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The Challenges of Aluminum Recycling From End-of-Life Vehicles

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Abstract

The use of aluminum in automotive industry is expanding. Aluminum offers a lower weight alternative to steel, potentially increasing the efficiency of vehicles. However, the application of aluminum has been only in select areas of use, most notably cast aluminum in the engine, transmission, and wheels. Other areas offer the potential for growth that could significantly expand the amount of aluminum used in vehicles. Cost is the main barrier to increased aluminum use. Related to cos aluminum production technologies that are not yet advanced enough to produce aluminum components at low enough price points for aluminum to compete with traditional automotive materials. The amount of aluminum used in cars and light trucks is growing steadily. However, without new developments in aluminum recycling technologies, sheet from automotive aluminum could eventually flood all current markets for recycled aluminum. Environment-friendly production of automobiles is an important research subject for auto-maker companies. Production rate of automobiles increase yearly and therefore End-of-Life Vehicles (ELVs) increase. Companies who produce metallic parts have special view on ELVs as raw materials. To reach required product qualities with lowest costs, aluminum postconsumer scrap is currently recycled using strategies of downgrading and dilution, due to difficulties in refining. These strategies depend on a continuous and fast growth of the bottom reservoir of the aluminum downgrading cascade, which is formed by secondary castings, mainly used in automotive applications. With the global warming of concern, the secondary aluminum stream is becoming an even more important component of aluminum production and is attractive because of its economic and environmental benefits. Recycling of ferrous metals are easier because of separation by magnetic condition and recycling technologies. Non – ferrous metals have wide range of chemical analysis and require special technologies for separation from other metals so special look is necessary to recycling this type of metals. Effective strategies need to include an immediate and rapid penetration of dramatically improved scrap sorting technologies for end-of-life vehicles and other aluminum applications. This article concern the benefits and limitations and the challenges in direction of recycling of aluminum parts from used cars.

Keywords: Recycling, Secondary Aluminum, End of Life Vehicles, Automotive Recycling.

1. Introduction

In 1997, the European Commission for Auto Recycling (ECAU) put forth a controversial proposal for managing End-of-Life Vehicles (ELVs) in the Europe. This directive was meant to encourage two complementary strategies of avoiding waste by improving product design and increasing recycling and reuse of waste. This proposal has great impact on automakers and all economic operators within the recycling infrastructure. Industrial stakeholders, including automakers. Suppliers and recyclers fear the worst in terms of increased cost. Major market distortions, and exiting of key economic operators if all requirements of the ELV directive become mandatory. The key points in the aluminum industry stakeholders are specific recycling targets, recyclable material content in vehicle design, drastic reductions and recovery of certain hazardous chemicals and producers bear “all or most of the” costs for achieving the goals [1]. Fig. 1 illustrates the life cycle or products such as automobiles. The cycle begins with material extraction from nature and includes the material processing, manufacture, use and post – use handling of a product. Movement through the life cycle (clockwise motion) has costs (direct and societal) and energy consumption associated with it. The life cycle illustrates that even the post – use handling of a product (including de-manufacturing, treatment and disposal) adds to the life cycle costs and energy consumption.

The figure also indicates that in addition to the product disposal option, de –manufacturing also considers reuse, remanufacturing, and recycling. These options are preferred over disposal since they increase the useful life of the product. It may also be noted that the inner loops are preferred over the outer loops because potentially less raw materials, energy, time and cost would be involved in manufacturing. The increase in recycled metal becoming available is a positive trend, as secondary metal produced from recycled metal requires only about 2.8 kwh/kg of metal produced while primary aluminum production

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requires about 45 kwh/kg of metal produced [2-4]. It is to the industry and national advantage to maximize the amount of recycled metal both from the energy – saving and reduction of dependence upon overseas sources and also from ecological stand point. Fig. 2. illustrates material flows of ELVs. The current ELVs treatment system contains dissemblers, shredders and non-ferrous scrap separators. Important in the cost assessment of these will also be land filling. The international Bureau of Recycling of European Union estimates that there are close to 20.000 collectors / dismantlers, 220 shredder operators and 40 heavy media separators (non-ferrous separators) in Europe. In addition, entrepreneurial Auto Shredder Separators (ASR) is emerging in part due to the potential profitability of the directive.

