Proceedings of the 4th International Congress APMAS2014, April 24-27, 2014, Fethiye, Turkey

A Study on Thermo-Mechanical Behavior of AA5754 Alloy (Tread and Plain Sheet) Produced by Twin-Roll Casting

Y. Demiray[a,*], Z. B. Kavaklioglu[b], O. Yucel[a]
[a]Istanbul Technical University, Metallurgical and Materials Eng. Dept., 34469 Maslak, Istanbul, Turkey
[b]University of Applied Sciences, Schmalkalden, Germany

Aluminum alloy AA5754 is used for many technical and industrial applications. Twin roll casting is unique among the casting processes in that it is a combined "solidification/deformation" technique. The simultaneous solidification and hot rolling produces characteristic microstructure with a fine cell size and intermetallic particle distribution with some residual structure. In the study, first AA5754 alloy (tread and plain sheet) strips were fabricated by using a twin-roll caster equipped with water-cooled steel-rolls. To reduce the thickness of the strip, cold rolling process was applied until strip thickness got 3 mm. After homogenization step the strips were cut in to smaller specimens and annealed at 260 °C, 285 °C, 310 °C, 340 °C, 370 °C, 400 °C, 430 °C, 460 °C, 490 °C, 520 °C for 3 hours to obtain the desired temper conditions. Mechanical properties were investigated after processes. Tensile, hardness and bending tests were applied to monitor the effect of annealing after cold rolling process.

DOI: 10.12693/APhysPolA.127.1097
PACS: 81.05.Bx Metals, semimetals, and alloys

1. Introduction

Twin roll strip casting has advantageous features, such as low running cost, low energy cost, space saving, low equipment costs. Besides these features it also has some disadvantages, which are inferior mechanical properties and low casting speed [1, 2]. Twin-roll casting allows metal strip to be produced directly from molten metal instead of direct-chill (DC) casting and subsequent hot-roll milling processing. This results in a relatively low running and equipment cost. Cooling rate of twin-roll casting is higher then that of other casting methods, but in some aluminum alloys, the higher cooling rate helps mechanical properties to get improved. The technique is not suitable for other aluminum alloys with wide freezing range. Another disadvantages of the technique is its low productivity, because of low casting speed of the roll caster [3, 4]. To manufacture finished aluminum products, twin roll casting is followed by cold rolling process. As a effect of cold rolling process, there occurs strain hardening. At the end of cold rolling it is observed that yield strength of sheet increases and the ductility decreases [5, 6]. To obtain the desired mechanical properties and temper conditions, cold rolled byproduct is annealed. In this study, aluminum plates which are produced by twin roll casting were cold rolled to 4.60, 3.80 and 3.00 mm thickness and annealed at different temperatures to have different tempers assigned by EN.

2. Experimental

In our industrial scale study, 6.00 mm thickness and 1300 mm width of AA5754 aluminum alloy (chemical compositions is given in Table I) is cast using twin roll casting technology. Chemical analysis of product was determined by Bruker Quatron 6 Colombus spectrometer.

TABLE I

Chemical composition of the investigated cast alloy (wt.%) [7].

Alloy / Element	Mg	Mn	Si	Fe	Zn	Ti	Cu	Al
AA5754 (EN AW-Al-Mg_3)	2.6–3.6	0.50	0.40	0.40	0.20	0.15	0.10	Balance
5754 Product	2.95	0.45	0.30	0.50	0.06	0.02	0.03	Balance

As homogenization step, 6.00 mm thickness roll was annealed at 520 °C for 8 hours. After homogenization step, the strip was cold rolled to 4.60 mm thickness (23.3% deformation) by using cold rolling mill process. This 4.60 mm strip was cold rolled to 3.80 mm strip with deformation of 17.3%. 3.80 mm thickness strip was cold rolled to 3.00 mm tread and 3.00 mm plain sheets with deformation of 26.7%. At the end of twin roll casting and cold rolling processes, plain sheets which have thickness of 4.60 mm, 3.80 mm, 3.00 mm and tread sheet which has a thickness of 3.00 mm were obtained. The conditions and specifications of twin roll caster and rolling mill are given in Table II. Each sheets were then cut into 10 pieces which have dimensions 300 mm×300 mm. Annealing process was applied to this new small sized sheets. Temperature range was selected from 260 °C to 520 °C. Sheets were annealed at 260 °C, 285 °C, 310 °C, 340 °C, 370 °C, 400 °C, 430 °C, 460 °C, 490 °C, 520 °C for 3 hours. Laboratory scale electric resistance furnace was used for annealing process.

