Archives of Materials Science and Engineering

Volume 34
Issue 2
December 2008
Pages 95-98

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Evaluation of tensile properties of 5052 type aluminum-magnesium alloy at warm temperatures

F. Ozturk*, S. Toros, S. Kilic
Department of Mechanical Engineering, Nigde University, 51245 Nigde, Turkey
* Corresponding author: E-mail address: fahrettin@nigde.edu.tr

Received 22.09.2008; published in revised form 01.12.2008

ABSTRACT

Purpose: The purpose of the paper is to evaluate the tensile properties of 5052 type aluminum-manganese alloy in warm temperatures.

Design/methodology/approach: In this research, uniaxial tensile deformation behavior of 5052-H32 type aluminum magnesium alloy was studied range between room to 300°C and in the strain rate range of 0.0083-0.16 s^{-1}.

Findings: It was observed that the uniaxial tensile elongation of the material increases with increasing temperatures and decreases with increasing strain rates. The formability of this material at warm temperatures is better than the room temperature and the most suitable forming conditions were obtained at 300°C and 0.0083 s^{-1}.

Practical implications: Results indicate that strain rate sensitivity plays an important role in the formability of this material at warm temperatures.

Originality/value: The evaluation of the tensile properties of 5052 type aluminum-manganese alloy in warm temperatures.

Keywords: Mechanical properties; Aluminum-Magnesium alloys; Al-Mg; 5XXX; 5052

PROPERTIES

1. Introduction

The In recent years, weight reduction has become a key issue for automotive manufacturers. For this reason, aluminum-magnesium (Al-Mg) alloys (5XXX series) have great attention in automotive industry due to their excellent high strength to weight ratio, corrosion resistance, weldability and recycling potential. Therefore, aluminum alloys could replace heavier materials in the automobiles to reduce the automobile weight. Requirements for fuel consumption, environmental laws, and global warming issues have significant influence on the choice of the materials [4, 6, 8], 5XXX series alloys are mostly used for inner panel applications because of the stretcher lines problem on the product surfaces. These surface defects are limiting the usage of the Al-Mg alloys in the outer panel applications. Forming of these alloys at warm temperatures is quite attractive, since undesirable stretcher lines, which often appear on the surface of the sheets during the cold forming operations, will disappear at high temperatures. Al-Mg alloys show less ductility at room temperatures. In the literature, there are several investigations which have documented that the poor room temperature ductility can be improved by changing the forming temperature and the strain rate [1-3,7,9]. In this research, uniaxial tensile deformation behavior of 5052-H32 type aluminum-magnesium alloy was studied range between room to 300°C and in the strain rate range of 0.0083-0.16 s^{-1}.

2. Experimental

The alloy sheet has a thickness of 1.6 mm, gauge length of 50 mm, and width of 12.5 mm at rolling direction. The chemical compositions of the sheet are listed in Table 1. The test specimens were prepared by using water jet cutting machine.

Table 1.
Chemical compositions of the specimen (wt. %)

Material	Al	Cr	Mg	Mn	Si
5052-H32	95.7	0.15	2.2	<0.1	<0.25

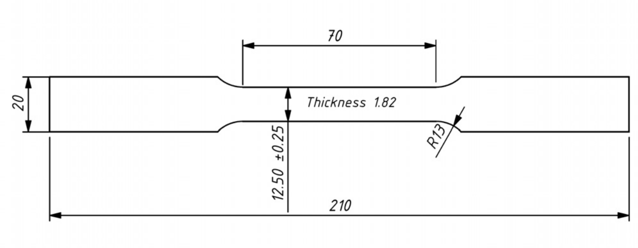

Fig. 1. Tensile test specimens (Dimension are in mm)

The uniaxial tensile specimens were prepared according to ASTM E8 standard as shown in Fig. 1. Tensile tests were performed on a Shimadzu Autograph 100kN testing machine with the data acquisition maintained by a digital interface board utilizing a specialized computer program. In the present study, the uniaxial tensile tests were performed at the temperatures of 25, 100, 200, and 300 °C and with the strain rates of 0.0083, 0.042, 0.083, and 0.16s^{-1}. Temperatures were controlled with a Shimadzu Autograph Thermostatic Chamber which has ±2 sensitivity. Material deformation was measured with a video-extensometer measurement system. Because the video extensometer was positioned out of the chamber, there is no thermal effect on the measurements during the tests.

