Investigation of Thickness and Thermal Treatments on the Deep Drawing Process for the Aluminum Plate

Hamid Mozafari[a], Meysam Hassanipour[b], Amran Ayob[c]

Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM, Skudai, Johor, Malaysia
[a]mozafari.h@gmail.com, [b]meysam.hp1@gmail.com, [c] amran@fkm.utm.my.

Abstract

Effective parameters on deep drawing include punch diameter, mold diameter, punch speed, power of preservative sheet, friction, traction and depth. In this work, the effect of precipitation hardening in 2618Al alloys was studied. In 2618 alloy the LDR values vary with the condition of heat treatment and the best condition at the value of 1.33 was obtained. Comparison of LDR in different conditions had shown that precipitation hardening cause decrement in limiting drawing ratio and consequently is detrimental to drawing ability. In 2618 alloy at SA and SW conditions, the LDR was decreased. In this paper, the effect of temperature on earing in 2618 Al alloy was also discussed. Results show that at the temperature at 350^{o}C the amount of earing is least.

Keywords: Deep drawing; Formability; Aluminum; Plates.

1. Introduction

The use of aluminum (Al) alloys in automotive applications has doubled, mostly due to their high strength to weight ratio and excellent recyclability, which subsequently translate to cost saving. However, since the costs of the Al alloys are higher than those of steels. Further decrease in costs is important so as to expand the usage of these alloys. In recent years, Al alloys produced by continuous casting have progressively attracted attention from investigators and producers, from the viewpoint of reducing production costs [1- 7]. Deep drawing is the most important process of shaping sheet and largely deformed metal sheets are turned into the hollow parts. Experimentally, several laboratory methods are utilized to assess ductility of the sheets. These test methods include cylindrical cup deep drawing and deep shaping operations [8]. In deep drawing sheet metal is draw into a hollow cylindrical shape where forces often are symmetrical [9]. The mechanical properties of the sheet are not often the same in all directions and the crystal anisotropy of sheet material can be the cause of heterogeneity in the direction of the grain crystallization [10]. Deep-drawn products further require operating margins, which would increase production costs and making thinner products would be helpful to the overall costs [11]. The deep-drawing industry produces metal containers such as pressure or vacuum tanks, some cars and aircraft spare parts, shell and bullet cans and canned soft drinks [7].

2. Materials and Methods

The primary material used is annealed 2618 aluminum sheet with a thickness of 2.3 mm. The circular dies were first prepared for the deep drawing test. In this study, the deep drawing test is done for different diameters, 55 mm up to 75 mm [5]. The thermal process for the alloy 2618 was done as:

1) Operation and dissolution, then cool at the temperature of the SA room
2) Operation and dissolution, then cool at the water temperature of SW

The experiment is done using a deep hydraulic tension machine with 30 ton capacity. The force applied is derived by:

$$BHF = \frac{\pi}{4}(D^2 - d^2)\frac{\sigma_y + \sigma_u}{200} \qquad (1)$$

In Equation (1) D is the rolling radius, d is the rasp radius, σ_y is the yield strength of the alloy and σ_u is the ultimate tension yield of the alloy.

Thus, for the alloy 2618 (annealed aluminum):

σ_y =95 MPa

σ_u =205 MPa

Therefore for a rolling diameter of 70 mm:

$$\frac{\pi}{4}(70^2-30^2)\frac{95+205}{200}=5100$$

The height of Earing is derived from these equations:

$$Earing=\frac{\Delta h}{\bar{h}}\times 100 \qquad (2)$$

$$\bar{h}=\frac{h_0+2h_{45}+h_{90}}{4} \qquad (3)$$

$$\bar{h}=\frac{h_0+h_{90}-2h_{45}}{2} \qquad (4)$$

To assess the strength and isotropic of the specimen, 6 specimens, respectively two along the 0-degree direction, two along 45-degree and two along 90-degree, from the direction of rolling is provided [8]. In next step, the experiment is applied with a uniaxial tension machine of 10 ton. From the stress-strain curve of the specimens and assuming the flow curve following the work hardening is derived by:

$$\bar{n}=\frac{1}{4}(n_0+2n_{45}+n_{90}) \qquad (5)$$

To calculate the anisotropy of the specimen, for every specimen five points are specified and the width of the specimens at these points 10 percent of strain before and after the test of tension are measured and the average are entered in this equation(w_0 is the width before tension, w_1 is the width after tension [10]).