*corresponding author; e-mail: yelizdemiray@gmail.com

The conditions and specifications of Twin-Roll Caster and Cold Rolling. TABLE II

The Conditions and Specifications of Twin-roll Caster		The Conditions and Specifications of Cold Rolling	
Main Drive Motor:	2 x 60 kWatt DC motor	Main Motor Power	2 × 750 kWatt DC motor
Aluminum alloy:	1000, 3000, 5000 series	Type of mill:	4 Hi non reversing
Setback:	60–70 mm	Back-up Roll Ø:	1100 mm
Caster Roll Ø:	1020 mm	Work Roll Ø:	430 mm
Separating Force:	2000 tones (max)	Rolling Force:	1600 tones
Strip Thickness:	6 mm (nominal)	Width:	1500 mm
Strip Width:	1500 mm	Entry Thickness:	6 mm
Capacity:	1200 tones mon^{-1}	Exit Thickness:	0.2 mm
Heat Box Temperature:	725–730 °C	Roll Bending Pressure:	180 bar
Casting Speed:	1.8 m min^{-1} (depends on alloy and thickness)	Rolling Speed:	400 m min^{-1} (max)

3. Mechanical testing

Tensile Test: Tensile tests were conducted to evaluate the strength and ductility of the annealed AA5754 alloy. Samples were prepared as mentioned in standard ISO 6892-1. Zwick Z050 model testing machine was used [8].

Hardness Test: Hardness measurements were made to observe the annealing response. Mirror polished cross sections specimens were prepared and Leica VM HT hardness test equipment was used. Load and loading time were selected as 1000 g and 12 s respectively.

Bending Test: Three point bending tests were applied by using Autograph AGS- Jthree point bending test equipment. Velocity was selected as 5 mm min^{-1}. Test was achieved according to BS EN ISO 7438:2005, metallic materials bend test [9]. The bending test was carried on until cracks formed at bending point. Angles that occurred after the bending test were compared.

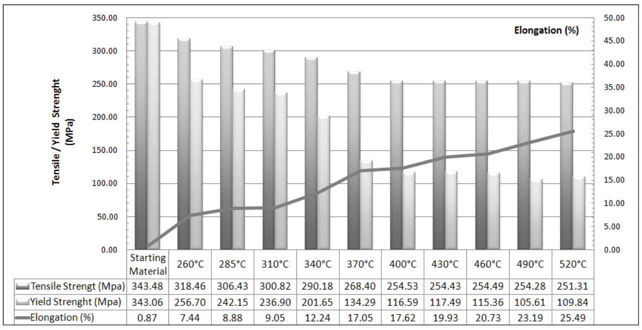

Fig. 1. Tensile strength, yield strength and elongation (%) of 3.00 mm plain sheets.

4. Results and discussions

The tensile strength, yield strength and elongation (%) properties depend on annealing temperature. In Fig. 1 mechanical test results of the 3.00 mm plain sheet are given as an example. Mechanical test results of 4.60 mm, 3.80 mm and 3.00 mm tread sheets show the same tendency as the results displayed in Fig 1. It is seen that elongation (%) increases as a result of decreasing yield stress.

According to the result of tensile tests and EN 485-2 and EN 1386 standards, it is seen that different temper conditions are reached at different annealing temperatures [10, 11]. H12 and H14 tempers are gained for all plain samples at 285 °C. H12 temper is reached for all plain samples at 310 °C and 340 °C. H22 and H32 tempers are gained for all plain samples at 370 °C. H244 temper is gained for tread sample at 340 °C. Above 400 °C only H111 temper is gained in both plain and tread sheets samples [10, 11].

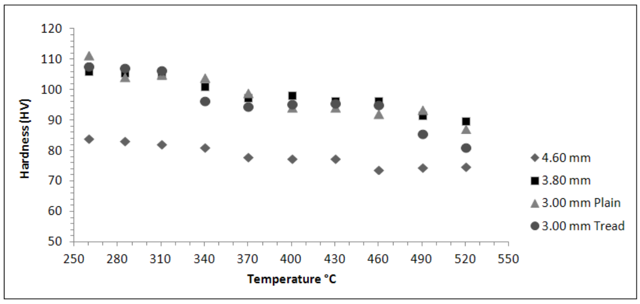

Fig. 2. The hardness values of the samples.

