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Microstructures and properties of extruded Al-0.6Mg-0.6Si aluminium alloy for high-speed vehicle

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Abstract

The Al-0.6Mg-0.6Si aluminium alloy was extruded for high-speed vehicle. The microstructure and mechanical property of extruded Al-0.6Mg-0.6Si aluminium alloy were investigated. The results of experimentation show that the tensile strength of extruded Al-0.6Mg-0.6Si aluminum alloy is above of 245MPa, and the percentage elongation after fracture is better than 8%. The microstructure is rolling structure, and the coarse second phases distribute in α-Al solid solution matrix structure. The second phases are inclusions, coarse stable phases of β' (Mg_2Si) or their collection. The tiny β' (Mg_2Si) strengthening precipitation phases mostly distribute in the grain boundary. The size of β' strengthening phase is about 5nm. The width of no precipitation band is above of 50nm. The fatigue life is 1.061×10^5 cycle when σ_{max}=0.75σ_b. The fatigue cracks initiate in surface of extruded Al-0.6Mg-0.6Si aluminium alloy sample. The fatigue fracture is composed of the initiation zone, the propagation zone, and the sudden fracture zone, which is characteristic of a mixed-type fatigue fracture.

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Key words: Extruded aluminium alloy; Microstructure; Mechanical property

1. Introduction

Al-0.6Mg-0.6Si high strength aluminum alloy has wide application in high speed train and automobile industries due to their superior properties compared to casting aluminum alloy [1-3]. This kind of alloy also has been used to produce aircraft in Boeing, Airbus, Bombardier, and so on [4, 5]. The Al-0.6Mg-0.6Si high strength aluminum alloy is suitable for producing large-scale extruded material using in train structure. Base on the principle of design and produce of the high speed train, the large-scale extruded shape of advanced aluminum alloy with higher

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strength and better ductile is developed [6, 7]. The long life and safe running of the high speed train depends on the quality of high strength aluminum alloy. The microstructure substantially influences the mechanical property and fatigue life of aluminum alloy. The fatigue property is significant to ensure the service life of the train. The Al-0.6Mg-0.6Si alloy is high strength aluminum alloy with extruding and quenching online. The aging treatment system, the strengthening mechanism and the effect of fatigue loading on mechanical properties of Al-0.6Mg-0.6Si aluminum alloy must go into further.

2. Experimental procedure

2.1. Experimental materials

The experimental aluminum materials are the Al-0.6Mg-0.6Si alloy, which conditions of heat treatment are T6. The chemical composition of Al-0.6Mg-0.6Si aluminum alloy is shown in Table 1.

Table 1.Chemical composition of extrusion aluminium alloy /%.

Al	Mg	Si	Zn	Fe	Cu	Mn	Cr	Ti
base	0.4-0.8	0.4-0.9	≤0.25	≤0.35	≤0.35	≤0.30	≤0.30	≤0.35

2.2. Test methodology

The mechanical property of Al-0.6Mg-0.6Si aluminum alloy was tested according to standard of GB/T228-2002, using an AG-10KNA tensile test machine with strain rate of 0.001mm/s. The fatigue life was tested in stress ratio (R) is 0.1 and the frequency (f) is 97 Hz.

The microstructure was observed by using a VHX-60 microscope, and the sample was etched by using hydrofluoric acid of 0.5%. The morphology of fracture and the fatigue damage microstructure was studied by using a S-3400 SEM. The precipitated phases were observed by a JEM-100CX TEM.

3. Results and discussion

3.1. Extrusion material

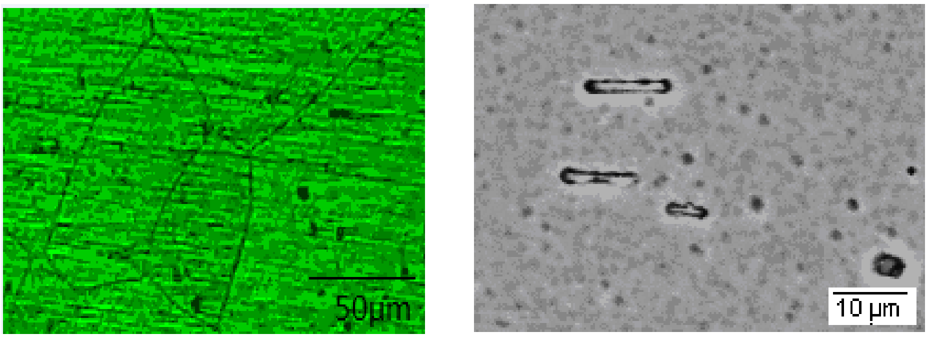
The appearance of extruded Al-0.6Mg-0.6Si aluminium alloy for high-speed vehicle is shown in Fig. 1. The feature of extrusion material is perfect. The defect do not found such as cracking, extrusion shrinkage and so on.

Fig. 1. Profile of extruded Al-0.6Mg-0.6Si aluminium alloy.

