



Effect of Magnesium Addition on Mechanical Properties of Recycled Aluminium

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ABSTRACT

Aluminium can recycle reduces waste, saves energy, conserves resources, and generates revenue while minimizing landfill use. This paper presents the effect of adding Magnesium (Mg) on the tensile strength and hardness of recycled aluminium from used beverage cans (UBCs). The UBCs were converted into aluminium ingots, various percentages of ingots/as-received magnesium ribbon (3 wt%, 6 wt%, 8 wt%, and 10 wt%) were die casted to Al-Mg alloys. Tensile and Hardness tests were conducted according to the ASTM Standards; ASTM B557 – 15 and ASTM E10 – 12 using Universal and Brinell Hardness, Testing Machines. The tensile strength is improved significantly with the increase in magnesium for all alloys; highest being 33.5Mpa (97.06% increase) for 90 wt% Al-10 wt% Mg (Al-10Mg) and the lowest being 20.8 Mpa (22.35% increase) for 97 wt% Al-3 wt% Mg (Al-3Mg) but the hardness was maximum at (Al-3Mg); 52BHN (160% increase) and minimum at 94 wt% Al-6 wt% Mg (Al-6Mg); 30.5BHN (52.50% increase). These results demonstrate that the present of magnesium particles as dispersion hardening material has impede dislocation movement, enhancing the recycled Al-Mg alloys' mechanical properties; specifi-cally tensile strength and hardness. Hence, the alloy of Al-10Mg configuration is recommended for high tensile strength applications, while that of Al-3Mg is recommended for high hardness applications.

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INTRODUCTION

Aluminium exhibits a complex sustainability paradigm. While its low density contributes to fuel efficiency, primary production via ore processing is highly energy-intensive. Conversely, recycling aluminium scrap substantially enhances its sustainability credentials, with remelting energy requirements approximating 5% of those associated with primary production (Raabe *et al.*, 2022). Currently, recycled scrap accounts for approximately one-third of global aluminium production (Graedel *et al.*, 2011), with projections indicating this share will rise to around 50% by 2050, based on 2019 data from the International Aluminium Institute (Daehn *et al.*, 2022).

Aluminium scrap recycling necessitates differentiation between pre-consumer scrap, typically generated during production with known alloy classifications, and post-consumer scrap, which is often mixed and requires sorting prior to remelting (Bertram *et al.*, 2017). The 2019 data indicates that post-consumer aluminium scrap tonnage is primarily derived from two key sectors: packaging and automotive, with these sources collectively accounting for the largest proportion of scrap volume (IAI, 2021).

In aluminium alloys, magnesium and zinc are highly soluble. The Al-Mg system forms the basis of the 5XXX wrought alloy series, where mechanical properties enhance linearly with increasing magnesium content. This has driven the development of alloys with up to 7% Mg for

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wrought applications and up to 12% Mg for castings. However, higher magnesium levels increase susceptibility to intergranular and stress corrosion. Aluminium-magnesium alloys are widely favored in the automotive and transportation sectors owing to their exceptional formability and outstanding corrosion resistance (Mohammadi *et al.*, 2021; Nomani *et al.*, 2024). Oreko *et al.* (2018) have determined the mechanical properties; specifically tensile strength, impact, and Brinell hardness of locally recycled aluminium alloy scrap. Hadi *et al.* (2020) reported increased in tensile strengths in automobile brake lining and drum material scraps-magnesium alloys. To the best of our knowledge, there has been no research on the effect of magnesium addition on the mechanical properties of post-consumer aluminium scrap from packaging sector; specifically used beverage cans (UBCs).

EXPERIMENTAL

For the preparation of this aluminium-based alloy, the aluminium ingots were produced from scraps of used can drinks; Figure 1. The scrap was received from a scrap dealer at Kofar Ruwa Market in Kano. The alloying element, Magnesium, was obtained in magnesium metal ribbon form; Figure 2, as-received from Toteil Limited, Niger Street, Kano. The magnesium metal ribbon contains 99% of Magnesium and 1% of Zinc and Lead.



Figure 1: Used aluminium can as-obtained from Kofar Ruwa



Figure 2: Magnesium metal ribbon as-received from Total Ltd.

