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Rapidly Solidified Powder Metallurgy Mg-Zn-RE Alloys with Long Period Order Structure

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Abstract

Mg-Zn-RE alloys had a novel lond period stacking ordered (LPO) structure. Their rapidly solidified powder metallurgy (RS P/M) alloys exhibited a combination of high strength and god ductility (tensile yield strength above 550 MPa and elongation above 5%). The LPO Mg-Zn-RE RS P/M alloys had high elevated temperature strength (tensile yield strength above 380 MPa at 473 K) and exhibited a high-strain-rate superplasticity at higher temperatures. In Japan, a national project for developing high strength LPO Mg-Zn-RE RS P/M alloys has started at 2003 for 5 years, which is founded by the Ministry of Economy, Trade and Industry (METI) of Japan. In the national project, project targets in materials performances have been achieved. The developed LPO Mg-Zn-RE RS P/M alloys exhibited higher tensile yield strength, fatigue strength and corrosion resistance than high strength aluminum alloys of extra-super-duralumin (7075-T6).

Keywords : Magnesium, Rapid solidification, Long period stacking ordered structure

1. Introduction

Mechanical properties of metallic materials have been improved through a rapid solidification (RS) technique, resulting from structural modifications such as reduction of segregation, refinement of grain size and increase in solid solubility. The RS powder metallurgy (P/M) magnesium alloys have been investigated for conventional alloys, resulting in no remarkable improvement in strength [1]. Moreover, nanocrystalline RS P/M magnesium alloys have been synthesized in glass-forming alloys. The nanocrystalline RS P/M alloys exhibited excellent tensile strength, while the ductility was very poor for practical use [2].

Recently, Mg-Zn-Y alloys combining high strength with good ductility have been developed by consolidation of gas atomized powders [2]. The newly developed Mg-Zn-Y alloys have a long period stacking ordered (LPO) structure [3]. It has been reported that the novel LPO structure is formed in Mg-Zn-Dy, Mg-Zn-Ho, Mg-Zn-Er, Mg-Zn-Gd, Mg-Zn-Tb and Mg-Zn-Tm in addition to Mg-Zn-Y. In Japan, a national project for developing high strength LPO Mg-Zn-RE RS P/M alloys has started at 2003 for 5 years, which is founded by the Ministry of Economy, Trade and Industry (METI) of Japan.

In this paper, I will report the performances of the LPO Mg-Zn-RE RS P/M alloys and introduce the Japan national project on the LPO Mg-Zn-RE RS P/M alloys.

2. Performance of Mg-Zn.-RE RS P/M Alloys

Figure 1 shows the relationship between the specific tensile yield strength and elongation of RS P/M alloys. There is a trade-off balance between the tensile strength and elongation in mechanical properties of RS P/M alloys with

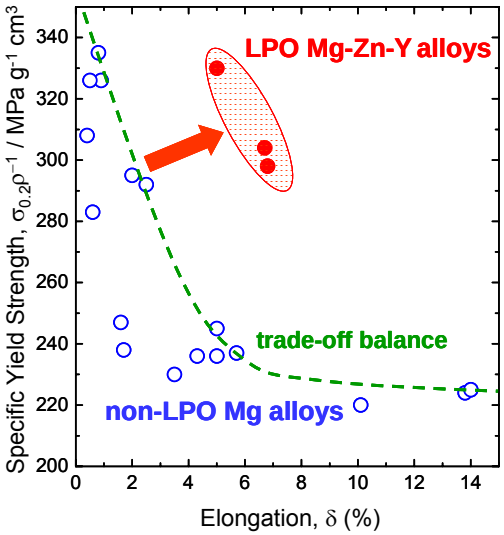

Fig. 1 Relationship between specific tensile yield stre ngth and elongation of LPO Mg-Zn-RE RS P/M all oys and previous RS P/M magnesium alloys with co nventional compositions, their modified compositions and glass -forming compositions.

conventional, their modified and glass forming compositions. The elongation must be sacrificed for improvement of tensile strength. On the other hand, the LPO Mg-Zn-RE RS P/M alloys deviates the trade-off balance and combined high strength with good ductility. The structure of the LPO Mg-Zn-RE RS P/M alloys is duplex and consists of hcp-Mg and LPO phases. It is noticed that the LPO Mg-Zn-RE alloys are not strengthened by any brittle intermetallic compounds. The high performances seem to be originated from the fined grains and ductile LPO phase.

