Aluminum Recycling: Economic and Environmental Benefits

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Probably the most significant property of aluminum is its ability to be recycled repeatedly without loss of product integrity and minimal material loss through oxidation (~1-2%). Further, recycling saves ~95% of the energy and emissions as compared to making it from the original ore, a key factor in a carbon-constrained world. The recycling advantage is demonstrated every day with the beverage can, which can be sold, consumed, recycled, and be available again in the store in as little as 60 days. In the past few years, the volume of aluminum recycled from automotive applications has surpassed that from beverage cans. This growing aluminum use in automotive applications, especially of recycled aluminum, is significant in that it decreases vehicle mass, improves fuel efficiency, and reduces emissions. Eventually, this application is anticipated to beneficially impact the carbon footprint of the aluminum industry.

Benefits of Recycling

In addition to energy and emissions savings, recycling has become a valuable source of metal units to the industry, reducing imports and helping the balance of payments. Recycling also requires only about 10% of invested capital compared to smelting, increases employment, helps to maintain a viable fabrication and manufacturing base, eliminates a good deal of landfill waste, and reduces climate change issues for the industry.

Comprehensive and ongoing surveys of the industry have quantified the benefits of aluminum recycling.[1,2,3] The production of primary aluminum, when all the electrical generation, transmission losses, and transportation fuels have been accounted for, requires ~45 kWh of energy and emits ~12 kg of CO_2 for each kilogram of metal. By contrast, the recycling of aluminum requires only ~2.8 kWh of energy and emits only~0.6 kg of CO_2 for each kilogram of metal. Thus, ~95% of the energy and ~95% of the environmental emissions are saved when the metal is recycled. The energy banked in the metal during the initial smelting process is recovered, with only minor losses, each time the material is recycled.

The document, "Aluminum Industry Vision,"[4] notes that the electrical energy embedded in metallic aluminum when first reduced from the ore can be considered as an "energy bank," because it can be recovered indefinitely during recycling. Thus, from a sustainability viewpoint, aluminum recycling is tapping into a convenient "urban mine" of material that enables reuse while saving energy and reducing environmental impacts. This urban mine analogy is becoming increasingly real as the amount of aluminum in vehicles continues to increase in order to reduce weight, increase fuel efficiency, and enhance safety, and as modern buildings incorporate more metal (e.g.. in curtain wall designs).

Shredding and Sorting Technology

The collection of aluminum components for recycling breaks down into several streams. Beverage cans and similar packages are generally captured in MRFs and find their way back to an aluminum recycler through an established dealer network. Beverage can remelting procedures have evolved to control the buildup of impurities such as Fe and Si in the alloys involved (i.e. 3004, 3104, and 5182). Currently, the recycling rate for beverage cans is ~54%, whereas the capture of the aluminum content of a scrapped automobile is >90%. This discrepancy is likely due to the fact that recycling of beverage cans is mostly voluntary, while regulations require that automobiles and other large consumer durables, like freezers and washing machines, etc., be recycled. If you eliminate individual choice, then the recycling rate increases. As an incentive to collect cans, deposit laws generally increase recycling in states where they have been applied to reduce littering. However, the industry has been reluctant to advocate this approach and has preferred to rely on volunteer efforts to recycle cans.

High strength 2xxx and 7xxx alloys used in aircraft and aerospace generally are not recycled, as old planes are stored in desert sites and are selectively dismantled as a source of spare parts. A recertified aircraft component has a much greater economic value than aluminum scrap, so the bulk of commercial shredder streams today consist of automotive hulks and old consumer durables, mostly composed of the 3xxx, 5xxx, and 6xxx alloys.

A paper by Gesing, Wolanski, and Dalton in 2003 breaks down the infrastructure of the recycling of aluminum from automobiles.[5] More than 6,000 collection and dismantling operations throughout the country supply material to about 200 shredders, where the iron content is magnetically separated from the stream following shredding. The remaining metallic recyclables are then sorted in about ten sink-float density separation plants, where the heavier metals like copper, brass, lead, bronze, etc. are separated from the lighter metals of aluminum and magnesium. This non-magnetic shredder fraction, which is composed of ~75% aluminum alloy, is finally shipped to the nation's main sorting plant, Huron Valley Steel Corporation (HVSC), in Belleville, MI, for final treatment. Undoubtedly the number of plants in each category may have changed in the interim but this discussion serves to illustrate the process by which an aluminum-rich recycle stream is obtained.