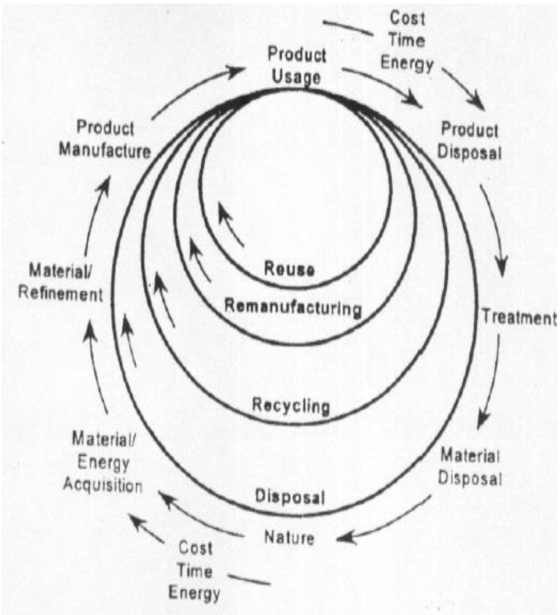

Fig. 1. Life Cycle of Products[1].

2. Challenges Impacting Recycling in 2020

Numerous challenges exist that impact automobile recycling in 2020.The top factors affecting Vehicle recycling are listed in Table 1. The ELV material constituency in 2020 (as a percent of vehicle weight) is expected to be similar to today's vehicle, as indicated in section 3. This implies that the challenges and key factors that will affect ELV recycling for the next years are similar to the key interrelationships. Key issues associated with the top factors affecting vehicle recycling are highlighted factors and challenges that the recycling industry faces today. The recovery depends on these complex in Fig. 2. [5].

Table 1. Top Factors Affecting Automobile Recycling for the Next 20 years[5].

• Economies Value of Recovered Material and Components.
• Material Content of Vehicles.
• Competing Vehicle Design Requirements.
• Capability to Separate and sort Material.
• Hazardous material and contamination.
• Capital availability to build infrastructure.
• Collection costs, transportation cost, and material supply.
• Regulations impacting recycling.
• Consumer option.
• Unforeseen factors

2.1. Light Meal Recycling from ELVs

Among the materials within ELVs light metals command relatively high prices and are therefore reclaimed at even particular effort is made to return it to its original application. Nonetheless, currently automotive consumption accounts for a large fraction of secondary aluminum demand, consuming some 40% to 50% of all aluminum scrap. This high level of consumption arises because of two facts: 1)Automotive aluminum demand comes predominantly in form of casting and 2) Castings with high alloying element specifications are more accommodating to the use of secondary raw materials. Interestingly, although the use of castings in autos continues to grow, the use of wrought alloys is growing even faster. These trends raise the possibility that the automobile would no longer be able to make use of an amount of scrap equivalent to the amount that it produces. Fortunately, several opportunities exist to prevent or at least mitigate this situation.

2.2. A Simple Analysis of Possible Scrap Reuse of Aluminum

Aluminum shipments for passenger cars and light trucks in North America expected to grow to 6.4 M lbs in 2009 (Fig. 4). This trend, combined with the more stringent compositional limits for wrought alloys, could comprise the ability of auto market to reuse the scrap it produces if current use and processing practice continue [5]. A simple analysis illustrates this possibility. In this analysis, two time horizons are considered: 2003 and 2013 for each of these years. The amount of aluminum that could be made from scrap is compared with the amount of scrap available from vehicles produced 13 years before (1990 and 2000 respectively). For this analysis, it was assumed that 10% of all scrap is lost and that 80% of cast materials could be made from scrap while wrought materials could use only 10% scrap. Alloy demand for the period 2010 to 2013 was also extrapolated from forecasted growth rates for the period 2000 to 2009[6-8]. Table 2. shows that in 2013, with existing practices, there will be more scrap to be recycled than the amount that can be consumed in the production of new casing and wrought alloys. Because of this emerging issue, it is important that strategies be devised to maximize the amount of post – consumer scrap that can be recycled. These strategies might target usage patterns, production, practices or the manner in which secondary materials are reclaimed, segregated and sorted [8-11].