$$r=\frac{\varepsilon_w}{\varepsilon_t}=\frac{\ln\frac{w}{w_o}}{\ln\frac{t}{t_o}}=\frac{\varepsilon_w}{-(\varepsilon_w-\varepsilon_t)}=\frac{\ln\frac{w}{w_o}}{\ln\frac{wl_o}{w_o l}} \qquad (6)$$

Therefore the normal anisotropic $\bar{r}$ and plane anisotropic Δr is calculated.

$$\bar{r}=\frac{1}{4}(r_0+r_{90}+2r_{45}) \qquad (7)$$

$$\Delta r = \frac{1}{2}(r_0 + r_{90} - 2r_{45}) \tag{8}$$

The deep drawing force is supplied by a 100 kN hydraulic press machine. The maintaining forces are between 4 to 8 kN to prevent the shrinkage of the Earing. The speed of the punch is selected 0.6 mm/h. For the calculation of LDR rolling with diameters between 60 and 70 mm and thickness of 2.3 mm is provided and considering the results of deep drawing the LDR is derived.

3. Results and Discussion

The anisotropy values for different specimens with different grain directions, is shown in Table 1.

Table. 1. The normal and planar anisotropic in different temperatures.

Annealed temperature	**350°**	**400°**	**450°**	**500°**	**550°**
$\bar{r}$	0.77	0.8	0.82	0.83	0.86
Δr	0.16	0.19	0.22	0.29	0.33

Considering the high value of $\bar{r}$ in the plate 2618 it is expected that the deep drawing specifications are improved. For this purpose the relational limit drawing is derived with different approach.

$$LDR = e^{f\sqrt{(1+\bar{r})/2}} \tag{9}$$

And also late leu formulation is compared.

$$LDR = \sqrt{e^{2fe^{-n}\sqrt{(1+\bar{r})/2}} + e^{2n\sqrt{(1+\bar{r})/2}}} - 1 \tag{10}$$

In the above equations the *f* factor represents the effect of type of drawing in the samples [10]. As observed the difference between the above two equations is in the work hardening which is considered in the latter. In Table 2 the LDR and the percent of earing is derived.

Table. 2. LDR and Earing in different temperatures.

Annealed temperature	**350°**	**400°**	**450°**	**500°**	**550°**
LDR	1.63	1.92	2.13	2.21	2.27
%Earing	2.14	2.94	3.68	5.28	7.42

As shown in Figure 2 the plate which was annealed at 550 centigrade has a high value $\bar{r}$, and also the relational deep drawing shows a better drawing specification. Considering Δr, the earing of the cup edge resulting from deep drawing is increased. The result of deep drawing is in Table 1.

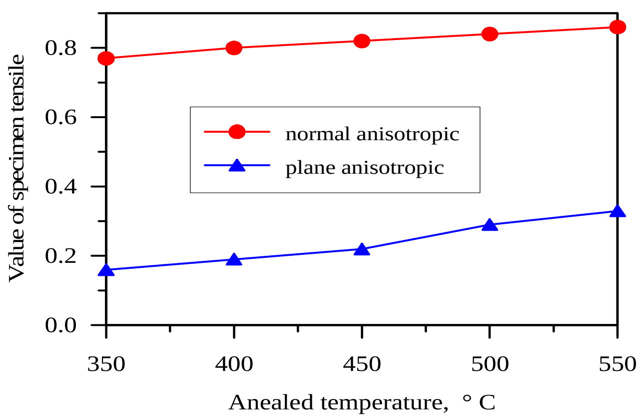


Fig. 1. Comparison of planar and normal anisotropy at different annealing temperatures

