Recycling of Aluminum Scrap by Shear Assisted Extrusion

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Introduction

Automotive manufacturers are interested in recycled aluminum because it generates 95% less CO_2, requires 95% less energy, and produces 90% less solid waste during production than primary aluminum [1,2]. Twitch, an aluminum scrap made from 20-80% automotive scrap, costs 59% less than primary aluminum making it appealing to manufacturers focused on sustainability [3,4]. Twitch is often too rich in Si, Cu, Fe, Mn, and Mg to produce wrought parts without dilution with primary aluminum. Pre-consumer scraps, such as 6061, have cleaner compositions and may provide an alternative dilution option.

Shear Assisted Processing and Extrusion (ShAPE) combines friction and deformation to soften aluminum scrap so that it can be extruded through a die. This deformation may help to overcome the challenges of excess alloying elements, as the alloy microstructure is refined during extrusion.

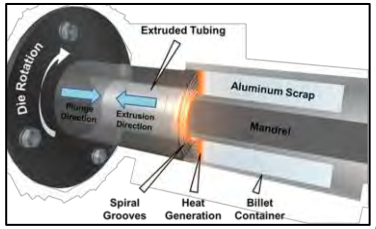

Fig. 1 Diagram of ShAPE

The goal of this project is to determine if Twitch mixed with pre-consumer scrap and extruded with ShAPE produces an alloy suitable for wrought products.

Materials And Methods

Three mixtures of Twitch and 6061 were cast into billets:

Alloy	Twitch (%)	6061 (%)	Si (Wt%)	Fe (Wt%)	Cu (Wt%)	Mn (Wt%)	Mg (Wt%)
6061	0	100	0.6	0.4	0.3	0.1	1
C1	100	0	3.7	0.5	1.1	0.4	0.5
C2	75	25	2.9	0.5	0.9	0.3	0.6
C3	50	50	2.1	0.4	0.7	0.2	0.8

Each billet was homogenized, then extruded at 525 °C into a tube with an outside diameter of 12 mm and a wall thickness of 1 mm (Fig. 2). The tubes were aged to T6 temper, then sectioned into 5" lengths for tensile testing and 1" lengths for microstructural analysis with energy-dispersive spectroscopy (EDS).

Fig. 2 Twitch scrap, homogenized billet, and extruded tube

Research Highlights

An aluminum alloy comparable to industry alloys can be made from 100% secondary scrap

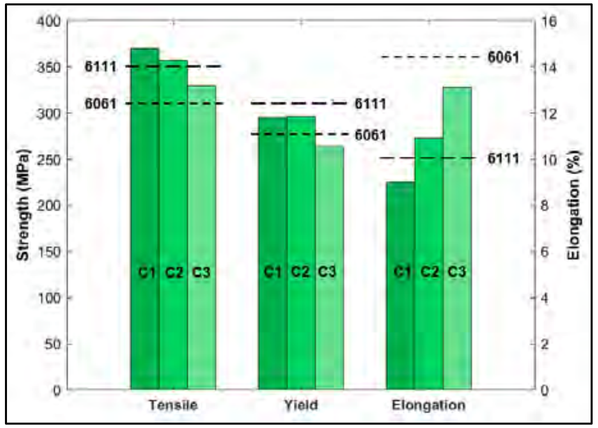

Fig. 5 Mechanical properties of Twitch/6061 and ASM alloys [5]

Processing with ShAPE removes the need for primary aluminum, reducing CO_2 emissions and required energy by 95% while producing 90% less waste.

Results

Si, Si-Mg and Fe-Mn rich intermetallic phases are present on the grain boundaries and in the interdendritic regions after homogenization (Fig. 3A). After extrusion, these particles become finer and more dispersed (Fig. 3B).

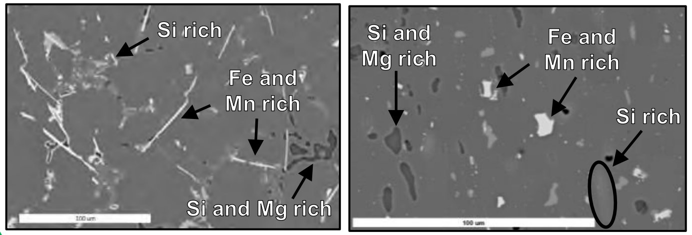

Fig. 3A and 3B Homogenized and extruded microstructures of C2

By comparison of the compositions using a MATLAB script (Fig. 4), the cast alloys should have similar mechanical properties to the industry alloy 6111 (Fig. 5).

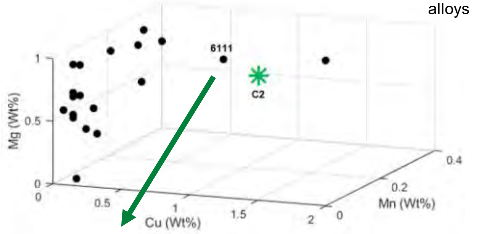

Fig. 4 Comparison of C2 and industry alloys

Alloy	Si (Wt%)	Fe (Wt%)	Cu (Wt%)	Mn (Wt%)	Mg (Wt%)
6111	0.9	0.2	0.7	0.3	0.8

Discussion and Conclusions

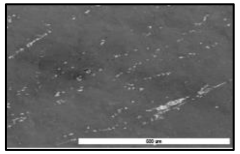

Fig. 6 Rolled 6111 microstructure [6]

The extruded microstructure has refined precipitates like the rolled 6111 structure, leading to comparable strength and ductility (Fig. 6). The increase in strength with increasing Twitch content is expected because Twitch contains excess Si, Mg, and Cu, which strengthen the alloy through formation of additional precipitates. However, excess Si appears to causes a decrease in ductility, as Si-rich precipitates are brittle. These trends show that the mixture of Twitch and pre-consumer scrap can be tailored to provide desired mechanical properties.

Future work will include analysis of corrosion properties, surface finish, and anodizing performance. Combinations with other scrap streams provide further alloying opportunities, such as the inclusion of used beverage cans (UBC) to produce alloys with lower Si and higher Mg contents.

Acknowledgements Research was funded by the U.S. Department of Energy Vehicle Technologies Office (DOE/VTO) LightMAT Program. Pacific Northwest National Laboratory is operated by Battelle Memorial Institute for the United States Department of Energy under contract DE-AC05-76RL01830.

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IR # PNNL-SA-187150