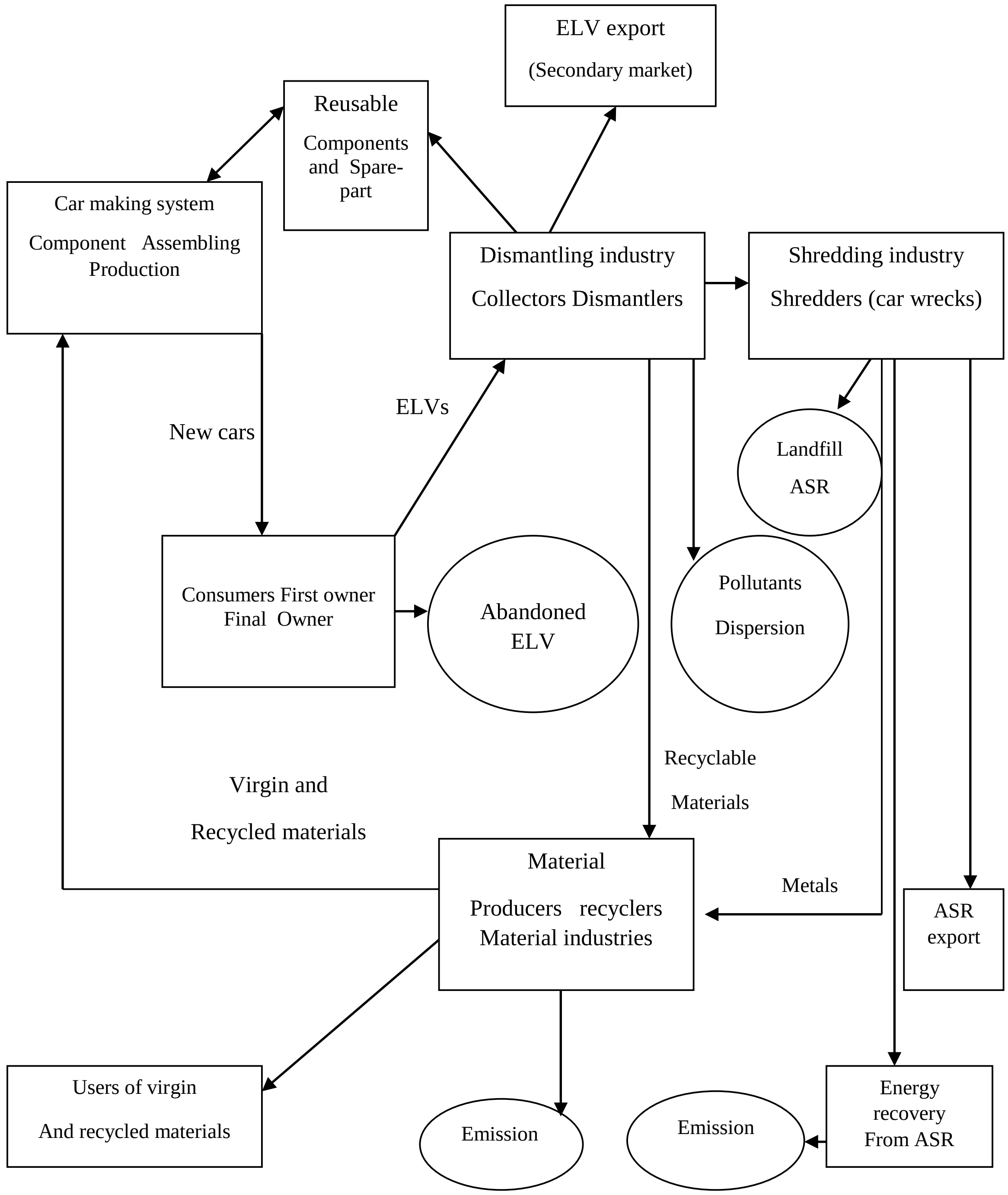

Fig. 2. Sketch of ELV Systems[5].