3. Results and discussion

Tensile tests were performed at prescribed test conditions. Load, crosshead displacement, and gage length strain were measured as raw data. True stress and true strain values were calculated. Figure 2 (a-d) demonstrates the true stress vs. true strain curves of the 5052-H32 Al-Mg alloy in the directions of 0° (rolling direction) at various temperatures and strain rates. Each test was repeated at least three times for each temperature and strain rate and average curve was plotted for each condition. Besides other mechanical properties of the alloy such as strain hardening coefficient (n), strain rate sensitivity (m), and strength coefficient (K) were calculated and plotted.

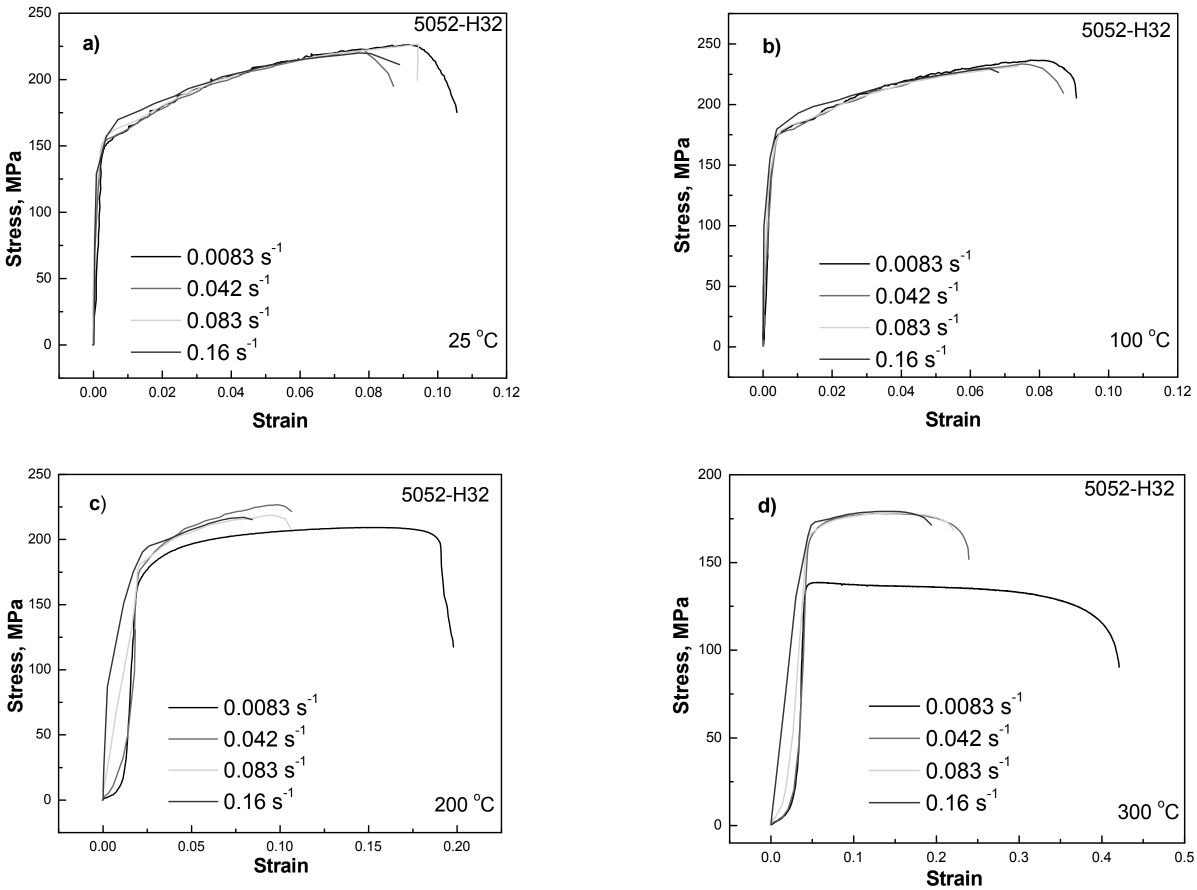

Fig. 2. True stress versus true strain curves at various temperatures and strain rates

