

# Effect of Pulsing Current and Aging Treatment on Microstructure and Mechanical Properties of Rare Earth Magnesium ...

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## ABSTRACT

Due to the highly development of technology, consumers have extended the requests of product from functional oriented to higher quality and light weight property. Also, according to the environmental awareness, the material 's selection, such as reducing pollution emission, improving fuel efficiency and high recycling ratio, are considered to fabricate the products. Therefore, magnesium alloys become the dominant material in new generation. Research was carried out the TIG weld and post-weld heat treatment on yttrium containing AZ80 magnesium alloy plate. By changing the frequency of pulsing current and heat treating parameters, to find the best combination of pulsing frequency and precipitating mechanism enhance the weld quality of this types magnesium alloys. From experimental results shown, with increasing the frequency of pulse current, grain was refined on the fusion zone which will also reveal from the mechanical properties, especially at the frequency of 9 Hz has the best performance than other parameters. Therefore, welds with 9 Hz and 0 Hz frequency were selected to study the difference in the following post-weld aging treatment experiment. Types of precipitates on 0 Hz and 9 Hz aging weld are quite similar. In short aging time, the discontinuous layer-shaped precipitates are able to enhance the hardness and tensile strength of welds, but show inferior influence to elongation. Further increasing the aging time, the short-rod-shaped and mat-shaped precipitates will uniformly precipitate inside the grain, but these precipitates unable to further increase the strength of weld, and the elongation is still decreasing. Based on experimental results, selecting 9 Hz pulse current can obtain better mechanical properties in this rare earth containing AZ80 magnesium alloy TIG weld. For post-weld aging treatment, choosing 400 - 1 hour for solid solution and following with 200 - 8 hours for aging treatment, can effectively improve the strength of pulsed weld.

Keywords : AZ80 Rare-earth Magnesium Alloy、Yttrium Element、Gas Tungsten Arc Welding、Frequency of Pulsing Current、Grain Size、Aging Treatment、Precipitates、Mechanical Properties

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## REFERENCES

- [1]王建義, “ 鎂合金板材之壓型加工技術 ”, 工業材料雜誌170期, pp.132~136, 2001.
- [2]F. Czerwinski, “ Magnesium and its Alloys ”, Magnesium Injection Molding, 2008.
- [3]金重勳, “ 工程材料 ”, 復文書局, 1996.
- [4]曾寶貞, “ 工業材料雜誌156期 ”, pp.153~159, 1999.
- [5]機械材料編輯委員會, “ 機械材料 ”, 高立圖書有限公司, 1998.
- [6]楊榮顯, “ 工程材料學 ”, 全華書局, 1997.
- [7]吳炳南等人編著, “ 機械材料 ”, 高立書局, 1993.
- [8]黃振賢, “ 機械材料 ”, 文京書局, 1998.
- [9]R.W. Cahn, P. Haasen and E.J. Kramer, “ Structure and Properties of Nonferrous Alloys ”, Materials Science and Technology, Vol. 8, p.131~212, 1996.
- [10]T. Lyman and H.E. Boyer, “ Metals Handbook Vol. 8 Metallography, Structures and Phase Diagrams ”, Metals Park, Ohio American Society for Metals, pp.305~311, 1974.
- [11]陳超明, “ 鎂合金的高速超塑性成型技術 ”, 工業材料168期, pp.102~104, 2000.
- [12]N. Kashefi, R. Mahmudi, “ The Microstructure and Impression Creep Behavior of Cast AZ80 Magnesium Alloy with Yttrium Additions ”, Materials and Design 39, pp.200~210, 2012.
- [13]B.F. Zhou, H. Yan, “ Application of Yttrium in AZ61 Magnesium Alloy and the Semi-solid AZ61 Alloy ”, Mechanic Automation and Control Engineering (MACE), 2010.
- [14]吳仕偉, “ 輕金屬應用汽車、電子-環保、省能、輕量化是國際趨勢 ”, 機械技術, pp.60~64, 2003.
- [15]蔡幸甫, “ 輕金屬產業的發展趨勢 ”, 工業材料雜誌166期, pp.165~168, 2000.
- [16]王俊傑, “ 鋁鎂合金於汽機車產業之應用發展趨勢 ”, 金屬工業研究發展中心, 1999.
- [17]A. Weisheit, R. Galun, B.L. Mordike, “ Laser Beam Welding of Magnesium Alloy ”, Welding Journal, pp.149~154, 1998.
- [18]宋剛, 劉黎明, 王繼鋒等, “ 變形鎂合金AZ31B電子束鐳接之研究 ”, pp.327~329, 2003.
- [19]T. Asahina, M. Ohkubo, “ Mechanical Properties of Electron Beam Welded Joints of AZ80 Magnesium Alloy ”, Journal of Japan Institute of Light Metals, Vol. 44, No. 4, pp.210~215, 1994.
- [20]L. Shanping, F. Hidetoshi, N. Kiyoshi, “ Marangoni Convection and Weld Shape Variations in Ar-O<sub>2</sub> and Ar-CO<sub>2</sub> Shielded GTA Welding ”, Materials Science and Engineering A, Vol. 380, No. 1-2, pp.290~297, 2004.