HVSC has been actively pioneering the development of more sophisticated sorting technology. Some of this work has been in collaboration with the major automobile companies and with The Aluminum Association. Techniques like eddy current, color sorting, x-ray, and laser induced break-down spectroscopy (LIBS) have all been employed and have demonstrated the feasibility of ultimately sorting aluminum material down to an individual alloy basis. In fact, with the success of the technological developments at HVSC, a sorting operation involving LIBS for the treatment of 50,000 tons a year was brought on stream in 2003.

LIBS technology demonstrates the ability to separate Al-Mg (5xxx) alloys from Al-Si-Mg (6xxx) alloys. Both these alloy series are used extensively in automotive construction, thus this sorting capability will undoubtedly be useful in the future. Another benefit of LIBS is that the costs of the technology are anticipated to fall as the costs of laser and computer equipment continues to decrease.

Another suggestion to improve the efficiency of sorting operations was made by Gesing during a workshop on Automotive Lightweight Metals Recycling held in Detroit, MI, in 2008.[6] Often in sorting systems, both aluminum and magnesium are commingled in the light metal stream. Gesing advocated that it would be important to separate these two streams. This would reduce aluminum and magnesium losses in the event of subsequent fluxing to control impurity levels, as well as help grow a viable secondary magnesium industry, which will be needed in the future.

The Issue of Impurities

HVSC does now sell various sorted aluminum products, which help to preserve as much value in the aluminum as possible. For example, HVSC can readily separate cast alloys from wrought alloy and sells batches of material accordingly. This is important since a build up of Si and Fe impurities can gradually occur with scrap processing. In time, if these impurities build up to significant levels, they cause difficulties with mechanical properties, fracture toughness, and corrosion performance.

The separation of cast and wrought alloys enables cast scrap to be recycled into new cast products. Castings have a much wider range and tolerance for Si and Fe impurities. For instance, the nominal compositional value for Si and Fe in alloy AA 356.0, a common casting alloy, is 7.0 and 0.6 weight%, respectively. The high silicon value confers excellent fluidity when the metal is cast.

Wrought aluminum alloys on the other hand are much less tolerant of Si and Fe and other impurities, and their composition limits are correspondingly tighter. In this regard, it is useful to have the capability of LIBS technology to sort material down to an alloy-by-alloy basis.[5] This capability, though technically feasible, is not yet in demand commercially. However, LIBS technology could be used to reject particles with high Fe content, setting aside that material to be used as deoxidation product for the steel industry. Note that deoxidation products contain relatively high Fe content, and thus is a win-win product for both the steel and aluminum industries. For steel, oxygen content is reduced by the addition of aluminum and Fe content adds to the steel inventory, while for aluminum, this represents a viable product line and a significant outlet for a troublesome impurity.

In all scrap handling and processing operations, the concept should be to preserve as much of the value of the original aluminum as possible, to minimize further energy input, and therefore constrain the carbon footprint of the overall process. Consistent with this approach, the aluminum industry should develop more recycling compatible aluminum alloys. Furthermore, automotive designers should be urged to use these recycling compatible alloys and to limit the variations of alloys used, thereby, minimizing recycling impurity issues. In an analogous manner to beverage can recycling, where the impurities levels of the alloys 3004 and 3104 (used in the can wall) and alloy 5182 (used for the can lid/tab) are compatible across the whole range of elements during remelting (with the exception of Mg, which can be easily removed by fluxing), it would be critical to simplify alloys use in automotive design. This may be difficult to achieve due to the differing performance requirements of various components. However, some progress is being made in this direction as companies like Toyota use alloy 6022 for both inner (-O temper with greater formability) and outer (-T4 temper with greater strength and dent resistance) body components. In this way, compatibility issues with alloy impurities are reduced.

