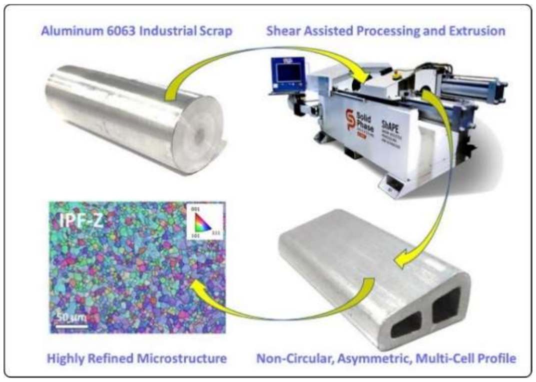
Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Automotive Components

CHALLENGE

The use of lightweight aluminum extrusions in the automotive industry is increasing at a rapid rate due to the electrification of passenger vehicles. Multicell aluminum extrusions are used extensively in the battery tray to absorb energy and enable more efficient structures for electric vehicles. Many battery tray designs incorporate a combination of aluminum extrusions and advanced high strength steel. The aluminum extrusion absorbs energy during a collision event, minimizing the g-force imposed on the occupants, and the advanced high strength steel avoids intrusion into the battery cell area, preventing a thermal event associated with breaching the battery cell.



A porthole die configuration is integrated within the rotating ShAPE process to extrude circular, square, trapezoidal, and 2-cell trapezoidal profiles from aluminum alloy 6063 (AA6063) industrial scrap.

Although multicell extruded aluminum profiles are efficient energy absorbers and effective as structural components, the greenhouse gas emissions associated with the manufacture of aluminum components using conventional processing methods remains high. Secondary aluminum extrusion alloys are typically comprised of 22 to 30 percent primary aluminum. Primary aluminum is used to dilute and combat the levels of iron and other undesirable elements imposed by the remelting process used to recycle aluminum scrap by conventional means.

SOLUTION

Magna International, the largest automotive supplier in North America, engaged in an industry-led LightMAT project with Pacific Northwest National Laboratory to evaluate the feasibility of scaling the ShAPE process to manufacture multicell asymmetric aluminum extrusions comprised of 100 percent secondary scrap for electric vehicle battery tray applications.

In addition to the reduction in manufacturing cost associated with using secondary feedstock and increased process yield, ShAPE processing of secondary feedstock reduces the embodied energy by more than 50 percent and the carbon dioxide emissions by more than 90 percent, relative to conventional extrusion processing of primary aluminum.

The project approach included a systematic increase in complexity to evaluate the effects of chemical composition, billet homogenization and extrusion geometry associated with nominal 2 mm wall extruded profiles, demonstrating the ability to extrude noncircular, asymmetric, multicellular profiles comprised of unhomogenized secondary aluminum scrap

RESULTS

The ShAPE process evolved from a drawn over mandrel manufacturing process capable of producing round extruded profiles to a direct extrusion process capable of producing multicell profiles using a port hole die and a rotating billet better suited to enable scaling of the ShAPE process for commercial use. Round, square, trapezoidal, and 2-cell trapezoidal profiles were successfully manufactured using the ShAPE process and examined using scanning electron microscopy and electron backscatter diffraction. The results include a refined and homogeneous microstructure, excellent mechanical properties, and absence of detectable weld seams.

Extrusions made from AA6063 industrial scrap by ShAPE producing (a) circular, (b) square, (c) trapezoidal, and (d) two-cell trapezoidal profiles.

Tensile properties associated with ShAPE extruded profiles comprised of 100 percent scrap Al 6063, containing elevated levers of iron (0.34 percent Fe) met or exceeded ASTM and ASM standards.

Al 6063 Feedstock	Method	Yield Strength (MPa)	Ultimate Strength (MPa)	Elongation (%)
Wrought T5	Floating Mandrel	198 ± 16	243 ± 14	11.0 ± 6.9
Chipped Briquette, 100% Secondary Al	Floating Mandrel	204 ± 9	231 ± 8	17
Unhomogenized Casting, 100% Secondary Al	Porthole Die	247 ± 10	271 ± 10	16.5 ± 2.4
Unhomogenized Casting, 100% Secondary Al 0.34 wt% Fe	Floating Mandrel	206 ± 5	238 ± 5	16.3 ± 1.1
ASTM Minimum Standard for Primary Aluminum	N/A	170	205	8
ASTM Typical Values for Primary Aluminum	N/A	214	241	12

IMPACT

The results associated with the LightMAT project demonstrated the feasibility of scaling the ShAPE process to manufacture multicell asymmetric aluminum extrusions comprised of 100 percent secondary scrap and iron levels up to 0.34 percent for electric vehicle battery tray applications, providing a significant reduction in cost and total embodied energy.