Trends in the Global Aluminum Fabrication Industry

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The aluminum fabrication industry has become more vital to the global economy as international aluminum consumption has grown steadily in the past decades. Using innovation, value, and sustainability, the aluminum industry is strengthening its position not only in traditional packaging and construction applications but also in the automotive and aerospace markets to become more competitive and to face challenges from other industries and higher industrial standards. The aluminum fabrication industry has experienced a significant geographical shift caused by rapid growth in emerging markets in countries such as Brazil, Russia, India, and China. Market growth and distribution will vary with different patterns of geography and social development; the aluminum industry must be part of the transformation and keep pace with market developments to benefit.

INTRODUCTION

The aluminum industry makes a substantial contribution to the global economy and to individual national economies in more than 30 countries. Forty-five million tonnes of annually fabricated production, including ~14 million tonnes from recycled aluminum,[1–4] make aluminum the most recycled material and the second most used metal in the world. (See the sidebar for more on sustainability in the aluminum industry.) The aluminum industry directly employs more than one million people worldwide and indirectly generates four times as many jobs in downstream and service industries. The U.S. aluminum market is the largest, consuming about 10 million tonnes in products and imports in 2005.[4]

The top markets for the aluminum industry include transportation, packaging, building, and construction. Transportation continues to be the largest market, accounting for 30% of the total aluminum output. As the transportation industry faces growing demand for high fuel efficiency and low gas emissions, aluminum will become an increasingly important factor, offering attractive properties and light weight for aerospace and automotive applications.

AEROSPACE APPLICATIONS

Aluminum comprises ~80% of the unladen weight of an aircraft; the standard Boeing 747 jumbo jet contains ~75,000 kg of aluminum. Because aluminum is corrosion resistant, the metal does not need painting, which can save several hundred kilograms of weight if airlines choose not to paint their planes.

In the past 30 years, the weight of the passenger car doubled as horsepower and performance increased, and aluminum has been used increasingly by the industry to keep vehicle weight under control.

Currently there are approximately 5,300 commercial passenger aircraft and many thousands of light aircraft and helicopters worldwide, and the demand for commercial aircraft is expected to increase by ~60% in the next decade. North America is the leading player in the global aerospace industry, with a 39% share in 2005 shipments. As the North American market matures, Asia will become the driving force behind growth in the industry, led by the rapid growth in civil aviation in China and India.

AUTOMOTIVE INDUSTRIES

Aluminum has made great strides in taking a portion of the automotive spotlight from steel, especially considering its relatively recent entrance into not only the automotive industry but also the metal industry.[4,7–9] According to the Aluminum Association, the use of automotive aluminum quadrupled between 1991 and 2005. Annual global vehicle production is expected to increase by 11 million to reach 67.8 million in 2009; with a 3% annual growth rate, aluminum consumption could be even greater in this industry. A recent global study by Ducker Research Company on aluminum content in light vehicles showed that the aluminum content has maintained consistent, uninterrupted, annual growth for the last 30 years and is expected to continue to climb at a rate of approximately 3.6–4.5 kg/vehicle, or about 3%, for the near future.[7] These percentages will fluctuate before stabilizing if the use of aluminum grows as predicted.

The rise in energy costs and the need for emissions reduction worldwide make aluminum more attractive for automotive use. In the past 30 years, the weight of the passenger car doubled as horsepower and performance increased, and aluminum has been used increasingly by the industry to keep vehicle weight under control.

The oil crisis in the 1970s made people aware of the need for fuel-efficient cars, and recent energy price hikes demand speedy action for weight reduction. This

further drives the increased use of aluminum, which already has been applied in a variety of parts, including the engine, body, hood, and front end. The Ducker report stated that 61.9% of passenger car and light truck aluminum content is castings for the components, such as engine blocks, cylinder heads, and manifolds. Another 12.9% of the aluminum content of a typical North American-built car or light truck is aluminum foil, largely for heat exchangers such as the radiator. According to the report, the remaining aluminum applications include wheels (15.7%, mostly castings), exterior trim and interiors (4.6%), chassis and suspensions (2.6%), closure panels (1.2%, mostly hoods), body structures (0.7%), and bumper systems (0.4%).

