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Microstructure and Mechanical Extruded Properties of Extruded AM50+xCa Magnesium Alloys

Wang Qudong1,a, Peng Jianguo1,b, Liu Manping1,c, Chen Yongjun1,d,

Ding Wenjiang1, M.Suéry2,e, J.J.Blandin2,f

[1]National Engineering Research Centre of Light Alloys Net Forming,

Shanghai Jiaotong University, 200030, Shanghai, P. R. China

[2]Institute National Polytechnique de.Grenoble(INPG)

Génie Physique et Mécanique des Matériaux(GPM2)

UMR CNRS 5010, ENSPG, BP46,38402 Saint-Martin d'Hères Cedex, France

[a] wangqudong@sjtu.edu.cn , [b]pengjianguo@sjtu.edu.cn, [c]manping-liu@263.net

[d]chenyongjun@sjtu.edu.cn, [e]Michel.Suery@gpm2.inpg.fr, [f]Jean-jacques.blandin@gpm2.inpg.fr

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Abstract: As-cast AM50 magnesium alloys containing 0, 1, 2 wt. %Ca were extruded firstly at 673K with an extrusion ratio 1:9, and then at 573K with an extrusion ratio 1:16. Microstructure, tensile properties and fractographs were investigated. With Ca content increasing, the amount of Al2Ca increases and that of Mg17Al12 decreases. Ca refines the microstructure of as-cast and extruded AM50 magnesium alloys. For the extruded magnesium alloys, tensile strength improved and elongation decreased at room temperature, while tensile strength was reduced a little and elongation reduced at the temperature of 100˚C, 150˚C and 200˚C with increasing Ca content. The tearing face increases with Ca content increasing for the tensile fractographs.

Introduction

Magnesium alloy, as the lightest structural metal, has been widely used in automobile, electronics and aerospace industries[1]due to its desirable combination of properties, including low density, high specific strength and specific stiffness, superb damping and electromagnetic shielding capacities, excellent machinability and good castability[2]. However, the commonly used Mg alloys such as AZ91 alloy and AM60 alloy are unsuitable for use above 150-200˚C [3]. It was found that Ca addition greatly improves the elevated temperature properties of as-cast Mg-Al alloys because of the formation of the heat-resistant Al_2Ca phase, which has a relatively high melting point[4]. Alloying with Ca is becoming more common in the development of cheap creep-resistant alloys, essentially replacing $Mg_{17}Al_{12}$ with Al_2Ca[4-5]. Besides, extrusion technique is effective to refine coarse microstructure and enhance mechanical properties of magnesium alloy. However, studies on extruded magnesium alloy are few and the studies on the effect of Ca on the microstructure and mechanical properties of extruded Mg-Al alloys are lack. In order to developed heat-resistant wrought magnesium alloys, AM50 magnesium alloys containing Ca were hot extruded and the microstructure and mechanical properties are investigated in this paper.

Material and Experimental Procedure

In the present experiments, commercial AM50 alloy was chosen as master alloy. The composition of the studied magnesium alloys containing different calcium is listed in Table 1. These alloys were melted under SF_6+CO_2 atmosphere in electronic resistance furnace. The extruded process is: firstly, the as-cast ingots were held at 410˚C for 30 minutes, then the φ60mm ingots were hot extruded into bars of φ20mm at temperature 400˚C with a extrusion ratio of 1:9; secondly, the as-extruded φ20 mm bars was held at 300˚C for 30 minutes, then they were extruded into strips with section size 2×10mm at temperature 315˚C with an extrusion rate 1:16. The strips were machined into tensile specimens with a gage length 8mm and 2×2mm section. Microstructure was observed by optical microscopy and the tensile fractographs were observed by scanning electron microscopy (PHILIPS SEM515).

Table 1 Composition of the studied alloys (wt %)

	Al	Mn	Ca
AM50	4.33	0.36	---
AM50+1Ca	4.33	0.35	1.23
AM50+2Ca	4.33	0.33	2.33

Results and Discussion

Microstructure. The microstructure of as-extruded AM50 alloy consists of primary (Mg) solid solution and intermetallic $Mg_{17}Al_{12}$ (Fig.1(a)). $Mg_{17}Al_{12}$ surround the primary Mg. The grains are almost equiaxed and the average grain size was about 20μm. When 1wt%Ca is added into AM50 alloy, the grain size diminishes remarkably which can be seen in Fig.1(b). The main intermetallic in AM50+1Ca alloy are Al_2Ca . Some Al_2Ca, which looks like stringers, distributed at the grain-boundary along extrusion direction; the others, which looks like particles or short rods， disperse in the Mg solid solution. Fig.1(b-c) indicates that the amount of Al_2Ca phase increases with increasing Ca content and the amount of $Mg_{17}Al_{12}$ is considerably less due to the formation of Al_2Ca. The reason is partly correlated with the two aspects: First, the cohesion force between Al and Ca is rather big, so the Al_2Ca phase is more stable than $Mg_{17}Al_{12}$ phase. Second, the melting point of Al_2Ca is much higher, so it can precipitate before $Mg_{17}Al_{12}$ [3].