3.2 .Microstructure

The microstructure of extruded Al-0.6Mg-0.6Si aluminum alloy is shown in Fig. 2. The optical microstructure (Fig. 2(a)) is rolling structure with coarse second phases. The SEM microstructure (Fig. 2(b)) indicates that the coarse second phases distribute in α-Al solid solution matrix structure. The second phases are inclusions, coarse stable phases of β (Mg_2Si) or their collection. When the inclusion or coarse stable phases are distributed in surface or subsurface, the fatigue micro-cracks are caused under the larger fatigue stress. The inclusions or coarse stable phases also cause the crack rapid propagating.

The TEM image of extruded Al-0.6Mg-0.6Si aluminum alloy is showed in Fig. 3. The tiny β' (Mg_2Si) strengthening precipitation phases were observed in the grain boundary. The size of β' strengthening phase is about 5nm. The strengthening of Al-0.6Mg-0.6Si aluminum alloy depends largely on β' precipitation phases. There no precipitation phase was found in the zone next to the grain boundary. The width of no precipitation band is above of 50nm. Because the β' strengthening phase is very tiny, it isn't easy to cause the fatigue crack initiate.



(a) (b)

Fig. 2. Microstructure of extruded Al-0.6Mg-0.6Si aluminum alloy: (a) OM 400×,(b) SEM.

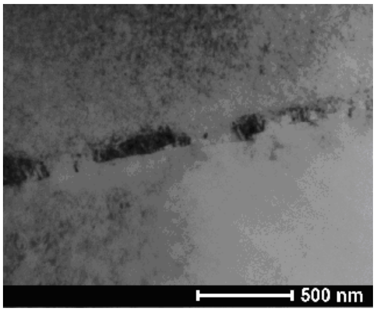


Fig. 3. Intergranular precipitated phase of extruded Al-0.6Mg-0.6Si aluminum alloy.

3.3. Mechanical property

The mechanical property was investigated as shown in Table 2. The results of tensile strength test indicate that tensile strength of extruded Al-0.6Mg-0.6Si aluminum alloy has been well above of 245 MPa, and the percentage elongation after fracture is better than 8%. The zone of fracture is located in the center of the sample, as show in Fig. 4.

Table 2. Mechanical properties of extruded Al-0.6Mg-0.6Si aluminum alloy.

Tensile strength σb (MPa)	Non-proportional extension $\sigma_{0.2}$ (MPa)	Percentage elongationafter fracture δ (%)	Microharness (HV)
≥245	≥205	≥8	102

Fig.4. Tensile fracture sample of extruded Al-0.6Mg-0.6Si aluminum alloy, The thickness of the sample is 4mm.

The fracture morphology presents the cleavage characteristic along the rolling direction, as shown in Fig. 5. There still are some dimples in fracture.

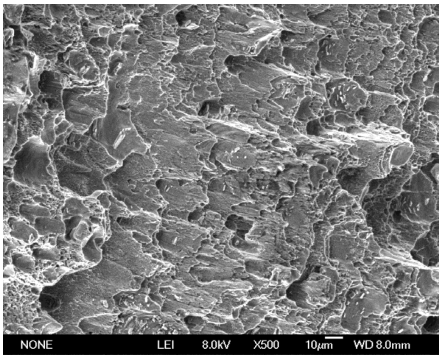


Fig. 5. SEM of tensile fracture sample in extruded Al-0.6Mg-0.6Si aluminum alloy.

3.4. Fatigue property

When σ_{max}=0.75σ_b, the cycle fatigue life is 1.061×10^5 cycle. The fatigue failure is located in the shoulder of the extruded Al-0.6Mg-0.6Si aluminum alloy sample.

The fatigue fracture is composed of the initiation zone, the propagation zone, and the sudden fracture zone. As shown in Fig. 6, it is characteristic of a mixed-type fracture. The fatigue fracture microstructure of the extruded Al-0.6Mg-0.6Si aluminum alloy is composed of dimples and cleavage planes. The fatigue crack initiates in the surface of extruded aluminum alloy sample. While, as is shown in Fig. 7, there is no fatigue striation in propagation zone, there mostly is cleavage plane. In the sudden fracture zone (Fig.8), there are some dimples.

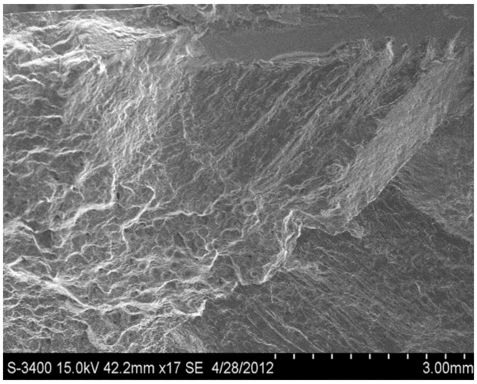


Fig. 6. Feature of fatigue fracture.

