

The Effects of Cold Rolling Process and Annealing Treatment on Damping Properties of 3105 Aluminium Alloy

Z. M. Syafiq

*School of Materials Engineering, Universiti Malaysia Perlis,
02600 Arau, Perlis, Malaysia
Email: syafiqnm@gmail.com*

Abstract. The aluminium alloy have deformed by cold rolling process to 50 percent, 60 percent, and 70 percent rolling reduction. In order to reduce the strain hardening of the samples, an annealing treatment was performed after cold worked process. The lower the rolling reduction, the higher the damping capacity of the samples. The sample for 50 percent rolling reduction before annealed has increase in damping capacity from 0.0361 to 0.1318. When the samples undergo two different annealing temperatures and soaking hours, the damping properties such as loss modulus, storage modulus, and damping capacity show some changes in trend curves and experimental value. The damping capacity for sample 50 percent rolling reduction and after annealed at temperature 300 °C for one hour was increased from 0.0193 to 0.1405 at temperature 50 °C to 380 °C. The hardness measurement showed that, the value of Vickers hardness were decrease after annealed due to the decreasing in strain hardening.

Keywords: Rolling reduction, annealing treatment, damping capacity, hardness.

1. Introduction

Generally, cold rolling is used as a last step in manufacturing procedure because it can produce a chosen thickness with a smooth surface [1]. Cold rolling is an important part of the process route when making metallic strips of different thicknesses and widths. In order to form a metal, rolling process is used to obtain slabs, sheets, plates, bars and other structural parts [3]. Annealing is defined as a material that has been slowly cooled in furnace after heating at an elevated temperature for a several time. Annealing is one of the heat treatment processes that used to eliminate the stress after cold working method. In addition, annealing treatment also can improve the mechanical properties of a material. In general, the damping capacity of a material refers to its ability to convert mechanical vibration energy into thermal energy or other energies [8]. Damping capacity ($\tan \phi$) is one of the important considerations in the selection of a structural member which exposed to a dynamic environment [7]. In an ideally elastic material, $\phi = 0$ and $\sigma/\varepsilon = E$, the Young's modulus. However, most materials are inelastic owing to some energy dissipation, which occurs in the same frequency range as the imposed stress, therefore the strain lags behind the stress and ϕ is not zero. The ratio of σ/ε is the complex modulus, E^* , and is defined as

$$E^* = E' + iE'', \quad [6]$$

where E'' and E' are the components of E^* and are known as the storage modulus and loss modulus, respectively. The ratio of two elastic modules $E'' / E' = \tan \phi$ is the damping capacity of the material. Damping capacity is significant for some materials because the mechanical vibration can cause to destruction in material. Materials that have high damping capacity usually have low mechanical performance. The purpose of this research is to study the effects of cold rolling and annealing treatment on damping properties of 3105 aluminium alloy.

2. Experimental Procedure

This project was started by cutting the material into a rectangular shape with a specific dimension. The dimension was 10 mm (width) $\times$ 70 mm (length) $\times$ 2 mm (width). After that, the sample was preceded to the cold rolling process at room temperature, 25°C. Then the samples were rolled with variety of rolling reductions which were 50 percent, 60 percent, 70 percent of reductions and it will result a specific thickness which are 1.00 mm, 0.80 mm, and 0.60 mm respectively. In this process, the samples undergo heat treatment in muffle furnace at 10 °C/min heating rate. There are two significant parameters that be tested. Some of the samples were annealed at 300 °C while few of them were annealed at 345 °C. Annealing treatment was done with two different soaking times which were 1 hour and 2 hours. There were two testing that have been done in this project. The testing included dynamic mechanical analysis test and hardness test. A dynamic mechanical analyzer (Pyris Diamond DMA model, USA) was used to measure the damping capacity. Dynamic mechanical analysis was carried out in the three point bending mode using a dual cantilever system. The sample was cut into dimension 10 mm $\times$ 50 mm $\times$ 2 mm. The heating rate that was used was 10 °C/min while the test temperature range were 50 °C to 400 °C. The second testing was continued by hardness test by using Vickers hardness. This test was performed to determine the hardness profile of every sample either before annealing or after annealing. The load that used was 1 kgf at 5 seconds dwelling time.

3. Results and Discussion

Loss modulus

Figure 1 shows the loss modulus curves as dependence on temperature for various rolling reductions after annealed at 345 °C for two hours. In this graph, all the three samples were not stable. Those three rolling reductions start with differ temperatures as their initial value of loss modulus. Based on the graph that had plotted in Figure 1, 70 percent rolling reduction increased steadily from 70 °C to 360 ° before it dropped slowly until temperature at 370 °C and dropped drastically to 390 °C. It was proved that if non heat treatable aluminium was heated to a temperature 350 °C, the alloy will return to their initial stage.