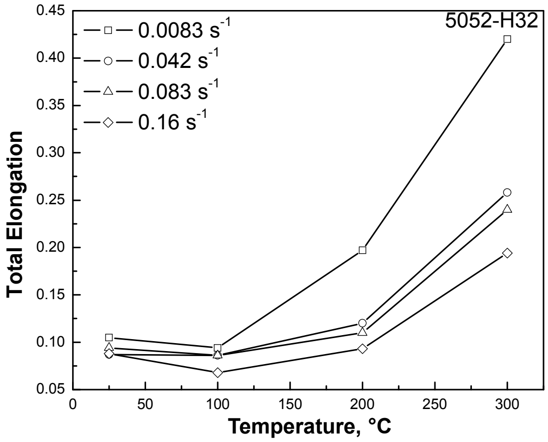

Fig. 3. Total elongation versus temperature

One of the most important parameter which is used for determining the formability of the material is ductility. Ductility can be determined by measuring the total elongation or reduction of area of the material. Total elongation was plotted as seen in Fig. 3. The figure indicates that the total elongation of the material was gradually increased after 100°C for each strain rate. However the total elongation did not show very significant difference at room temperature with increasing the strain rates and it is approximately 10%. The total elongation at 300 °C was increased up to % 42, 25, 24, 19 for 0.0083, 0.042, 0.083, and 0.16 s^{-1} strain rates respectively. The total elongation was significantly enhanced above 200 °C. It is obviously seen that the best forming condition of the 5052-H32 aluminum-magnesium alloy is at 300°C and 0.0083s^{-1}. The post uniform elongation was increased with increasing temperatures and decreased with increasing strain rates. The higher post uniform elongation, which is related to higher strain rate sensitivity in Al-Mg alloys, is believed to occur due to the solute drag effect.

Strain rate sensitivity is the intrinsic resistance of a material to strain localization through the accommodation of strain rate change. Therefore, as strain localization initiates, the local strain rate accelerates to maintain compatibility with the far-field displacement. In this study the strain rate sensitivity (m) was determined by using two true stress vs. true strain curves which are obtained at two different strain rates and all calculations were done for uniform strain by using Eq. 1.

$$m = \frac{\partial \ln \sigma}{\partial \ln \dot{\varepsilon}} \tag{1}$$

During the tests the post uniform elongations were also observed at 300 °C and the uniform elongations were calculated by using Eq. 2 [7] The strain rate sensitivities at this temperature were also calculated by using the data which were obtained from this equation.

$$(n - \varepsilon_u) \approx \sqrt{-n \frac{dA_o}{A_o}} \tag{2}$$

Where n is strain hardening coefficient of the material A_0 is the initial cross sectional area of the test samples and ε_u is the post uniform elongation.

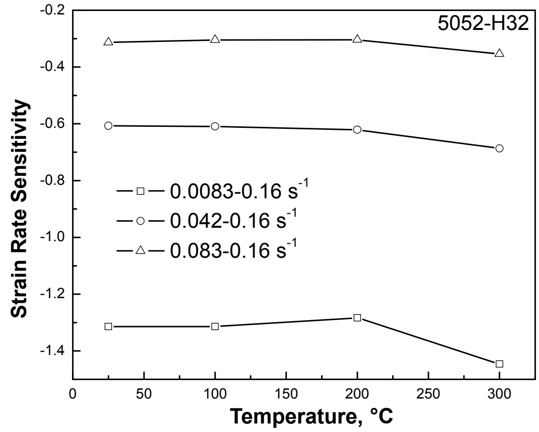

Fig. 4. Strain rate sensitivity versus temperature

As shown in Fig. 4, the strain rate sensitivity was decreased with increasing the strain rate difference at all temperatures. However, there is no significant difference with changing the temperatures except for 300°C. The figure indicates that the strain rate sensitivity was slightly decreased after 200°C at all conditions. Strain hardening is an ability of material to strengthen or harden with increasing strain level and is one of the most important properties influencing the formability of sheet metals. Strain hardening coefficient was calculated by using Eq. 3 and the variations with temperature were plotted in Fig. 5.

$$n = \frac{\partial \ln \sigma}{\partial \ln \varepsilon} \tag{3}$$

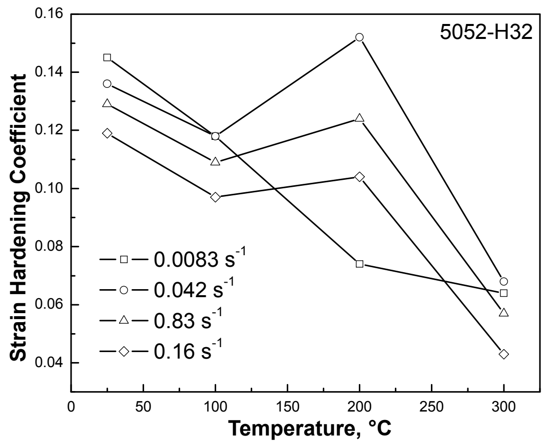

Fig. 5. Strain hardening coefficient (n) versus temperature

Fig. 5 shows the variation of the strain hardening coefficient (n) with temperature. Similar behavior was observed for each strain rates except 0.0083s^{-1}. Although strain hardening of the material was continuously decreased from room to 100°C, it started increasing between 100 to 200°C. After 200°C, a gradual decrease was observed except for 0.0083s^{-1} strain rate. The strength coefficient (K) was also determined for this alloy (Fig. 6).