The LPO Mg-Zn-RE RS P/M alloys have high elevated-temperature tensile strength. The LPO phase has a high strength at elevated temperatures. Accordingly, the high performance at elevated temperatures seems to be originated from the LPO phase. The LPO Mg-Zn-RE RS P/M alloys also exhibit high-strain-rate supeplasticity at 623 K. The superplasticity is superior to nanostrucutred RS P/M alloys with conventional compositions such as AZ91 and AZ31alloys. Since the structure of the LPO Mg-Zn-RE RS P/M alloys has higher thermal stability than conventional Mg alloys, the LPO Mg-Zn-RE RS P/M alloys are expected to be superplastically formed into complex shapes without loosing the superior mechanical properties.

3. National Project of Mg-Zn-RE RS P/M Alloys

Japan national project on advanced materials & process development for next generation aircraft structures is carried out from 2003 to 2007, which is sponsored by the Ministry of Economy, Trade and Industry in Japan (METI) and is administrated by R&D Institute of Metals and Composites for Future Industries (RIMCOF). The aim of this project is development of innovative lightweight materials and processes technologies for civil aircraft structures. This project consists of three subjects, development of advanced magnesium alloys technology, development of radiation curing technology on polymer matrix composites (PMC) structures, and development of structural health monitoring (SHM) technology of polymer matrix composites (PMC) structures. The development of process technologies of LPO Mg-Zn-RE RS P/M alloys is main subject in “the development of advanced magnesium alloys technology”. Kumamoto University, Mitsubishi Heavy Industries, Ltd., Fukuda Metal Foil & Powder Co., Ltd. and Kobelco Research Institute, Inc. are involved in the subject of “the development of process technologies of LPO Mg-Zn-RE RS P/M alloys”. The object of the subject is development of advanced magnesium alloys (LPO Mg-Zn-RE RS P/M alloys) with high strength and high corrosion resistance for aircraft structures by development of alloy compositions, production system and technology and application technology for aircraft structures. The target of material properties is tensile strength of 1.3 times as high as and corrosion resistance similar to an aluminum alloy of extra-super-duralumin.

We have carried through the target. Though the tensile yield strength and elongation of 7075-T6 aluminum alloy are 550MPa and 11%, respectively, the developed $Mg_{97}Zn_1Y_2$ RS P/M alloy exhibited the tensile yield strength of 580 MPa and the elongation of 8%. The corrosion rate of the $Mg_{97}Zn_1Y_2$ RS P/M alloy in sort water spray test is 0.132 mg/cm^{2}day which is similar to 0.132 mg/cm^{2}day of 7075-T73. Moreover, 7075-T6 aluminum alloy exhibits no fatigue limit and its fatigue strength decreases continuously with cycles. On the other hand, the $Mg_{97}Zn_1Y_2$ RS P/M alloys exhibits a fatigue limit of 325 MPa or higher around 10^7 cycles. This fatigue limit is much higher than the fatigue strength at 10^7 cycles of 250 MPa of 7075-T6 alloy.

4. Conclusions

The Mg-Zn-Y RS P/M alloys with a long period stacking ordered structure have high strength and good ductility at ambient temperature, high elevated temperature strength, high-strain-rate superplasticity at higher temperatures, and high corrosion resistance. The LPO Mg-Zn-RE alloys are the promising candidate among lightweight structural materials. The strengthening using LPO phase is expected to become the mainstream in the development of high strength magnesium alloys.

5. Aknowlegements

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