SUSTAINABILITY OF THE ALUMINUM FABRICATION INDUSTRY

It is estimated that while annual production of primary aluminum from bauxite is 32 million tonnes, there are still 400 million tonnes of the metal in use that will eventually be available for recycling. Today, the secondary aluminum stream is becoming an even more important component of aluminum production and is attractive because of its economic and environmental benefits, which can significantly improve the sustainability of the aluminum fabrication industry.

Aluminum has been referred to as an "energy bank" in that once the energy has been invested in it through the smelting process it can be effectively drawn upon again through recycling. It requires 45 kWh to produce 1 kg of primary aluminum, whereas the same amount of secondary aluminum produced from recycled metal requires only 2.8 kWh. Recycling aluminum saves 95% of the energy to produce virgin aluminum, whereas recycling steel saves between 40% and 75% of the energy required to produce virgin steel from its ore. This is mostly a function of the higher melting temperature of steel as compared to aluminum.

Primary aluminum production consumes 2% of the worldwide electricity supply, and one-third of the total energy consumption in primary aluminum production comes from coal-generated electricity. Air pollution from primary smelting includes hundreds of thousands of tonnes of carbon dioxide and nitrogen oxide, which can be controlled by environmentally friendly practices such as recycling. According to the Bureau of International Recycling, the energy saved by recycling lead, steel, copper, and aluminum is 65%, 74%, 85%, and 95%, respectively, as compared to primary production. Energy saved translates into reduced environmental emissions, which means recycling aluminum scrap emits only 5% of the carbon dioxide produced in making new primary metal.

Recycling aluminum alloys provides major economic benefits. In the United States, shipments of aluminum in the form of both wrought and cast products have increased from 8 million tonnes in 1992 to 10 million tonnes in 2002, while primary aluminum production has been shrinking. Although imports have increased, secondary aluminum has become an increasingly important component of metal supply. Secondary aluminum benefits the aluminum fabrication industry by using low-cost, recycled aluminum instead of expensive primary aluminum. To survive in this competitive market of high energy and raw material costs and relatively low finished goods prices, producers must minimize conversion costs while maximizing the recoverable metal units.

In the case of the aluminum beverage can, the significant economic advantages of aluminum recycling have also been demonstrated[5,6] in a joint study by Secat, the Center for Aluminum Technology, and the Sloan Industry Center for a Sustainable Aluminum Industry, which showed that for each 1% increase in the amount of aluminum cans recycled, the savings to the U.S. economy is $16 million per year. This value could approach $800 million if all available cans were recycled.

Despite the benefits of recycling aluminum cans, the industry is facing a new challenge as recycling rates decline. Whereas aluminum recycling in sectors such as transportation and construction is about 95% in North America, only 52% of recovered beverage cans were recycled in 2005 as compared with 67% in 1992. By comparison, the global recycling rate averages 63%.

One of the major tasks in building a sustainable aluminum fabrication industry is to develop recycling-friendly alloys. So far, the identification of new alloys that will more readily use recycled aluminum has received little attention and, in fact, is considered impractical by some because of the generally negative effects of impurity elements. However, the potential economic and environmental benefits are sufficiently great that it is indeed useful to consider this approach.

CHANGING PATTERN OF THE GLOBAL MARKET

The global geography of the aluminum fabrication industry has experienced major reconstructive and geographic changes driven by energy, environment, and market. In contrast to the matured market in North America, aluminum consumption is growing approximately 11% annually in China and 6% in Russia.[1,4] Compared to western countries, the per-capita aluminum consumption in developing countries is still very low. However, considering that half of the world population is concentrated in only four countries (Brazil, Russia, India, and China), a few kilograms increase per capita in these countries will result in tremendous growth for the entire industry.

