Effect of Rolling Process on Microstructure of 2A66 Al-Li Alloys Sheet

Wang Guanyi1, Bai Yujie2
1 Beijing Institute of Aeronautical Materials, Beijing, 100095, China
2 Institute of Physical and Chemical Engineering of Nuclear Industry, Tianjin, 300180, China

*Corresponding author’s e-mail: ivyby1988@163.com

Abstract. Influences of rolling process on microstructures of 2A66 Al-Li alloy thin sheet are investigated. Specimens with three different rolling processes and two heat treatments are taken into consideration. Results show that the passes of rolling process have a significant influence on Al-Li alloy textures. When the cold rolling reduction is 26%, there are some coarse particles identified as Al3Zr phase existing in the alloy and the anisotropy becomes obvious with low grain refinement. Under the cold rolling reduction 44.4%, the recrystallization grain increases and the grain refinement becomes better with the appearance of recrystallization, besides little larger grain. With a cold rolling of 48.7%, textures in alloy are better than 44.4% at homogeneity except the stratified phenomenon.

1. Introduction
Al-Li alloy shows excellent mechanical properties with low density, which attracts more researchers to study and implement this material in aerospace industry [1-6]. In early days the ALCOA contributed a lot in developing the Al-Li alloy [7]. With the rapid development this material was applied in military battle planes of Americans and the Soviet Union [8-9]. From 1970s researchers gradually found better Al-Li alloy with lower density, better tear resistance and mechanical properties. However, in these decades this material still showed bad plasticity and toughness performance. Then in recent years the aspect that only a few properties should be focused on instead of all the properties was accepted by more analysers.

The rolling technology has been reported to have a significant influence on the mechanical properties of Al-Li alloy. The plasticity and toughness performance is modified by the ECAP process without improving the strength [10], which attributes to the reduction of gas holes created in the casting process. The hot-mechanical process of Al-Li alloy during 180°C and 330°C was studied to reveal the crystal internal structures, and recrystallization process was analysed. The 2A66 Al-Li alloy is reported to exhibit better performance with addition of some metal elements. And influences of rolling technologies on the crystallographic textures of this 2A66 Al-Li alloy will be presented in this paper.

2. Experimental Procedure
An Al-1.4Li-3.6Cu-0.4Mg-0.12Zr-0.5Zn-0.4Mn (wt%) alloy ingot was melted in vacuum resistance furnace and subsequently homogenized at 720°C for hours. The ingot began the cold rolling process at 480°C and the final rolling temperature is 380°C. Then three cold rolling technologies entitled as A, B
and C are implemented on the 8mm sheets. A is an 8.0mm → 7.0mm → 5.6mm → 3.9mm → 2.7mm → 2.0mm process and the deformation of the last step is 26%. B is an 8.0mm → 7.0mm → 5.6mm → 3.9mm → 2.7mm → 1.5 mm process and the deformation of the last step is 44.4%. C is an 8.0mm → 7.0mm → 5.6mm → 3.9mm → 2.0mm process and the deformation of the last step is 48.7%. And then two different heat treatments labeled as T3 and T8Y were applied in the final 1.5/2.0mm thin sheets. The T3 treatment was aging at 510°C for 1 hour with a 1~3% pre-tension. The T8Y was aging at 125°C for 15 hours besides T3.

The microstructure along the L, LT and ST directions of three cold rolling technologies was obtained using the metallographic observations, TEM and EBSD. The crystallographic textures including grain size, structure, precipitated phase and fracture faces were carefully observed and analyzed to reveal the effect of cold rolling technologies on the Al-Li alloy’s microstructures.

3. Results and discussion

Rolling technology is very important to form the metal or alloy materials. In this way the goal of fining grain is achieved by controlling the experimental conditions in the hot rolling process. In previous researches the cold rolling technology is more frequently used because of the limited knowledge of this technology. The cold rolling technology is applied to improve the mechanical and fracture properties through cooling down and pressing force, when the circumstance temperature is low. Recent studies show that when used in all the rolling process, the cold rolling technology helps accurately control not only the mechanical and fracture properties, but also the recrystallization, precipitated phase etc. So the final alloy will be better and steadier with low cost and low greenhouse gas pollution.