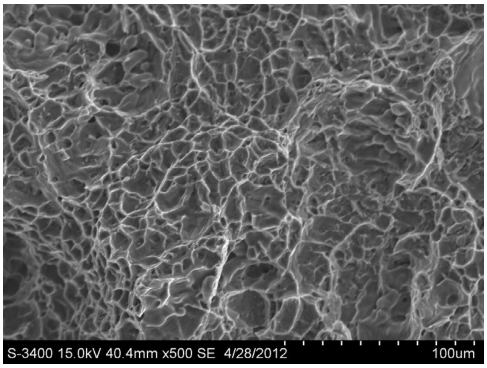


Fig. 7. Extension zone of fatigue fracture.

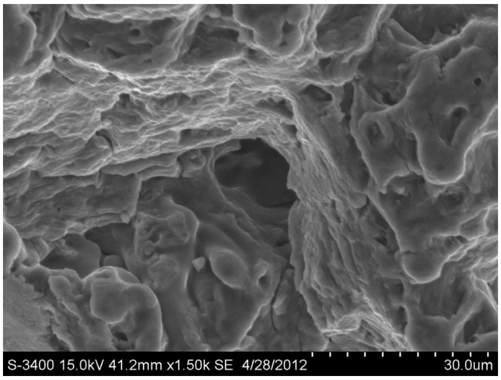


Fig. 8. Sudden fracture zone of fatigue fracture.

Fig. 9 is the surface damage of Al-0.6Mg-0.6Si aluminum alloy in fatigue sample. It shows that the tiny crack initiate in the suface. In surface of fatigue sample, the defect, inclusion, coarse grain and brittleness particles cause stress concentration in microstructure, promote the micro-crack initiation. So the surface structure has large affects on fatigue property.

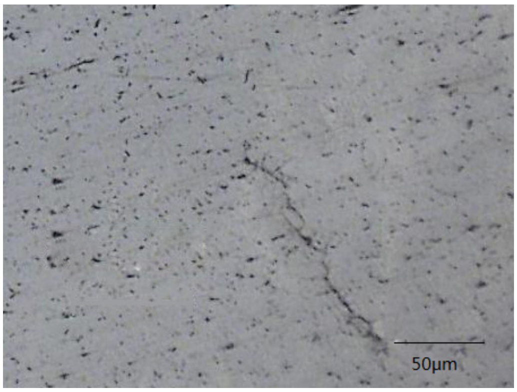


Fig. 9. Surface damage of Al-0.6Mg-0.6Si aluminum alloy in the fatigue test 400×.

4. Conclusion

(1) The tensile strength of extruded Al-0.6Mg-0.6Si aluminum alloy is above of 245MPa, and the percentage elongation after fracture is better than 8%.
(2) The microstructure is rolling structure, and the coarse second phases distribute in α-Al solid solution matrix structure. The second phases are inclusions, coarse stable phases of β' (Mg_2Si) or their collection. The tiny β' (Mg_2Si) strengthening precipitation phases mostly distribute in the grain boundary. The size of β' strengthening phase is about 5nm. The width of no precipitation band is above of 50nm.
(3) The fatigue life is 1.061×10^5 cycle in σ_{max}=0.75σ_b. The fatigue fracture is composed of the initiation zone, the propagation zone, and the sudden fracture zone, which is characteristic of a mixed-type fatigue fracture. The fatigue cracks initiate in surface of Al-0.6Mg-0.6Si aluminum alloy sample.

Acknowledgments

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References

[1] Yang SL, Lin QL,2011. Microstructures and properties of the Al-4.5Zn-1.5Mg-0.5Mn aluminium alloy welding metal. Advanced Materials Research 148-149, 640-643.
[2] Singh RK, Sharma C, Dwivedi DK, Mehta NK, Kumar P.,2011. The microstructure and mechanical properties of friction stir welded Al-Zn-Mg alloy in as welded and heat treated conditions. Materials and Design 32(2), 682-687.
[3] Sullivan A, Derry C, Robson JD, et al.,2011. Microstructure simulation and ballistic behaviour of weld zones in friction stir welds in high strength aluminium 7xxx plate. Materials Science and Engineering A 528(9), 3409-3422.
[4] Di SS, Yang XQ, Fang DP, et al.,2007. The influence of zigzag-curve defect on the fatigue properties of friction stir welds in 7075-T6 Al alloy. Material of Chemical and Physical 104(2/3), 244-248.
[5] Tu JF, Paleocrassas AG.,2011. Fatigue crack fusion in thin-sheet aluminum alloys AA7075-T6 using low-speed fiber laser welding. Journal of Materials Processing Technology 211(1), 95-102
[6] Singh RK, Sharma C, Dwivedi DK, et al.,2011. The microstructure and mechanical properties of friction stir welded Al-Zn-Mg alloy in as welded and heat treated conditions. Materials and Design 32(2),682-687.
[7] Kalemba I, Dymek S, Hamilton C, et al.,2011. Microstructure and mechanical properties of friction stir welded 7136-T76 aluminum alloy. Materials Science and Technology 27(5), 903-908.