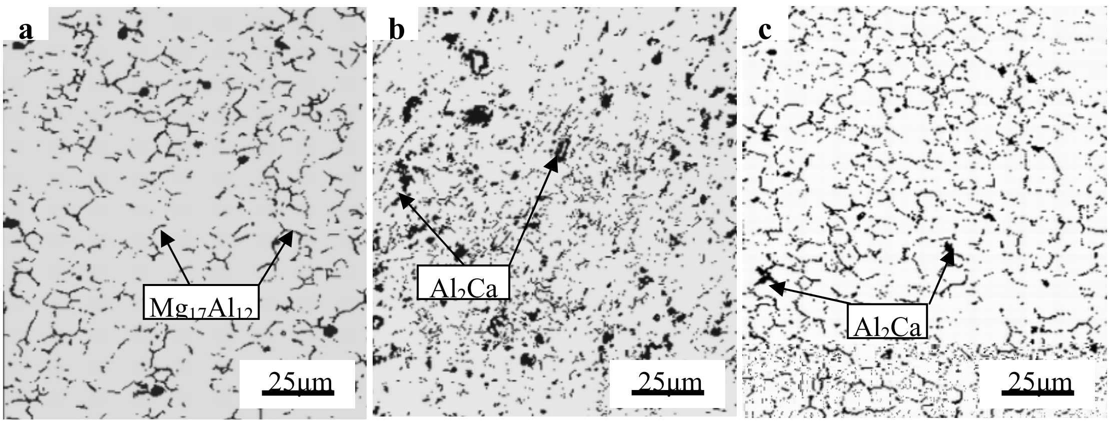

Fig.1.Optical microstructure of Extruded AM50+xCa alloys,
AM50+xCa alloys, (a)AM50; (b)AM50+1Ca;(c)AM50+2Ca

Tensile Properties. Fig.2 shows the ultimate tensile strength of extruded AM50 alloys at different temperature. The results show that the tensile strength of AM50+xCa alloy is influenced by Ca content and experimental temperature. With the increasing temperature, tensile strength decreases. With increasing Ca content, tensile strength improves at room temperature, however, it reduces a little at 100˚C,150˚C and 200˚C.

The effect of Ca content and temperature on elongation is shown in Fig.3. The results show that the elongation decreased with the increasing Ca content. Besides, with increasing temperature, the elongation increases firstly, then decreases after temperature is higher than 150˚C. As can be seen, the extruded AM50+xCa alloys have the highest elongation at 150˚C.