Following the current trend, global primary aluminum production is projected to reach around 60 million tonnes by 2020,[1,4,10] which is double the current production. The Asia market will contribute to 63% of the increase, as shown in Figure 1. The growing aluminum consumption in emerging markets extends to almost all sectors of the aluminum industry, including transportation, construction, and packaging; however, the emerging market is focused on infrastructure building, transportation, and simpler commodities (Figure 2), which is different from the patterns in western countries.[4]

In aluminum packaging, 100 billion aluminum beverage cans are consumed each year in North America, but the market has been flat since peaking in 1999. In the same period, the world aluminum packaging market grew rapidly, mostly from emerging markets in Asia and Eastern Europe. With continuing massive international investment, China has the world's fastest growing economy (the gross domestic product increased by more than 11% in the first half of 2006), and its aluminum beverage can market is reflecting this with growth of close to double digits. In the next year, China's two-piece beverage can market will far exceed 10 billion cans.[11] The market share of aluminum packaging is only 8% in China as compared to ~20% of total aluminum production in the Western world.[4,10] Considering the potential greater market share in developing

countries, the growth of the aluminum packaging market could be tremendous.

The aluminum supply chain is also experiencing major change within the existing market as well as in the emerging market. The increase in energy costs and raw materials prices require more efficiency in operation and management. As a result, the aluminum industry in the Western countries has been consolidated and reorganized in the past years; the market share is split between more competitive but fewer suppliers as some players went out of business. One example is the aluminum rolled sheet for the beverage can industry. Despite the vast available market, the supply of rolled can sheets is provided only by Alcoa, Novelis, ARCO, and Wise Aluminum in North America. New players in the aluminum fabrication industry have emerged as a result of mergers and acquisitions, such as Aleris International.

Following the example of the automotive manufacturers, the aluminum fabrication industry has set up new facilities in the emerging markets.[10] For instance, Novelis has two rolling mill plants in Korea to provide can sheets to the Asian market. Also, Alcoa acquired a Russian facility to access the fast-growing Russian and Commonwealth of Independent States markets and invested in a plate facility for the aerospace industry. Alcoa plans to double its production in Russia in the next 5 years.

The business and profits in the emerging market are becoming more important for growth. For every dollar Alcoa generated in 2005, ~$0.40 came from the overseas market. International corporations are not only building new manufacturing facilities and acquiring local manufacturers in the emerging market, but also redistributing their existing facilities worldwide. For example, Hydro moved its production of cylinder heads, engine blocks, and bumper beams from Europe to China.

On the other hand, the suppliers in Brazil, Russia, India, and China are growing at unparalleled speed because of effective cost, soaring demand, and strong government support. The Russian aluminum giant Rusal became one of the largest aluminum suppliers in the world after merging with two partners. Chinalco (Aluminum Corporation of China) also is ranked among the leading global aluminum companies, with a market share of more than $12 billion. The company expects to quadruple its total assets, revenues, and realized profits of 2000 in another 10 years.

CURRENT CHALLENGES AND FUTURE OPPORTUNITIES

Although the aluminum fabrication industry is currently successful in key markets such as transportation, packaging, and construction, a number of challenges are emerging from the increasing energy and raw material costs and stronger competition from other industries such as steel and plastics. Innovation is the key to staying competitive and growing in the face of these challenges and opportunities.

Innovative products are needed to meet a variety of market needs besides traditional aluminum packaging.

Packaging Market

The aluminum packaging industry experienced steady growth in the 1980s but shipments became flat in the 1990s. Worldwide, 200 billion aluminum beverage cans are consumed each year, half by North America. An industry shift shows discouraging signs for the aluminum can for the rest of this decade, as plastics are beginning to take an increasing share of the carbonated soft drinks and water market.

In the past decade, the aluminum industry has worked hard to keep its share of the packaging market.[12] To reduce the cost of the two-piece aluminum can (3104 can body and 5182 can end), the metal gauge for the most popular 12-oz aluminum can body was reduced from 18 thousandths of an inch to just 10 thousandths of an inch. In addition, the can design was modified to strengthen the can body and minimize the size of the more-expensive 5182 can end. New coatings and graphic designs were developed and applied widely in the industry; however, the efforts are not sufficient to increase the market share. Diverse groups on technology, research, and development must be created to devise new strategies to provide innovative and enhanced cost-effective solutions.