New Applications of Aluminum

In a carbon-constrained world, the recycling of aluminum is pivotal to the continued growth of the aluminum industry as a greater percentage of the metal used will need to come from recycling. In a recent monograph, the International Aluminium Institute (IAI) details the growth and progress of the global recycling industry and how it is a cornerstone of sustainable development.[7] It shows that the recycling industry has increased its output by almost 400% from 5 million metric tons in 1980 to close to 18 million metric tons in 2007 from old and new traded scrap. Meanwhile, during the same time, primary aluminum use has only increased by 250% from 15 to 38 million metric tons (Figure 1).

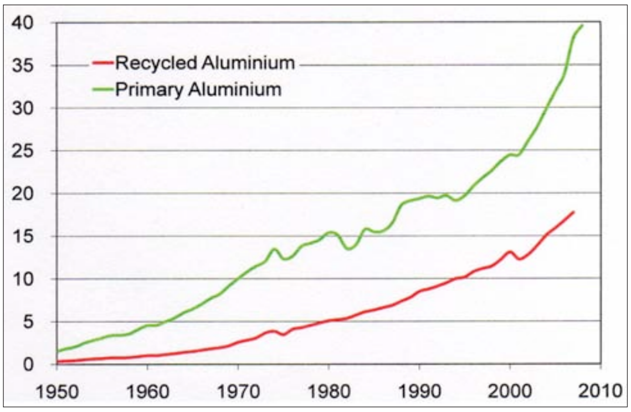

Figure 1. Growth of aluminum supplies per IAI flow models.

While recycling will clearly help the industry to grow, especially in North America where the smelting portion of the industry is declining, nothing will help the industry grow like the continuous development of unique and compelling new applications for the metal.

Energy Generation: Aluminum has always been the preferred material for vertical axis wind turbines, where the long struts are a fine fit for the extrusion process. More recently, premium quality aluminum castings are being evaluated for rotor hubs of large horizontal axis wind turbines, where the need for superior fatigue and corrosion resistance is key. For example, Southwest Windpower has indicated that it has selected aluminum castings for several tower-top components in their wind turbines.[8] Permanent mold cast A356.0-T6 was selected for the nacelle, face, yaw shaft, and blade due to its superior soundness and surface quality, as well as the properties of the PM casting as compared to die cast alloys such as 380.0-F or T6. Likewise, Lucid Energy Technologies is developing a new design of turbine that is being considered for use both in wind applications and under water, i.e. in streams.[9,10] The concept is to develop a turbine generator for a distributed electrical system, which would especially be adaptable for application in rural areas. In the turbine design, slats of aluminum extrusions are mounted vertically around the circumference of the turbine. The Lucid wind/water turbine is undergoing testing and appears to have much promise.

The application of aluminum in solar power generation is also anticipated to increase substantially. For example, Hydro Aluminum's Extrusion Americas unit has signed an agreement with Florida Power and Light to supply custom aluminum extrusions for the first hybrid solar/fossil fuel energy generating facility in the world.[11] When it comes on line in 2010, the plant will produce 75 MW of electricity and will be the second largest solar plant in the world. Hydro will produce the frames, supports, legs and connectors that will raise the 180,000 curved mirrors off the ground and allow them to track the sun throughout the day. According to Hydro, the extruded aluminum frames provide enough torsional resistance to withstand hurricanes. The company adds that the manufacturing process allows the frames, which contain a high percent of recycled metal, to be machined to precise tolerances for quick assembly. With prior experience from a plant in Nevada, the company claims that aluminum is ideal for structural frames for the massive project because of its lightweight, high strength, and corrosion resistance. A good amount of aluminum paneling and structural members are going into solar panel construction as well.

Architectural Applications: Aluminum is increasingly being used in architectural design, with applications such as curtain walls, facades, roofing, and shading louvers, as well as in interior design. An excellent example of this aluminum architectural use can be seen in the new NFL stadia currently being constructed and refurbished, with large quantities of aluminum specified in each case. The combination of the innate properties of aluminum as well as its attractive appearance, extrudability, and recyclability—is critical to the success of each project.