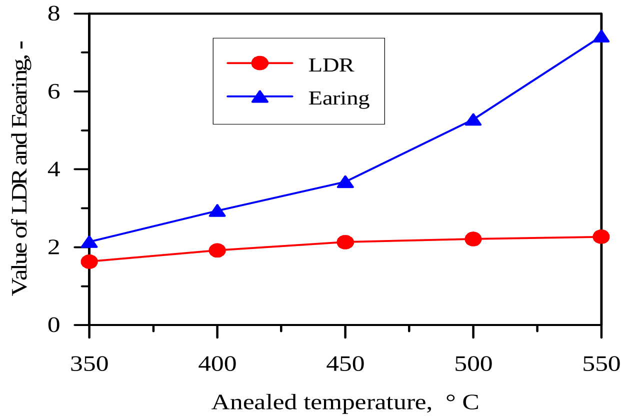


Fig. 2. Effect of annealed temperature on Earing and LDR

In this study, the effect of thickness on drawing LDR and the earing is furthe investigated. The plate (2618 Al alloy) with three different thicknesses was investigated. The results are shown in Table 3 and illustrated in Figure 3.

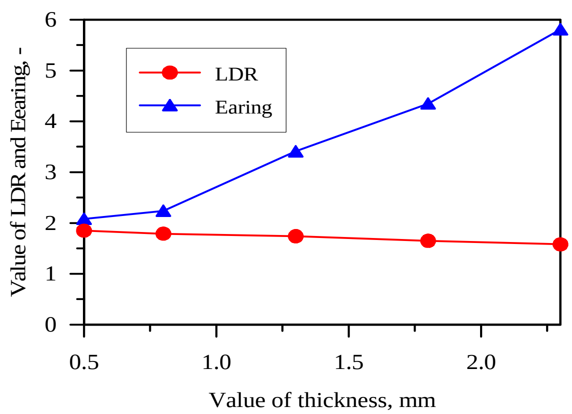


Fig. 3. Effect of thickness on LDR and Earing

As observing in the graphs of figures 3 decreasing the thickness will increase the LDR and theEaring will decrease. The results of deep drawing for the specimen which are quenched and applied to dissolve thermal operation are shown in table 4. Considering the results of table 4 and figure 4 the highest value of LDR is SA and the lowest is SW which the reason is the hard sediment in the alloy.

Table 3. LDR and Earing from different plate thicknesses.

Thickness	LDR	%Earing
2.3	1.58	5.81
1.8	1.65	4.35
1.3	1.74	3.41
0.8	1.79	2.24
0.5	1.85	2.08

Table 4. LDR from different thermal operations.

LDR	**350°**	**400°**	**450°**	**500°**	**550°**
SA	1.42	1.40	1.31	1.34	1.36
SW	1.33	1.29	1.21	1.16	1.11

Table 5. %earing from different thermal operations.

% Earing	**350°**	**400°**	**450°**	**500°**	**550°**
SA	2.73	3.05	3.55	5.32	7.38
SW	2.17	2.88	3.21	5.03	6.91

The occurrence of the hard sediment causes the LDR to be decreased. The tensile strength is decreased due to the decrease of flexibility of the alloy. These results can be fully perceived from the Table 5 and Figure 5.