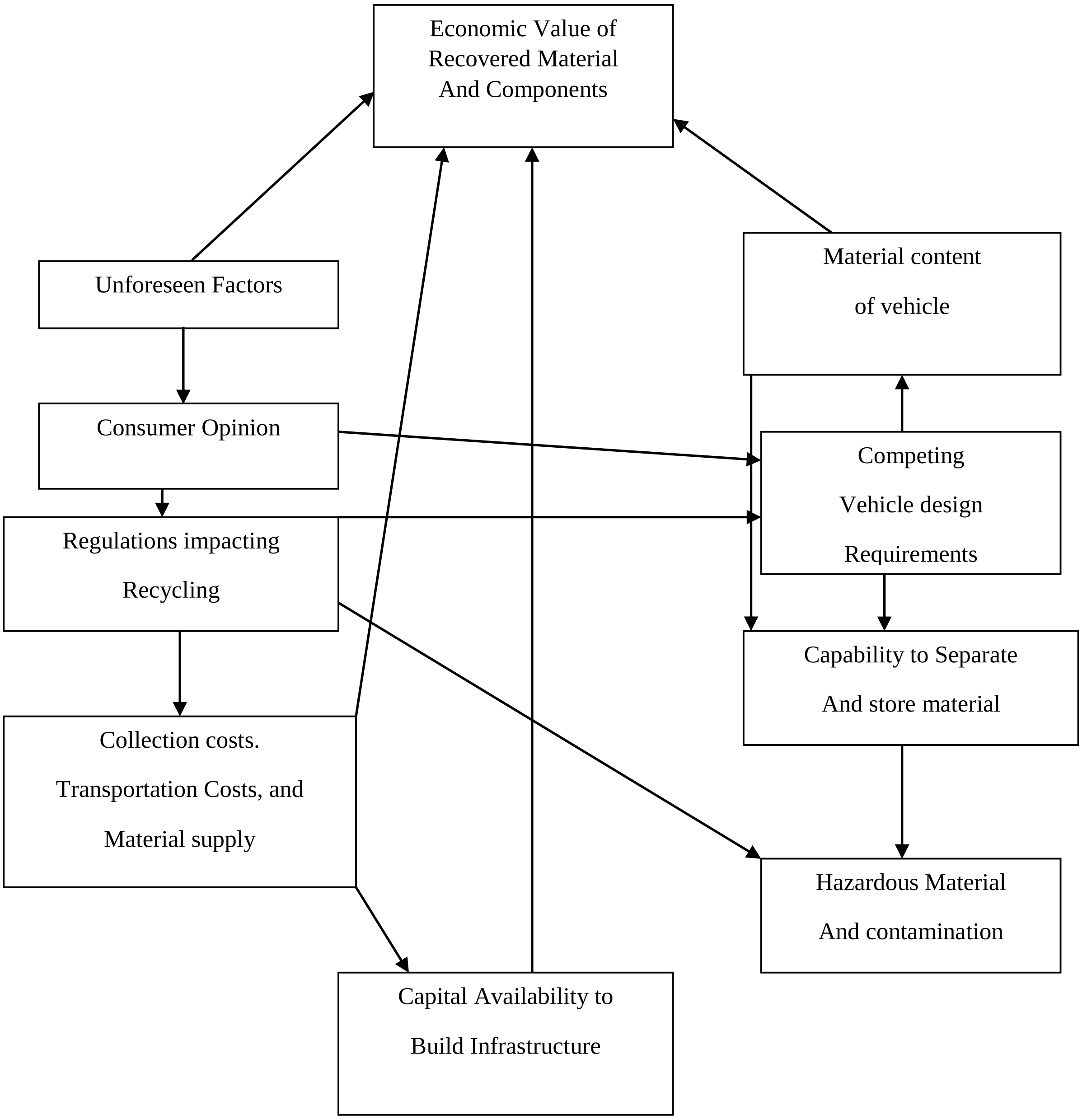

Fig. 3. Major Interrelationship Among the top Factors[18].