- [21]B.C. Howard, " Modern Welding Technology " , 4th Edition, Prentice Hall, New Jersey, 1998.
- [22]N. Kazuhiro, " Weldability of Magnesium Alloy " , Journal of Light Metal Welding & Construction, Vol. 39, No. 12, pp.26~35, 2001.
- [23]董基良, " 鐸接學 " , 三民書局, pp.15~39, 1991.
- [24]A. Munitz, C. Cotler, A. Stern, G. Kohn, " Mechanical Properties and Microstructure of Gas Tungsten Arc Welded Magnesium AZ91D Plates " , Materials Science and Engineering A302, pp.68~73, 2001.
- [25]T.S. Kumar, V. Balasubramanian, M.Y. Sanavullah, " Influences of Pulsed Current Tungsten Inert Gas Welding Parameters on the Tensile Properties of AA 6061 Aluminium Alloy " , Materials and Design 28, pp.2080~2092, 2007.
- [26]施建志, " 摩擦攪拌AZ31 鎂合金之微觀組織及機械性質之溫度效應探討 " , 國立成功大學碩士論文, 2005。
- [27]N. Afrin, D.L. Chen, X. Cao, M. Jahazi, " Microstructure and Tensile Properties of Friction Stir Welded AZ31B Magnesium Alloy " , Materials Science and Engineering A472, pp.179~186, 2008.
- [28]D. Kotecki, " Welding of Magnesium Alloys " , ASM Handbook, Vol. 6, Welding, Brazing, and Soldering, pp.772~782, 1993.
- [29]R.E. Reed-Hill, Physical Metallurgy Principles, 3rd edition, pp.532~535, 1994.
- [30]I.J. Polmear, " Magnesium Alloys and Applications " , Material Science and Technology, Vol. 10, pp.1~16, 1994.
- [31]土重晴, 島陽原著, 陳永璋譯, " 鎂合金之熱處理 " , 金屬熱處理, Vol. 63, pp.72~81, 1999.
- [32] " Heat Treating of Nonferrous Alloys " , ASM Handbook, Vol. 4, 1991.
- [33]G.Y. Yuan, Y.S. Sun, W.J. Ding, " Effects of Bismuth and Antimony Additions on the Microstructure and Mechanical Properties of AZ91 Magnesium Alloy " , Materials Science and Engineering A308, pp.38~44, 2001.
- [34]劉銘仁, " 脈衝電流及時效處理對AZ91D鎂合金鐸道強韌性及析出物析出機制影響之探討 " , 大葉大學碩士論文, 2005。
- [35]Z.Y. Zhang, X.Q. Zeng, W.J. Ding, " The Influence of Heat Treatment on Damping Response of AZ91D Magnesium Alloy " , Materials Science and Engineering A392, pp.150~155, 2005.
- [36]M.X. Zhang and P.M. Kelly, " Crystallography of Mg<sub>17</sub>Al<sub>12</sub> Precipitates in AZ91D Alloy " , Scripta Materialia, Vol. 48, pp.647~652, 2003.
- [37]林榮輝, " 鎂鋁鋅合金時效析出相變之分析 " , 國立中央大學碩士論文, 2002。
- [38]G.L. Song, A. Andrej, D. Matthew, " Influence of Microstructure on the Corrosion of Die Cast AZ91D " , Corrosion Science Vol. 30, pp.249~273, 1999.
- [39]G. Song, A.L. Bowles, D.H. St. John, " Corrosion Resistance of Aged Die Cast Magnesium Alloy AZ91D " , Materials Science and Engineering A366, pp.74~86, 2004.
- [40]S. Celotto, " TEM Study of Continuous Precipitation in Mg - 9 wt.% Al - 1 wt.% Zn Alloy " , Acta. Materialia, Vol. 48, pp.1775~1787, 2000.