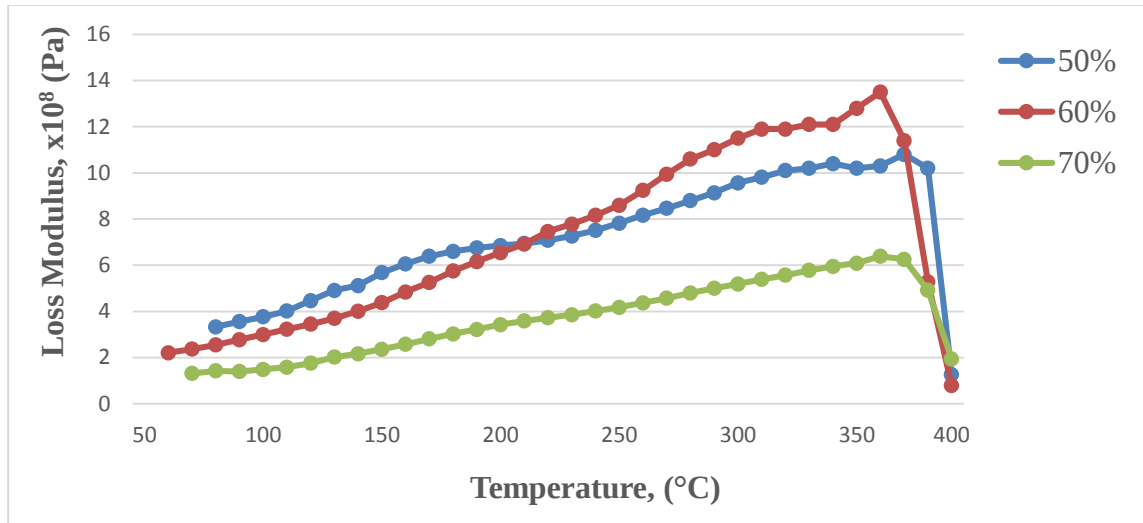


Figure 1: Graph of loss modulus against temperature for three different rolling reductions after annealed at temperature 345 °C for 2 hours

Storage modulus

As shown in Figure 2, 70 percent rolling reduction shows the highest storage modulus compared to the other two samples. It was because of the thickness of the sample was more than 50 percent and 60 percent rolling reduction. Cold working can cause some amount of energy stored in the crystal lattice as a dislocation [2]. By means, if the rolling reduction is higher, the storage modulus will increase due to high energy that had stored in the crystal lattice.

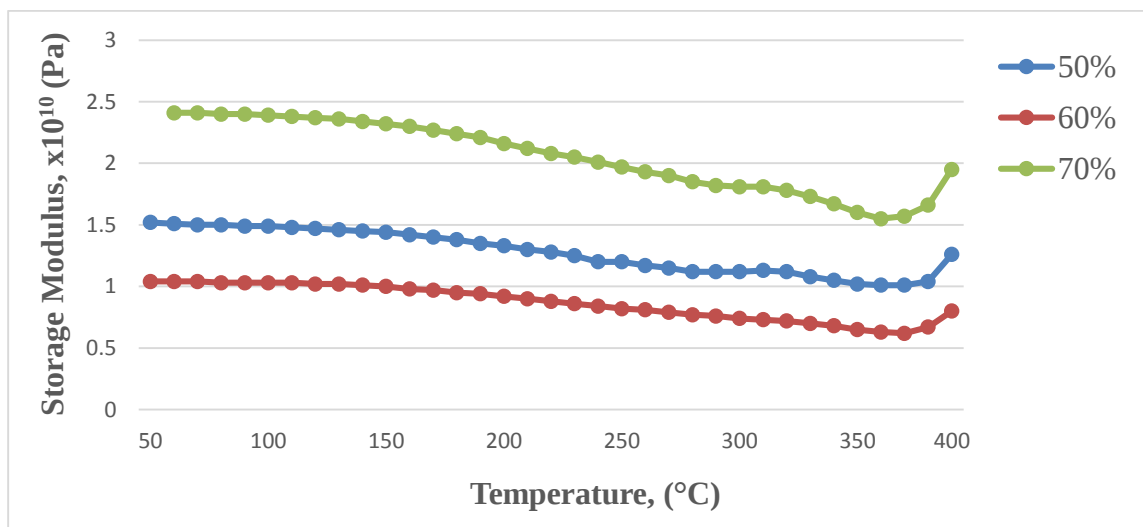


Figure 2: Graph of storage modulus against temperature for three different rolling reductions after annealed at 300 °C for one hour.