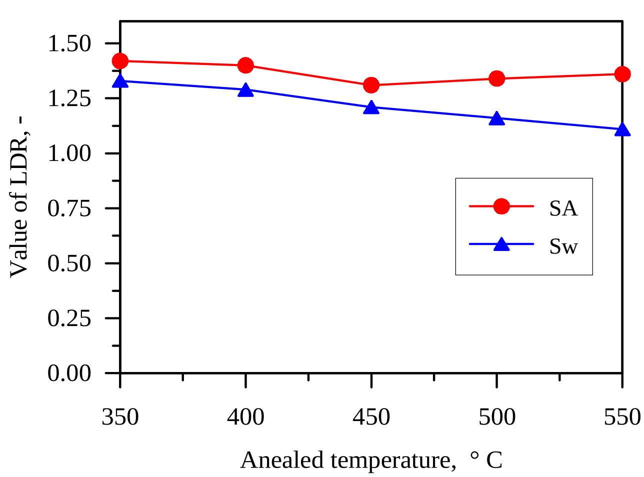


Fig. 4.Effect of dissolution temperatures with two chilling methods on LDR

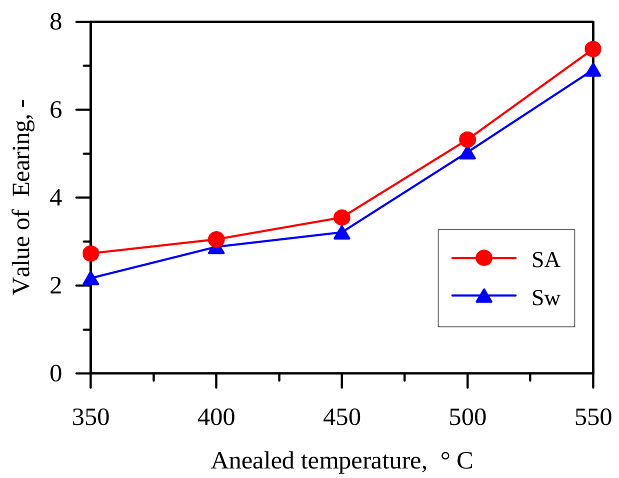
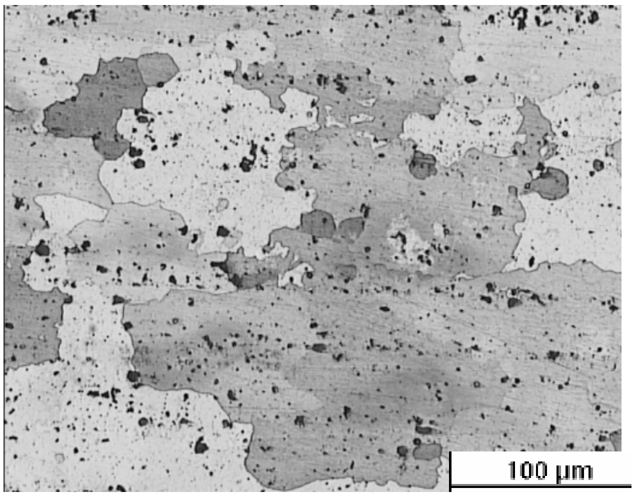
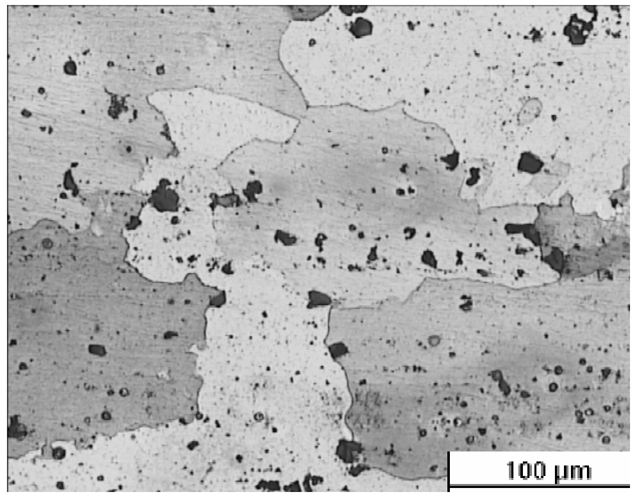


Fig. 5.Effect of dissolution temperatures with two chilling methods on Earing

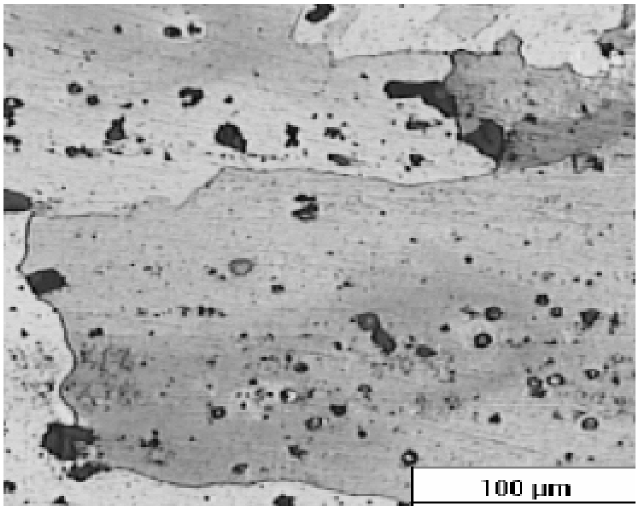
a)



b)



c)



d)