In New Orleans, new aluminum panels are being installed on the Louisiana Superdome's exterior walls (Figure 2). The work marks the final phase of a $219 million facelift following Hurricane Katrina. Approximately 16,000 panels, representing about 220 tons of aluminum and featuring a custom anodized light bronze finish, will cover the 365,000 sq. ft. exterior. The panels are being roll formed in Michigan City, IN, by the company Kalzip FC. Furthermore, an all aluminum scaffolding system has been specially designed to fit the curvature of the wall, allowing for panels to be easily removed and replaced. Installation is expected to be completed in the spring of this year.

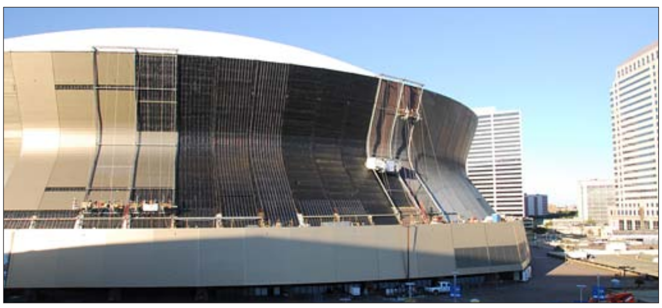

Figure 2. Installation of the anodized aluminum panels has begun on the exterior of the Louisiana Superdome.

The New Meadowlands Stadium in East Rutherford, NJ, a 50/50 joint venture between the New York Giants and the Jets, recently completed installation of 30 miles of mobile aluminum louvers that cover the eight levels of the building exterior. Made of 10% recycled aluminum, the louvers create a sleek profile, which rotates and combines with the stadium's interior lighting to allow the stadium to easily switch colors, depending on which team is playing. The light weight of the metal facilitates the movement of the louvers.

Aluminum in Passenger Vehicles

A recent Ducker assessment, suggests that the aluminum content of the average North American vehicle will increase by 4-6 lbs per year through 2020.[12] This growth is due to the various properties of aluminum, which allow for improved fuel efficiency, vehicle performance, and safety. The new fuel efficiency standards, mandated by the Obama administration, will further emphasize this trend. Weight reduction is critical for fuel savings in that a lighter vehicle requires a smaller powertrain and thus less energy to operate. It has been found that a 10% reduction in vehicle weight translates to a fuel savings of ~7%.[13]

This fuel savings can have an additional benefit regarding greenhouse gases. It has been estimated that in automobiles, the use of 1 ton of aluminum can displace 2 tons of conventional materials (steels), eliminating 20 tons of CO_2 emissions over the lifetime of an average vehicle. This estimate assumes a vehicle life of 120,000 miles, an aluminum use comprised of 74% cast, 23% extruded, and 3% rolled aluminum, and the industry recycling rates in effect in 1998.[4]

More recent material flow modeling, based on the technology available in the industry in 2003, provides further ramifications. The fuel efficiency and emission savings due to the use of aluminum in transportation can be contrasted with the emissions generated from the global production of aluminum used in transportation. This contrast shows that the emissions savings from using aluminum in transportation are increasing at a greater rate than the emissions generated to produce the aluminum required. When these two curves cross, the aluminum industry will be saving more emissions than it will be producing, and will thus have a "negative" carbon footprint.[12] When this drift into a negative carbon foot print will occur depends on a variety of factors, including how quickly aluminum use in transportation increases, what improvements in smelting efficiency occurs in coming years, and the amount of recycled material employed. However, metal flow models suggest that this crossover into a negative footprint will occur around the year 2020.[14]

Conclusion

Material flow models demonstrate that about 70% of all the aluminum ever produced, since the Hall-Heroult process was discovered in 1886, is still in active use today. This is a testament to the economic value of recycling, which has occurred within the industry without regulation or government mandate and is due to an awareness of the intrinsic value of the metal. In this current carbon-constrained world, recycling makes more economic and environmental sense than ever before.

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