Innovative products are needed to meet a variety of market needs besides traditional aluminum packaging. Aluminum packaging does more than provide basic packaging; it also offers functionality and security to the customers. Great progress has been achieved, such as the shaped bottle and the specialty can, which provide a new appearance and more convenience. A departure from conventional direct-chill casting to continuous casting should enable the supply of rolled sheet at a significantly lower cost that can be converted without compromising manufacturing efficiencies or affecting ultimate container perfor-

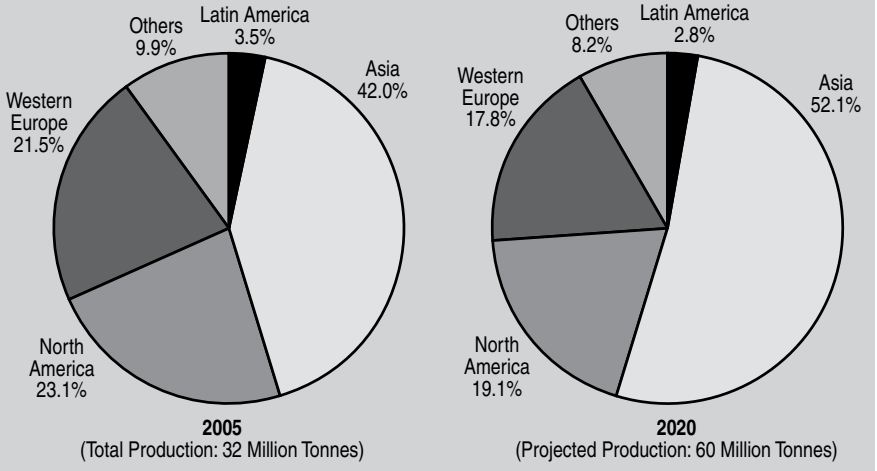

Figure 1. The world consumption of primary aluminum, in millions of tonnes.[1,4,10]

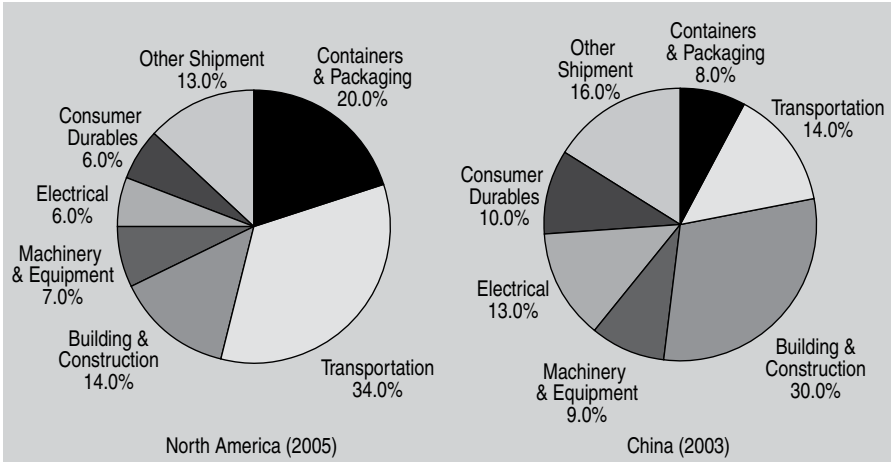

Figure 2. The current market share by application sectors.[4,10]

mance. Radical changes in can design, such as flat-bottomed containers, could lead to less metal in the dome of the can, saving a predicted 6% in metal cost. The intrinsic value of aluminum, which generates more revenue for recyclers than other materials, will also continue to provide a competitive advantage.

Transportation Market

Aluminum has one-third the density of steel, which means a component can be 1.5 times thicker than a steel version and retain a 50% mass advantage. It can also absorb twice as much energy as steel at the same mass. Aluminum has a naturally high resistance to corrosion because of an invisible oxide film formed with exposure to air. This corrosion resistance may be further improved by an electrolytic anodic oxidation treatment, known as anodizing, in which a thicker and more adherent oxide skin is developed.

The vehicle body alone accounts for about 25% of the total mass of a typical vehicle and now offers the greatest potential for mass savings because other engine and transmission applications have already converted to aluminum. Aluminum is considered the favored material for this savings because it is much lighter than steel and widely available.