Production of the Recycled Aluminium Ingots

Several used aluminium cans for drink were gathered and compressed to fit into the crucible. All were put inside the crucible and the crucible was put on blacksmith's hearth. An attached blower to the hearth was used to blow a hot charcoal that is already in the hearth to generate heat and melt the scraps at above 400°C. The impurities were removed, and the remaining pure recycled aluminium was cast to ingots; Figure 4, using a mould. A local blacksmith workshop was used for the casting process; Figure 3.



Figure 3: a) Local blacksmith's hearth b) a blower buried in the sand and connected to the hearth (Zawaciki, Kano)

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Figure 4: As-cast aluminium ingots

Alloy Casting (Die casting)

The blacksmith's hearth was heated with charcoal and attached to the hearth is a blower to be blowing the charcoal for source of heat. A weighed number of aluminium ingots was put into the crucible and the crucible was placed on the furnace. The tong, slag removing tool and the mould were kept close to the furnace to avoid moisture. When the temperature of the melted aluminium reached about 450°C, it was then stirred with the tong. The magnesium metal ribbon according to the weight % were added into the crucible. The crucible was then heated for about 5 minutes. The crucible was then taken out and the melted alloy was poured into the mould. Similarly, the aluminium alloys; Figure 5 were produced using varying composition of magnesium (3 wt%, 6 wt%, 8 wt%, 10 wt%) and aluminium the balance. Three specimens for each composition were produced to test for both Tensile and Hardness properties. A metal of cylindrical shape of 150mm in length and 18mm in diameter was used as a mould for the casting process.



Figure 5: Al-Mg alloy produced from recycled Al and magnesium ribbon

Tensile Test

A total of 12 specimens (i.e. 3 for each composition) were prepared and the tensile test was conducted using the Universal Testing Machine. the tests were carried out at a room temperature and in accordance with the ASTM B557 – 15 Standard. The 12 specimens were tested, and the average values of the tensile strength are reported in Figure 6. The test specimen was loaded on a Universal Testing Machine at a crosshead speed of 5 mm/min until the specimen failed.

Hardness Test

The hardness test of the alloys was conducted using Brinell Hardness Testing Machine. The test conditions were ball indenter with a diameter of 10 mm, indentation force of 500 kg and dwelling time 30 s as mentioned. The hardness test was conducted according to ASTM E10 – 12 standards. 3 readings were taken for each specimen at different locations to avoid the possible effect of any alloying element exclusion and their values were recorded as depicted in Figure 7.

RESULTS AND DISCUSSION

Result of Tensile Tests

The tensile strengths of the same alloy with different percentage of alloying elements are shown in Figure 6, it is evident that the tensile strength increases from 3 wt% Mg to 6 wt% of Mg, and then it increases with addition of Mg up to 8 wt% and 10 wt%. Similar trend has been reported by Hadi et al. (2020), Shittu et al. (2021) and Nomani et al. (2024). They respectively associated the increment due to the formation Mg₂Si, dispersion of Mg particles, and intermetallic compound Al₃Mg₂.

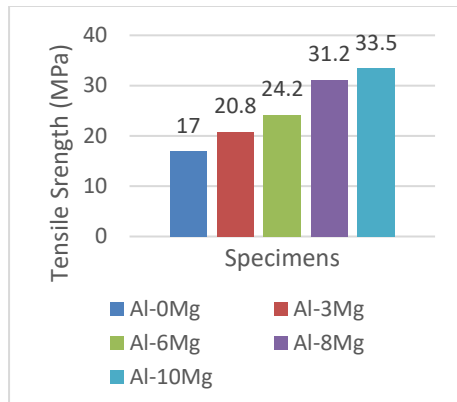


Figure 6: Tensile Strengths Comparison with unalloyed specimen

Result of Hardness Test

The hardness values obtained for Al-3Mg is 52HB; 160% increase as compared to unalloyed Al, which is the highest hardness value among the four alloys. It was also discovered that when Mg is increased to 6% the hardness value dropped to about 30.5HB; 52.50% increase as compared to unalloyed Al, and at 8% of Mg there is an increment to 32HB and at 10% Mg there is an increase to about 45HB. The Hardness behavior of the alloys is presented in Figure 7. Similar trend for hardness has been reported by Nomani et al. (2024), who describe that the anomaly could be due to coarsening of the second phase precipitate of Al_3Mg_2 that could not restrict the movement of dislocation effectively.