Damping capacity

Figure 3 shows the graph of damping capacity ($\tan \delta$) against temperature with different rolling reduction after annealed at 300 °C for one hour. For sample 70 percent rolling reduction, the damping capacity starts at 60 °C with value 0.0305. From the observation, there were some noises that can make it difficult for the important or useful information to be seen clearly. The noise can be clearly seen from test temperature 300 °C to 380 °C. Noise also known as unstable trend. Sample of 60 percent rolling reduction also had noise at the initial damping capacity but then it increase proportional to temperature. This is because of the existence of abnormal grain at certain temperature. When the alloy was annealed at a temperature close to the solvus line, it may produce abnormal grain growth [4]. It have been reported that the grain boundary for high rolling reduction were difficult to slip at high temperature and cause the damping capacity decreases and also believe to be depending also on the annealing parameters used [5]. Above certain temperatures, dislocations would move faster and then break away dramatically from the weak pinning points. It would then become a long dislocation in the condition of hard pinning such as network node of dislocation and in second phase, the energy dissipated by dislocation motion would not increase, and thus the damping capacity values might decrease slightly. Consequently, a damping peak is caused. Afterwards, the damping capacity may increase again due to the appropriate damping mechanism at elevated temperatures [6].

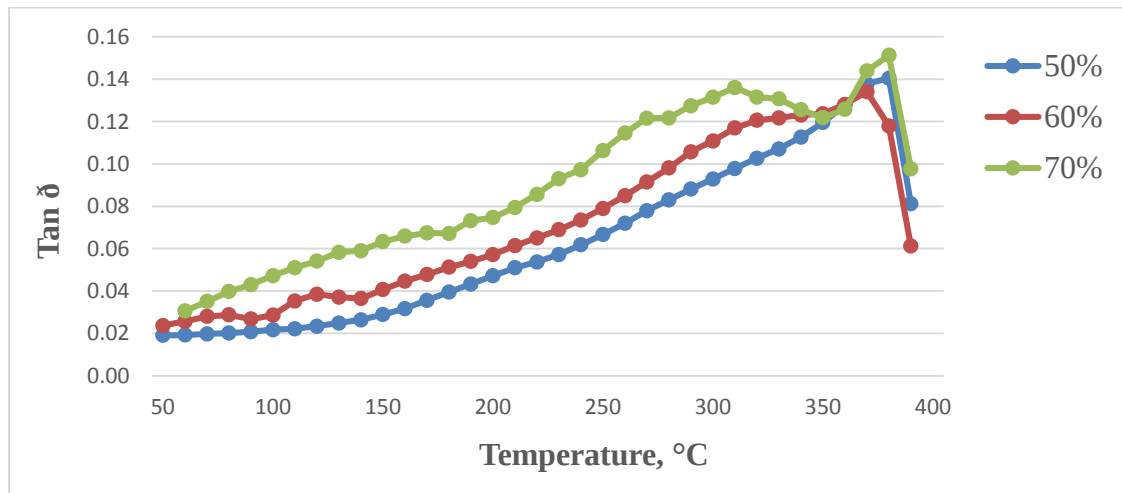


Figure 3: Graph of damping capacity against temperature for various rolling reductions after annealed at 300 °C for one hour.

Hardness

Alphabet (A) represent the sample before annealing treatment, (B) represent after annealed at 300 °C for one hour, (C) represent after annealed at 300 °C for two hours, (D) represent after annealed at 345 °C for one hour, and (E) represent after annealed at 345 °C for two hours. Based on the graph in Figure 4, the value of hardness Vickers for samples before annealing treatment was always produced the highest hardness value compared to sample that experienced annealing treatment. This is because the strain hardening was decreased

during cold work process. The dislocation density were decreased when a material were heat up at certain temperature after cold working process [12].