![Figures 1 and 2: Metallography and TEM images of 2A66 Al-Li alloy specimens](image-url)
3.1. Microstructure evolution in rolling process

Figure 1 and Figure 2 show the metallography and TEM images of alloy sheets under different cold rolling process A, B and C, with different hot treatments T3 and T8Y. With the A-T3-L, A-T3-T and A-T8Y images, it is clear that because of the Al3Zr, which interrupts the growing of recrystallization grain, the deformation energy in materials is reduced and the recrystallization grain is lessen. These will lead to the stratified phenomenon and single growing direction of grain. So the poor performance of fracture properties and anisotropy in alloy materials are obtained.

From the B-T3-L, B-T3-T and B-T8Y images, it’s found that with the larger deformation during the last two passes, the more deformation energy and recrystallization are achieved. This will reduce the textures during the rolling process and lead to less anisotropy besides improving the ductility. But with more amount of recrystallization the mechanical properties will be weaker.

C-T3-L, C-T3-T and C-T8Y images show that the obvious stratified phenomenon and textures appear because lacking of the last pass and larger deformation compared with A process. The tiny grain zones with more deformation energy lead to massive grain, which is accompanied by reduction of the hardness and tensile strength.

From all the images it is found that the passes of rolling process have a significant influence on Al-Li alloy textures. In A process it is easy to observe the anisotropy in former two passes and the unobvious fining grain. In B process the grain in alloy is wholly fined with the appearance of recrystallization, besides little larger grain. Textures of C process is similar with the B with better homogeneity.

3.2. Microstructure of cold rolling and annealing states

In Figure 4 is shown the microstructures of different specimens. In A process from the different amplification there are more robust and large grain than B and C. Compared with A the grain in B and C is smaller and more even, which attributes to the smallest total deformation of A process. With the large deformation in rolling technology the dislocation in unit volume increases and some distortion appears, which is good to recrystallization and rolling softening.
4. Conclusions
The effects of cold rolling process on microstructures of 2A66 Al-Li alloy thin sheet are studied. Three different rolling processes and two heat treatments are taken into consideration. Results show that the passes of rolling process have a significant influence on Al-Li alloy textures. When the cold rolling reduction is 26%, some coarse particles identified as Al₃Zr phase appear in the alloy and the anisotropy becomes obvious and the grain refinement is low. Under the cold rolling reduction 44.4%, the recrystallization grain increases and the grain refinement becomes better with the appearance of recrystallization, besides little larger grain. With a cold rolling of 48.7%, microstructures in alloy are better than 44.4% at homogeneity except the stratified phenomenon.

References
[1] Sun J.Q. Zhang B.Z. (2013) Al-Li alloy properties and applications on the commercial aircraft. Advances in aeronautical science and engineering. 4(2): 158-163.
[2] Wang J.G., Wang Z.T. (2013) Advance on wrought aluminium alloys used for aeronautic and astronautic industry (1). Light alloy fabrication technology. 41(8): 1-6.
[3] Li J.F., Zheng Z.Q., Chen Y.L., etc. (2012) Al-Li alloys and their application in aerospace industry. Aerospace materials & technology. 42(1): 13-19.
[4] YIN D F, ZHENG Z Q. (2003) History and current status of aluminium—lithium alloys research and development. Materials Review. 17(2):18.
[5] Yang S J,Lu Z,Su B,Dai S L,Liu B C,Yan M G. (2001) Development of Aluminium-Lithium Alloys. Journal of Materials Engineering. 5:44.
[6] Zhang R X,Zeng Y S. (2007) Development, Technical Properties and Applications Abroad of Al-Li Alloy. Aeronautical Manufacturing technology. (Z1):438.
[7] Xue Z,Ma Y P,Li X L,Li S,Yu Y. (2013) Effect of heat treatment on microstructure and mechanical properties of Al-Li-Cu Alloy. Heat Treatment of Metals. 5(38).
[8] Zhang Q.Y., Zhuang H.S. (2011) Manual of ternary alloy phase diagrams. Machinery Industry Press. Beijing.
[9] Wang Z.X. (1988) Controlled Rolling and Controlled Cooling. Metallurgical industry press. Beijing.
[10] Xu Y.B. (1996) Fatigue and fracture behaviour of an aluminium-Lithium alloy at ambient and cryogenic temperature. Journal of material & science. (2):1.