3. Ideal Recycling World

In the ideal aluminum industry, the recycling of all used aluminum components would be the standard and the total content of recycled products would increasingly approach the total requirement. Consumption of required amount for primary production would be reduced and therefore the dependence on overseas production minimized. Recycled aluminum would be readily recovered and processed utilizing automatic sorting and shredding technology to put it in the best possible form for reuse in new products [8, 12-14]. A wide array of aluminum alloys compatible with the incoming composition of recycled metal would be available, so the opportunities for direct use of the recycled metal would be optimized. There would be a number of high – value applications to which the recycled metal would flow. In such situations, a product made directly from the recycled metal would readily meet specification, composition and mechanical property limits of the intended applications (Fig. 3.). There are a number of challenges to be met to create the recycling – friendly world, as discussed below [15-18].

4. Challenge Areas

The principle challenges that must be dealt with in creating the ideal recycling world include the following [19-21]:

Improving the recovery of used aluminum components for recycling.

Table 2. Amount of Auto scrap available and usable in 2003 and 2013[19].

.Year of production of new alloys	2003	2013
.Year of production of the alloys to be recycled	1990	2000
.Amount that can be made from scrap (MKg)	1.743	2.192
.Amount of scrap to be recycled (MKg)	.745	2.216
.Difference (MKg)	1000	-24

Improving and fully automating the recycling technology and making it more broadly available. Significantly broadening the range of available aluminum alloys that will perform well in quality products when they are produced directly from recycled metal. Identifying useful byproducts to handle elemental residual unable to be used in recycled metal, e.g., Fe. There are a number of more detailed challenges facing any effort to increase the number of aluminum alloys and applications suitable for direct production from recycled metal. Some of the efforts are following:

Most recycled aluminum involves a mixture of alloys from a fairly wide variety of applications, including a selection of casting containing rather high percentages of silicon (Si). While there is generally no problem recycling most of this metal as casting parts. There is a significant challenge in shredding, sorting and in some case further refinement of the metal to achieve acceptability. Impurity levels for products other than castings, including sheet, plate, forgings and extrusions depend on the following factors. Many premium alloys utilized today where requirements for exceptionally high ductility and toughness are common, call for very tight composition controls. Impurity levels above 0.10 Fe are unacceptable for example, in premium high – toughness aerospace alloys. High performance automotive alloys generally restrict both Si and Fe. Both of these elements (Fe and Si) are difficult to control in recycled metal and tend to increase with more the metal is recycled. Elements other than Fe may be expected to gradually increase with time and may require special attention [22]. Magnesium (Mg). Nickel (Ni) and Vanadium (V) are three examples. Typical compositions of recycled metal today are based upon eight representative studies by Adam Gesing of Huron Valley Steel Corp. (HVSC) and are shown in Table 3. in weight %. HVSC is capable of separating wrought and cast alloy scrap. So four samples were of representative wrought separations. Three of representative cast separation and one of the two mixed (wrought and cast alloys).

The result above illustrates several of the fundamental problems with reusing scrap aluminum. Even segregated wrought scrap can have relatively widely varying compositions: wrought 3 and wrought 4 for example, have higher Cu (from more 2xxx alloys) and higher Zn (from more 7xxx alloys) in the mix than do wrought 1 and wrought 2. It appears that auto bumper alloys like 7029 and auto body sheet alloys like 2036 are more highly represented in the wrought 3 and 4.

Some wrought recycled metal (1 and 2) match existing wrought alloys reasonably well, e.g. 3005, 3104, 3105 and 6061 and be readily reused, other like 3 and 4 will be more difficult to use directly. Cast alloy scrap differs significantly from wrought alloy scrap. Notably, with higher total alloy content, notably higher Si content [23-24].

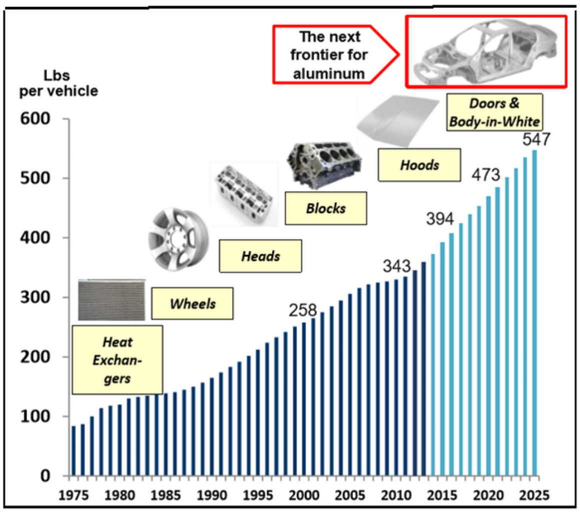

Fig. 4. Accelerating Aluminum Use in Automotive[23].