Although aluminum is lightweight, highly recyclable, and corrosion resistant, the cost per kilogram of aluminum sheet is currently four to five times more than steel for automotive applications. Aluminum is considered to be more difficult to weld and stamp than steel and behaves differently when stressed, which means engineering a body structure to meet crash safety and stiffness requirements demands a different approach. Typically, components such as door panels and hoods are formed using conventional mechanical presses that stamp steel or aluminum sheet into their final shape. Some components are designed to have sharp creases (e.g., a style line of a hood) or deep recesses and small radii (e.g., curves like those found in door inner panels), which sometimes create problems for manufacturing engineers when using aluminum. These problems may include splitting of the metal, wrinkling as material gathers in a corner, and spring back when the part is removed from the die.

Because of these issues, a single aluminum part might require more stamping stages than a comparable steel part or the part may have to be divided into two or more pieces that are then joined together, adding time and cost to the manufacturing process. A less desirable alternative is to make compromises on either the material choice or the part shape.[13] Thus, engineers have been trying to develop other methods to replace or complement the conventional mechanical stamping process to fully realize the potential mass savings of using aluminum components.

The semi-solid forming process combining casting and forming[14] rheocasting makes near-net-shaped parts, or parts that need little if any additional shaping after they are formed, thus saving time and expense. The technology has been applied on the Plymouth *Prowler* to produce suspension and wheel components such as control arms, rocker arms, and front and rear knuckles. Approximately 445 kg of the 1,298-kg *Prowler* consists of aluminum, including the body, frame, and suspension parts, using virtually every known alloy and form of aluminum. Researchers have experimented with a technique known as electromagnetic forming (EMF) to reduce or even eliminate the wrinkling and springback associated with conventional forming processes, as well as to increase the formability of aluminum sheet. Initial results based on trials with two aluminum parts indicate that EMF greatly improves aluminum forming. If EMF is to be employed on a large scale in the automotive industry, extremely robust coils must be developed.

An aluminum body technology crafted around the Audi Space Frame (ASF) has been created in the Audi *A8*. The ASF is a high-strength aluminum structure in which the large integral aluminum-sheet components also perform a load-bearing function. The actual frame consists of extruded sections joined by vacuum-formed die cast nodes. Acting as a safety cell, the aluminum alloy structural members of the ASF absorb energy better in relation to their weight than steel.

For the post-use stage, the amounts of carbon dioxide generated by aluminum and steel are based on the assumption that 90% of the material is recycled. Once the usage end-of-life of the vehicle is increased, the difference between the use costs for both materials becomes significant, making an aluminum structure a more economical option. After 10 years, the aluminum structure has a cost advantage of about 5% as compared with the steel structure.

CONCLUSIONS

Aluminum fabrication is in the midst of rapid growth and a market transformation. To sustain the growth, the industry must follow the changing pattern of the global economy. The growth of the mature market in the major developed countries will be different from the emerging market in the major developing countries such as Brazil, Russia, India, and China.

The industry in the developed countries will focus on innovation and technology because the market volume in these countries will grow at a relatively steady rate. Research and development is vital

to keep the market share in traditional applications such as packaging and construction and to expand the market in the areas of aerospace and transportation. A new model of research and development that consolidates the facility resources and intellectual capacity of several organizations appears to meet the needs of the entire industry to provide robust and cost-effective solutions.

In the near future it appears that urbanization in the developing countries will continue creating a large market for almost every sector of the aluminum fabrication industry, especially infrastructure building. Market growth and distribution will vary with different patterns of geography and social development; the aluminum industry must be part of the transformation and keep pace with market developments to benefit.

The future growth of the industry will require significant resources, which without new technological approaches may constrain the supply of raw materials and create additional environmental issues. New approaches that may reshape the industry itself are needed to keep the industry healthy and sustainable. Recycled metal already satisfies more than a quarter of world demand for aluminum. Because sustainability is becoming a priority within society, the fully recyclable nature of aluminum will help the industry to make a greater contribution to the future global economy.

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