It is seen that after cold rolling process the hardness of sheets increased as expected. The maximum hardness was measured as 111.3 HV on 3.00 mm plain sheet after 3 hours of annealing at 260 °C. After annealing process it is seen that hardness of sheets tended to decrease. The minimum hardness is measured as 73.8 HV on 4.60 mm plain sheet after 3 hours of annealing at 460 °C. The results of hardness test are in agreement with tensile properties. As hardness values have decreased, elongation (%) has increased as well. The results are given in Fig. 2.

Bending properties of the starting material and the annealed samples of 4.60 mm, 3.80 mm, 3.00 mm plain and 3.00 mm tread sheets are shown in Figure 3a, 3b, 3c and 3d respectively. Starting material has more brittle properties because of the cold rolling. It is seen that after annealing, ductility of AA5754 alloy has increased because of recrystallization [5]. The angle at the point of bending has increased as a result of the increased ductility and the decreased yield strength. No cracks were observed on samples of 3.80 mm annealed at 520 °C, 3.00 mm

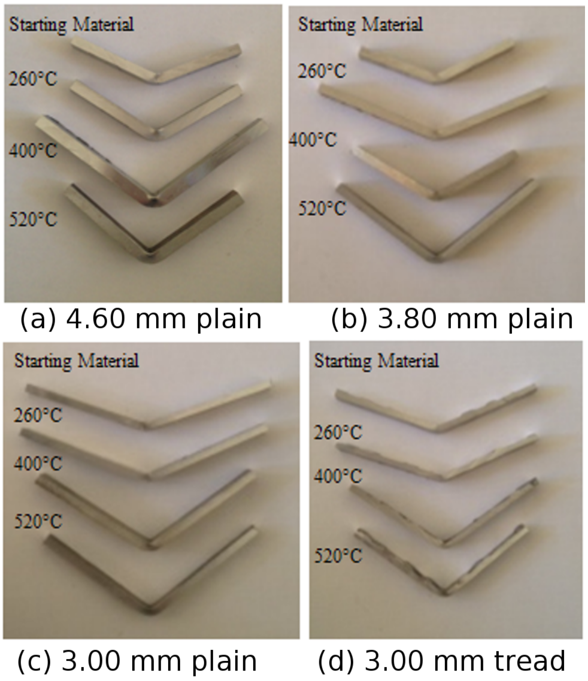

Fig. 3. Macroscopic photograph of the starting material and of the cold rolled and annealed samples.

plain annealed at 520 °C and 3.00 mm tread annealed at 520 °C.

References

[1] M. Yun, D.J. Monagham, X. Yang, J. Jang, D.V. Edmonds, J.D. Hunt, R. Cook, P.M. Thomas, *Cast Met.* **4**, 108 (1991).

[2] D.V. Edmonds, J.D. Hunt, D.J. Monagham, X. Yang, M. Yun, *Proceedings of the Extraction Refining and Fabrication of Light Metals*, CIM, Ottawa, 257 (1991).

[3] T. Haga, K. Tkahashi, M. Ikawaan, H. Watari, *J. Mater. Process. Tech.* **153-154**, 42 (2004).

[4] T. Haga, S. Suzuki, *J. Mater. Process. Tech.* **143-144**, 895 (2003).

[5] D. Askeland, P. Fulay, W.J. Wright, *The Science and Engineering of Materials*, Cengage Learning, 297 2010.

[6] M. Tajally, Z. Huda, Z.M. Masjuki, *J. Appl. Sci.* **9**, 3888 (2009).

[7] EN 573-3, *Aluminum and aluminum alloys - Chemical Composition and Form of Wrought Products*, 2007.

[8] ISO 6892-1, *Metallic Materials Tensile Test*, 2009.

[9] BS EN ISO 7438:2005, *Metallic materials Bend test*, 2005.

[10] EN 485-2, *Aluminum and Aluminum Alloys. Sheet, Strip and Plate - Part 2: Mechanical Properties*, 2008.

[11] EN 1386, *Aluminum and Aluminum Alloys - Tread Plate Specifications*, 2007.