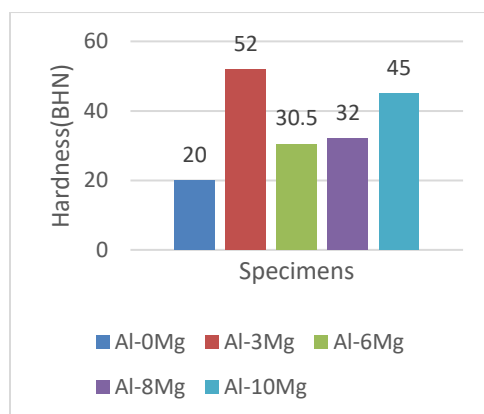


Figure 7 Hardness Comparison with unalloyed Specimen

CONCLUSION

1. Recycling aluminium translates to less energy used, reduced carbon emissions, save money for businesses, and end users.
2. To some extent the tensile and hardness properties of Al-10Mg are the best when compared with other variations of alloyed/unalloyed recycled Al

REFERENCES

- Bertram, M., Ramkumar, S., Rechberger, H., Rombach, G., Bayliss, C., Martchek, K.J., Müller, D.B. and Liu, G., 2017. A regionally-linked, dynamic material flow modelling tool for rolled, extruded and cast aluminium products. *Resources, Conservation and Recycling*, 125, pp.48-69.
- Daehn, K., Basuhi, R., Gregory, J., Berlinger, M., Somjit, V. and Olivetti, E.A., 2022. Innovations to decarbonize materials industries. *Nature Reviews Materials*, 7(4), pp.275-294.
- Graedel, Thomas E., Julian Allwood, Jean-Pierre Birat, Matthias Buchert, Christian Hagelüken, Barbara K. Reck, Scott F. Sibley, and Guido Sonnemann. "What do we know about metal recycling rates?." *Journal of Industrial Ecology* 15, no. 3 (2011): 355-366.
- Hadi, S., Aziz, A.H.N., Nugroho, P.W., Rizza, M.A. and Wicaksono, H., 2020. The Effect of Mg Adding in Recycled Aluminum Casting on Tensile Strength and Microstructure. *Logic: Jurnal Rancang Bangun dan Teknologi*, 20(3), pp.145-151.
- Hardness, A.B., 2015. Standard Test Method for Brinell Hardness of Metallic Materials1. International Aluminium Institute. Global Aluminium Cycle 2019. Alucycle 2021
- Mohammadi, A., Enikeev, N.A., Murashkin, M.Y., Arita, M. and Edalati, K., 2021. Developing age-hardenable Al-Zr alloy by ultra-severe plastic deformation: Significance of supersaturation,

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- segregation and precipitation on hardening and electrical conductivity. *Acta Materialia*, 203, p.116503.
- Nomani, M., Akter, A. and Haque, M.S., 2024. Effect of Mg Addition on the Improvement of the Mechanical Properties of Aluminum. *Available at SSRN 4874313*.
- Oreko, B.U., Samuel, O.D., Idi, S. and Fayomi, O.S., 2018, September. Evaluation of Mechanical Properties of Locally Recycled Aluminium Alloy Scrap. In *IOP Conference Series: Materials Science and Engineering* (Vol. 413, No. 1, p. 012024). IOP Publishing.
- Shittu, M.D., Olaniyi, A.E., Daniyan, A.A., Isadare, D.A., Oluwasegun, K.M. and Ibitoye, S.A., 2021. Effect of magnesium on some mechanical properties of 1200 Aluminium alloy. *Ife Journal of Science*, 23(2), pp.147-152.
- Standard, A.S.T.M., 2010. Standard Test Methods for Tension Testing Wrought and Cast Aluminum-and Magnesium-Alloy Products. *Annual Book of ASTM Standards*, 2.