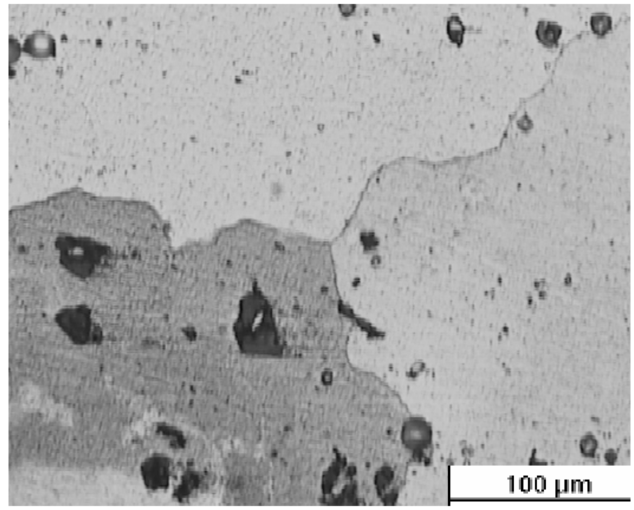


Fig. 6. Illustration of microstructures of a) the as-received 2618 Al alloy at 350°C, b) the as-received 2618 Al alloy at 450°C, c) the as-received 2618 Al alloy at 500°C, d) the as-received 2618 Al alloy at 550°C,

Figures 6 is shown the effect of increase of the annealed temperature on the geometry and size of the grains. As opposed to LDR, The Earing increases with an increase in the annealed temperature, due to the relation of anisotropic with the geometry of grains.

4. Conclusions

From the experiments which are carried out in this study, the following conclusion can be drawn:

1) Increasing the annealed temperature the normal and plane anisotropy are increased, with an increase of r specification.
2) Increasing the annealed temperature leads to an increase of LDR. The result of the increase of tensile specification with annealed temperature is derived.
3) Decreasing the thickness of plate results in an increase of LDR while the Earing percentage is decreased.
4) The LDR of the specimen considering the thermal operation in SA and SW are different. which in the analysis in all cases the highest temperature is for SA. Therefore the dissolution and chilling with the environment is preferred than in the water.

References

[1] B. Ren, Z. Li, J.G. Morris, Scripta Metall. Mater. 31 (1994) 387–392
[2] W.C. Liu, J.G. Morris, Mater. Sci. Eng. A 339 (2003) 183–193.
[3] W.C. Liu, T. Zhai, J.G. Morris, Mater. Sci. Eng. A 358 (2003) 84–93.
[4] W.C. Liu, J.G. Morris, Mater. Sci. Eng. A 363 (2003) 253–262.
[5] J.T. Liu, J.G. Morris, Metall. Mater. Trans. A 34 (2003) 951–966.
[6] Y.M. Zhao, W.C. Liu, J.G. Morris, Mater. Sci. Technol. 19 (2003)1379–1385.
[7] W.C. Liu, T. Zhai, J.G. Morris, Scripta Mater. 51 (2004) 83–88.
[8] K. Lucke, O. Engler, Mater. Sci. Technol. 6 (1990) 1113–1130.
[9] M. Koizumi, H. Inagaki, Met. Mater. 5 (1999) 511–517.
[10] Y.M. Zhao, W. Wen, J.G. Morris, Mater. Sci. Eng. 373 (2004)167–174.
[11] X.F. Yu, Y.M. Zhao, X.Y. Wen, T. Zhai. Materials Science and Engineering A 394 (2005) 376–384