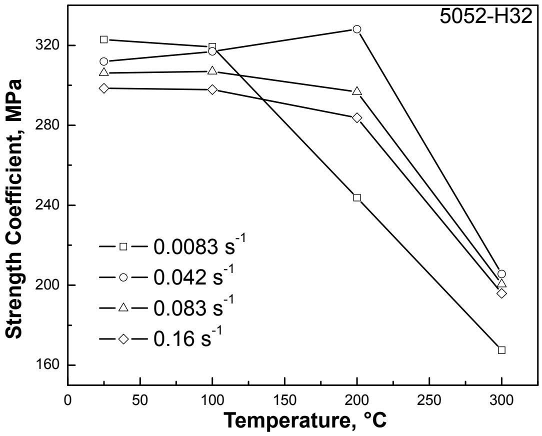

Fig. 6. Strength coefficient versus temperature

Figure 6 displayed that K started increasing with increasing temperature until 200°C except for $0.0083 s^{-1}$. After 200°C, K was sharply decreased for each strain rate. It looks that 200°C is a critical temperature for this alloy. The maximum value of K was found at room temperature.

4. Conclusions

In this research, the uniaxial tensile was performed for 5052-H32 Al-Mg alloy at the temperature range of room to 300 °C and at the strain rate range of $0.0083\text{-}0.16 s^{-1}$. Research revealed that the uniaxial tensile elongation increases with increasing the temperatures and decreases with increasing the strain rates. The post uniform elongation of the material was increased with increasing temperatures and decreased with increasing strain rates. The formability of this material at warm temperatures is better than the room temperature. Strain hardening coefficients of the material was increased between 100 to 200°C. It has the minimum value at the 300°C. Results indicate that strain rate sensitivity plays an important role in the formability of this material at warm temperatures. Finally, the most suitable forming conditions were obtained at 300°C and $0.0083 s^{-1}$ strain rate.

Acknowledgements

This work is supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK). Project Number: 106M058, Title: "Experimental and Theoretical Investigations of The Effects of Temperature and Deformation Speed on Formability". TÜBİTAK support is profoundly acknowledged.

References

[1] N. Abedrabbo, F. Pourboghrat, J. Carsley, Forming of AA5182-O and AA5754-O at elevated temperatures using coupled thermo-mechanical finite element models, International Journal of Plasticity 23 (2007) 841-875.

[2] T. Altan, Warm forming of aluminum alloys academic exercise or practical opportunity, Stamping Journal 14 (2002) 58-59.

[3] P.J. Bolt, N.A.P.M. Lamboo, J.F.C. van Leeuwen, R.J. Werkhoven, Warm drawing of aluminum components, Proceedings of the 7th Saxon Conference on Forming Technology, Lightweight Construction by Forming Technology, Chemnitz, 2000, 101-118.

[4] D. Carle, G. Blount, The suitability of aluminum as an alternative material for car bodies, Mater Design 20 (1999) 267-272.

[5] I.N. Fridlyander, V.G. Sister, O.E. Grushko, V.V. Berstenev, L.M. Sheveleva, L.A. Ivanova, Aluminum alloys: Promising materials in the automotive industry, Metal Science and Heat Treatment 44 (2002) 365-370.

[6] D. Li, A. Ghosh, Tensile deformation behavior of aluminum alloys at warm forming temperatures, Materials Science and Engineering A 352 (2003) 279-286.

[7] Z. Marciniak, L.J. Duncan, J.S. Hu, Mechanics of sheet metal forming, Butterworth-Heinemann, Oxford, 2002, 66.

[8] W.S. Miller, L. Zhuang, J. Bottema, A.J. Wittebrood, P. De Smet, A. Haszler, A. Vieregge, Recent development in aluminum alloys for the automotive industry, Materials Science and Engineering A 280 (2000) 37-49.

[9] T. Naka, F. Yoshida, Deep drawability of type 5083 aluminum-magnesium alloy sheet under various conditions of temperature and forming speed, Journal of Materials Processing Technology 89\90 (1999) 19-23.