5. National for Recycle – Friendly Aluminum Alloy

Employing the concept overviews, the following sets of parameters are proposed as a possible rationale for creating more recycle – friendly aluminum alloys [22]:

- Select alloying elements that are commonly and successfully used in alloys of various series such
- Adjust the limiting maximum levels of impurities to the levels of those elements typically found in recycled metals such as Fe.
- Development of one or two “unialloys” which meet all the requirements for large application such as automotive components. Unialloy concept was first developed by D. Mc Aulffe in late 1980.

Table 3. The Chemical Composition (wt. %) of Regular Cast and Wrought Aluminum Scraps[24].

LOT	Al	Cu	Fe	Mg	Mn	Si	Zn	Others
Wrought 1	97.1	0.11	0.59	0.82	0.21	0.51	0.45	0.19
Wrought 2	96.7	0.30	0.60	0.60	0.20	0.90	0.50	0.10
Wrought 3	93.1	0.95	101	0.89	0.12	2.41	1.25	0.27
Wrought 4	93.1	1.20	0.70	0.70	0.30	2.60	1.20	0.20
Cast 1	83.5	4.40	1.10	0.40	0.30	8.0	1.90	0.40
Cast 2	86.0	3.90	1.00	0.10	0.20	6.30	2.30	0.30
Cast 3	88.4	2.50	0.75	0.58	0.26	5.18	1.27	1.09
Mixed W&C	90.1	2.30	0.80	0.50	0.20	4.50	1.20	0.30

The concept was derived from the idea that unialloy had an average weighted composition of car body alloy AA3004 and can end alloy AA5182. This recycling idea achieved limited application due to economic and commercial factors.

- Development and improvement of recycling technology.
- The typical scenario for recycling of an old vehicle begins with dismantlers. At this step, parts are removed based on resale value or adherence to regulatory and product standards. The results of industrial research indicate that a dismantler recovers of 21% of vehicle received. Within the 21% of vehicle reused, 12% of them are actually rebuilt for sale and the remaining 88% of parts inventory. Parts resale is the most profitable portion of their operation. The remaining 79% of vehicle are sold as hulks after tires; radiators, batteries, gas tanks, air bag propellants and fluids are removed as required by shredders and regulators[25].
- After disassembly, the hulks are flattened and then transported to shredding facilities. There is a transaction cost between shredder and dismantler usually in the range of $30-$90 / tonne paid by shredder. The hulks are fed through large hammer – mill shredders that passes under an air suction region for removal of dust, fluff, foam and other light pieces. Then the shredder steams under magnets for ferrous removal. Al this point 95% of the steel and cast iron parts from a vehicle are recovered. The remaining non – ferrous materials can then be sorted with an eddy current recovery (ECR) system, which sorts non – ferrous metals from the rest of ASR. Finer non – ferrous separation can occur on the same site as shredders with the installation of additional non – ferrous separation equipment. However, often, no non-ferrous facilities exist and residual non-ferrous materials separated manually or sold to non – ferrous separators or landfill. It has been difficult to conclude the thoroughness of non – ferrous metals recovery by European or any other shredders. While non-ferrous metals have higher price and cost in comparison with ferrous metals or other residual materials [26].

6. Conclusions

1. The development and application of enhanced shredding and sorting technologies such as the HVSC, LIBS process should continue.
2. Strategies for the most cost – effective re-melting processes should be pursued, including technologies to facilitate separation of undesired elements such and Fe, Ni, and/or V by combination with Zr.
3. The development of alternative products such as Al-Fe de-oxidizing agents should be pursued to utilize that part of recycled aluminum that cannot be cost – effectively used in the production of new aluminum alloys.
4. Serious consideration and study should be given to the development of new aluminum alloys designed for application directly from recycled aluminum.

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