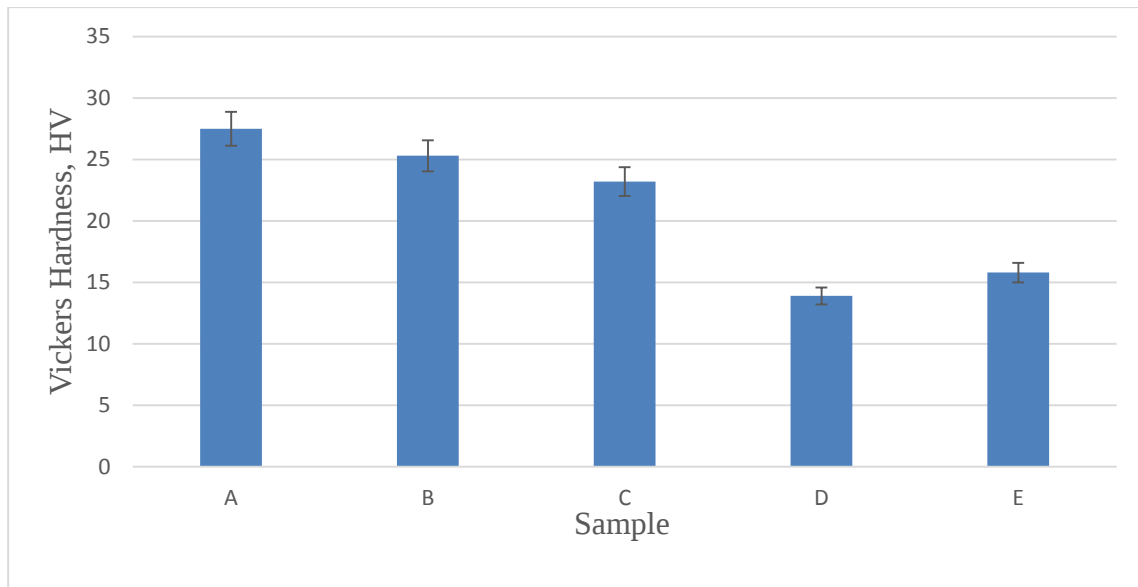


Figure 4: Hardness values of 50 percent rolling reduction samples.

4. Conclusion

As a conclusion, the effects of different rolling reduction, annealing temperature, and soaking hours on damping properties of 3105 aluminium alloy was studied. There were three damping properties that have been analyzed in this project which were loss modulus, storage modulus, and damping capacity. All the damping properties produced the different values due to the various rolling reductions, annealing temperatures, and annealing times. The parameters of rolling reduction and annealing temperature make changes to the grain boundaries. Thus, the grain boundaries gave effects to the value of damping properties. In other words, all these things correlated each other. The hardness values for different rolling reductions, annealing temperatures, and annealing times have been studied. It was shown that the samples before annealing produced the highest value of Vickers hardness.

5. Acknowledgement

The author gratefully thanked Universiti Malaysia Perlis (UniMAP), the dean of School of Materials Engineering and technician for providing the equipment and apparatus to carry out this project.

6. References

1. Keife, H., & Sjögren, C. (1994). A friction model applied in the cold rolling of aluminum strips. *Wear*, 179(1-2), 137-142.
2. Clarebrough, L. M., Hargreaves, M. E., & West, G. W. (1955, October). The release of energy during annealing of deformed metals. In *Proceedings of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* (Vol. 232, No. 1189, pp. 252-270). The Royal Society.
3. Sezek, S., Aksakal, B., & Can, Y. (2008). Analysis of cold and hot plate rolling using dual stream functions. *Materials & Design*, 29(3), 584-596.
4. Martin, J.W. (2007). *Concise encyclopedia of the structure of materials*. 1st Edition, Elsevier, UK.
5. M. N. Mazlee, J. B. Shamsul, Y. Yasmin, S. R. Shamsudin, M. S. Risby and M. Afendi, (2015). The Effects of Rolling Deformation and Annealing Treatment on Damping Capacity of 1200 Aluminium Alloy, *Materials Science Forum*, Vol. 819, pp. 123-128.
6. M. N. Mazlee, J. B. Shamsul & H. Kamarudin. (2010). Comparison of dynamic mechanical properties of non-superheated and superheated A357 alloys. *Kovové Materiály*, 48, 1-6.
7. M. N. Mazlee & J. B. Shamsul. (2008). Microstructure and Damping Properties of Al-Si-Mg/Stainless Steel Composites Produced via Gravity Casting Technique. *Malaysian Journal of Microscopy*, 4, 186-191.
8. Mazlee Mohd Noor, Shamsul Baharin Jamaludin and Zamri Yusoff, Fabrication and Dynamic Mechanical Properties of A357-Stainless Steel Composites, 8th Asian-Australasian Conference on Composite Materials (ACCM-8), 6th-8th November 2012, KLCC, Kuala Lumpur.
9. Lesko, J. (2008). *Industrial Design: Materials and Manufacturing Guide*. 2nd Edition, John Wiley & Sons, Inc, USA.
10. Liu, W. C., & Morris, J. G. (2005). Effect of initial texture on the recrystallization texture of cold rolled AA 5182 aluminum alloy. *Materials Science and Engineering: A*, 402(1), 215-227.
11. Wang, H., Tian, X. F., Yin, C. G., & Huang, Z. H. (2014). The effect of heat treatment and grain size on magnetomechanical damping properties of Fe–13Cr–2Al–1Si alloy. *Materials Science and Engineering: A*, 619, 199-204.
12. Xing, Q., Huang, X., & Hansen, N. (2006). Recovery of heavily cold-rolled aluminium: Effect of local texture. *Metallurgical and Materials Transactions A*, 37(4), 1311-1322.