0812 alloy

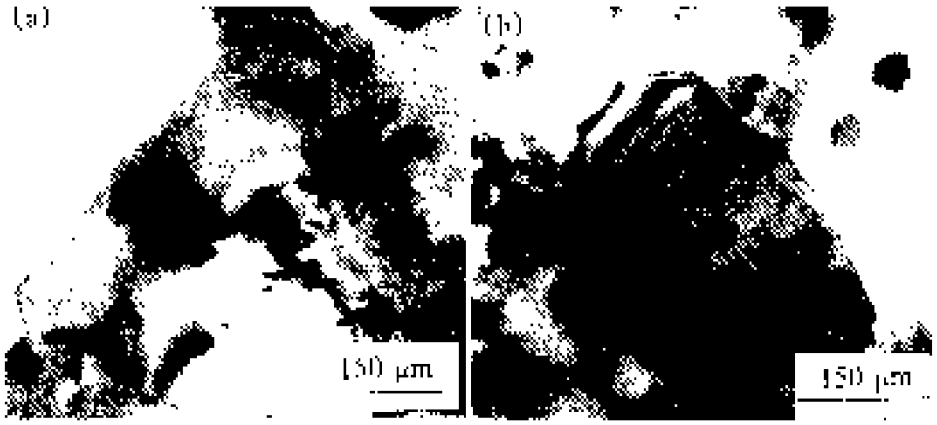

Fig. 2 TEM micrograph of the rolled FVS0812 plates
(a) —hot rolling, 3#; (b) —cold rolling, 8#

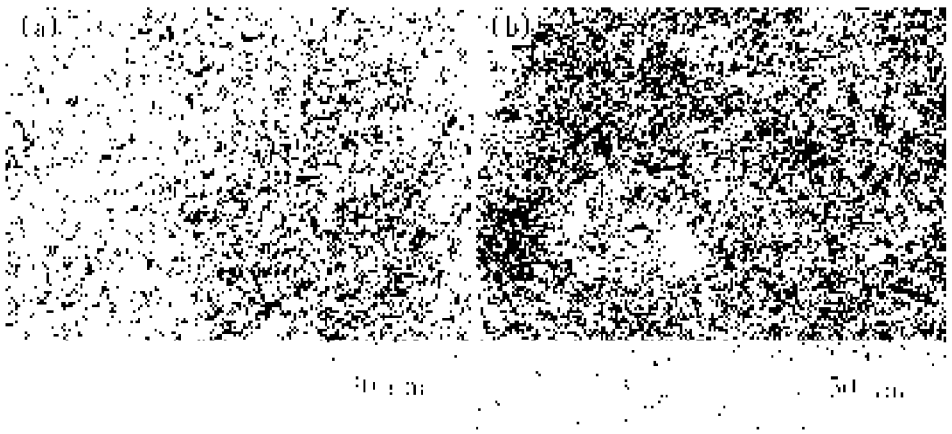

Fig. 3 Optical micrograph of the rolled FVS0812 plates
(a) —hot rolling, 3#; (b) —cold rolling, 8#

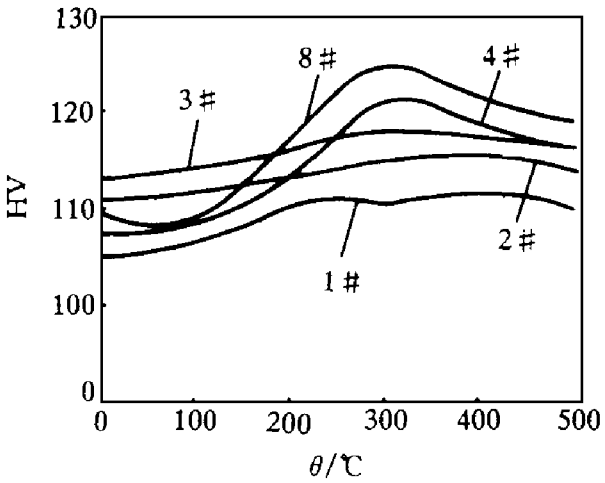

Fig.4 Change in the hardness versus the exposure temperature for 1 h

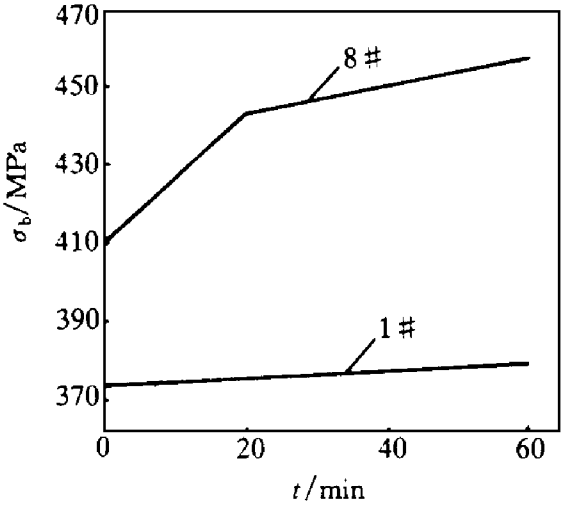

Fig. 5 Change in the tensile strength versus the exposure time at 300 ℃

held at elevated temperature for a long time during hot pressworking preceding the annealing.

The increase in strength and hardness of the cold deformed materials after an exposure at elevated temperature may result from the clusters of the transition metal solute—iron in the aluminum matrix, forming during the exposure at elevated temperature. Howar Jones pointed out that such kind of clusters exists in RS Al-Fe alloy[4]. Although it is less than 20 Å in diameter, too small to be observed by TEM, it may lead to a considerable increase in the hardness. A similar kind of structure was also reported by reference [5]. Furthermore, it can be destroyed by cold deformation. The data listed in Table 2 proof further the above supposition.

As shown in Table 2, an exposure at 300 ℃ for 1 h causes the strength of RS FVS0812 to increase from 403 MPa ($4^{\#}$) to 431 MPa ($5^{\#}$). However, this increase attributed to the clusters is offsetted by the following cold deformation. Consequently, the strength of $6^{\#}$ is even lower than that of $5^{\#}$, just as large as that of $8^{\#}$. After another exposure at 300 ℃ for 1 h, the lost strength can be regained because of the reformation of the clusters in aluminium matrix. Thus, the strength of $7^{\#}$ increases to 430 MPa. The investigation on the effect of an exposure at 200~500 ℃ on the strength of RS Al-Fe-W-Si alloy was also carried out and lead to similar results. As to the nature of the proposed clusters of the transition metal solute-iron in aluminum matrix, it is not very clear yet and remains to be studied.

Table 2 Tensile strength of RS FVS0812 plates

No.	$4^{\#}$	$5^{\#}$	$6^{\#}$	$7^{\#}$	$8^{\#}$
σ_b/MPa	403	431	414	430	411

4 CONCLUSIONS

(1) An exposure at elevated temperature (200~ 500 ℃) for a short time can lead to an increase in strength and hardness of the cold deformed RS Al-Fe-V-Si alloy.

(2) The cluster of the transition metal solute—iron in aluminum matrix forming during hot deformation or heat treatment is the cause resulting in the above increases of strength and hardness.

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