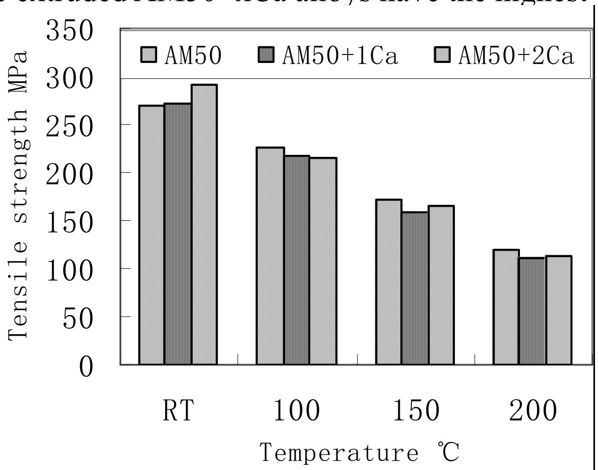

Fig2. Tensile strength of extruded AM50+xCa magnesium alloy

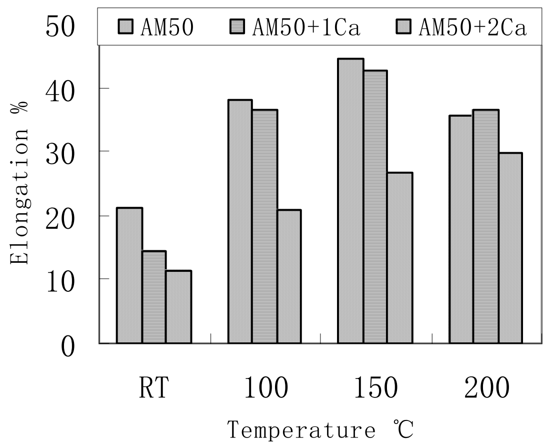

Fig3.Elongation of extruded AM50+xCa AM50+xCa magnesium alloys

Tensile Fractograph. Fig.4(a-c) shows SEM images of tensile fractographs at room temperature.

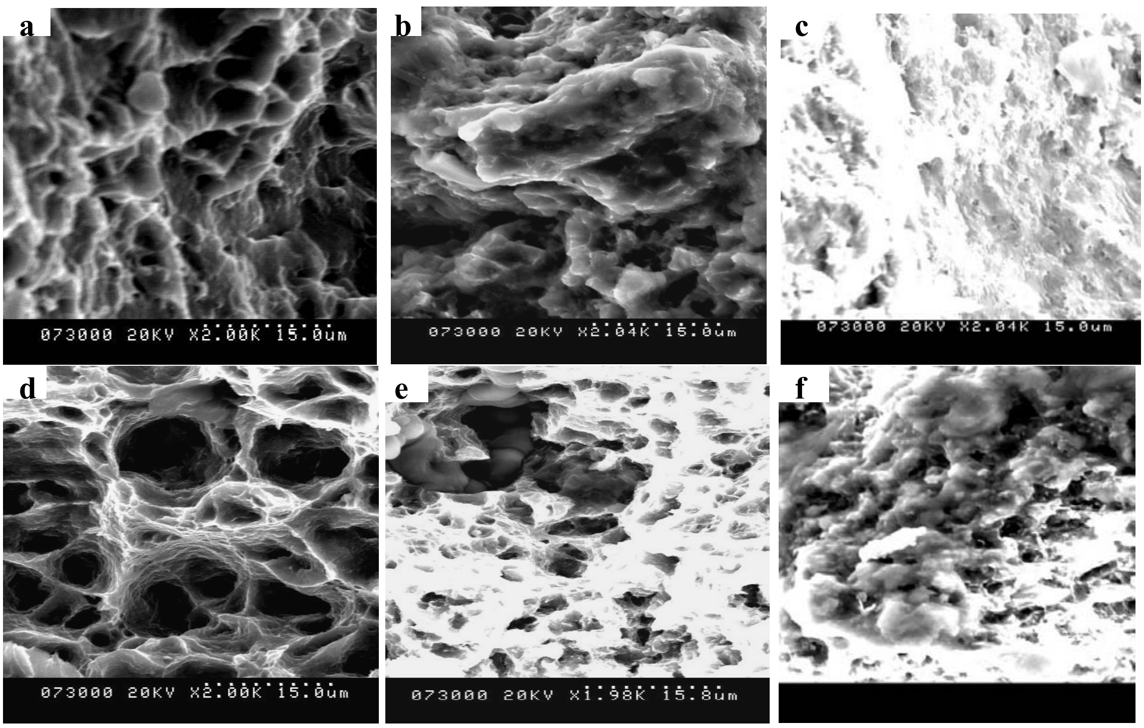

Fig.4 Tensile fracture of AM50+xCa alloys extruded at room temperature
(a)AM50,RT; (b)AM50+1Ca, RT; (c)AM50+2Ca, RT;
(d) AM50, 200℃; (e)AM50+1Ca 200℃; (f)AM50+2Ca, 200℃

tensile fractographs at 200˚C , which indicates the similar conclusion with those at room temperature. Contrasting the fractographs at room temperature with those at 200˚C, more anamorphic trace and cracked edges can be observed in the fractographs at 200˚C, so the ductility of extruded AM50+xCa alloys at 200˚C is higher than those at room temperature.

Summary

(a) With Ca content increasing, the microstructure is refined, the amount of Al_2Ca increases but $Mg_{17}Al_{12}$ decreases in AM50+xCa magnesium alloy.
(b) For the extruded AM50 magnesium alloys, the tensile strength increases at room temperature, reduces a little at 100□, 150□, 200□ while the elongation decreases at room temperature, 100□, 150□, 200□ with increasing Ca content.
(c) The ductility decreased with increasing Ca content and increased with the increasing temperature.

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