RECYCLING OF ALUMINIUM, STEEL AND SOME RELATED ITEMS

By

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Abstract: *This paper focuses onto recovery/recycling of alumina, aluminum, and touches briefly upon some items related to iron & steel making and plastics. The paper suggests a few modified recovery processes and gives a schematic process diagram for a new system for improving recovery of aluminium metal from dross and suggestions for recycling of slag, flue dust and mill scale in steel industry.*

1.0 Background:

Recovery and recycling are complementary process regimes. The extent of recycling in India can be gauged from the fact that used/bent nails are straightened and reused. Majority of the recovery and recycling units in India are in the un-organised sector involving door-to-door collection, manual sorting/cleaning/grading and packaging before reaching the processing units. Modernisation of the scrap processing though inevitable, depends mainly on socio-economic factors.

1.1 Philosophy of recycling: Recycling is cost reduction coupled with safeguarding the environment and maximizing resource utilisation. Recycled materials cost less due to reduced energy, handling and others in comparison to those for prime materials. Recycling is also strongly influenced by legislations. The origin of the legislation can probably be traced to greater awareness regarding the environment and dwindling reserves/access of quality ores/minerals in the developed countries. In developing countries the economic conditions and a large population with lower skill are the leading motivation factors driving the recycling activities.

1.2 Recycling rate: The recycling rate is the ratio of the scarp arising and the tonnage of scrap being remelted annually. The rate is highest for metals in countries like Mexico, Brazil and India. The proof for such high recycling rate in India can be adjudged from the fact that a scheme for generating electricity by burning garbage was found to be not feasible as collectors removed nearly all the combustibles.

1.3 US and Europe has lower recycling rates than those for developing countries probably due to the large degree of manual inputs required. Japan has the highest recycling rate for aluminium amongst the G-7 countries [1] and meets its requirement of aluminium from recycling and imported ingots saving energy and reducing environmental degradation. The recycling rate in developing countries can be related to the following:

1. A large size of relatively affluent population generating wastes.
2. Medium to High degree of industrialization.
3. Large population of urban poor with low skill or job opportunity.
4. Strong awareness regarding the recyclability of materials.
5. Innovation by the industry.

2.0 Items of Recycling:

The recycled items belong to a large number of categories. The subject of recycling is well researched and established and can be continuously improved upon. As already stated, this article deals with some specific areas of recycling with emphasis on alumina and aluminum and very briefly scans some items related to Iron and steel making and plastics as these may be of interest to the industry as a whole.

2.1 Recycling of components of Aulmina refining: Caustic soda used in refining bauxite to alumina is recovered @ 92% and recycled. The high basicity thixotropic gangue material termed redmud, is generated @ 1.6 to 1.8 tons per ton of refined alumina which is about 3 to 4 tons of redmud per ton of primary aluminum. India's aluminium smelting capacity slated to attain 1 mtpy, will generate about 3 to 4 mtpy of redmud excluding that for alumina meant for export/tolling. Typical composition of redmud is as follows:

Fe_2O_3	..	50-70%
Al_2O_3	..	10-20%
TiO_2	..	1-22%
SiO_2	..	4-20%
Na_2O	..	2-8%
CaO	..	Upto 12%

Following items in redmud, can be recycled:

- Improved recovery/recycling rate of caustic soda.
- Recycling of Iron oxide for DRI production.
- As filler material for bituminous road topping.
- Making hard industrial floors when mixed with cement.
- As soil stabiliser for sandy/acidic soils for retainment of fertiliser.
- Production of Ferro-Titanium and Ferro-Silicon.

2.1.1 Improving recovery of Caustic soda: Deep Drainage and Evaporation of Water (Deep DREW) method filters redmud thro' a sand bed with drainage pipes below to collect alkaline filtrate for recycling. Thickened Tailings Disposal (TTD) achieves a redmud of 50-70% solids, enhancing recovery of the alkaline filtrate[2]. The above methods may increase recovery of caustic soda by 3-4%.

2.1.2 Recycling of Iron oxide: Redmud with high percentage of iron oxide and alkali metals is unfit as feedstock for blast furnace. High iron content ore being easily available, redmud with high iron oxide content is relegated to the background. Theoretical models prepared on the basis of 20% redmud and 80% iron ore if used by the DRI units near aluminium refineries, may prove feasible saving cost.

2.1.3 Ferro-Titanium/Silicon/Vanadium: Pederson[3] process involving smelting of redmud, iron ore, coke and limestone in submerged arc electric furnaces to produce Ferro-Titanium, Ferro Silicon, Pig iron and alumina was done for Bauxite in a Swedish and one Norsk Hydro plants (both closed down). In a modified version of Pederson process, it is proposed that the bauxite in the charge be replaced by redmud. The revival of processes can be done to use the superior quality of Indian redmud. The proposed broad process steps are as follows:

- Redmud mixed with pulverised coal sintered at 1000^0 C and cooled.
- Addition of more coke to the cooled sinter for reducing impurities.
- Smelting of the sinter with coke in submerged arc furnaces.
- Ferrosilicon and Ferro-titanium sinks to the bottom and to be tapped.
- Alumina to be recovered by blowing steam and leaching with dilute H_2SO_4.

Ferrovanadium can be recovered and produced thro' Thermit route from redmud.

2.1.4 Recovery of Gallium: The Gallium recovered and refined to 99.99999% purity is used for the production of Gallium Arsenide for high efficiency photovoltaic panels for spacecrafts and others. Gallium is available in the spent liquor, i.e. the supernatant weak solution after filtration of aluminum trihydrate and recycling of the caustic soda in alumina refining. The concentration of Gallium in the spent liquor increases with the recycling of the liquor.

2.2 Recycling of Aluminium scrap: **Primary aluminium production is equivalent to energy as it is highly energy intensive. The world average for the energy required for each ton of primary aluminium is 15000 kWh. This is enough to meet the daily electrical energy requirement of 1500 Indian homes. New non-electrolytic and hybrid processes are expected to achieve reduction in energy consumption. These processes are awaiting industrial trials [4], [5]. A geographical shift from developed to developing countries is under way for the production primary aluminium. The developed countries are emphasising on recycling, which consume less energy (5% of primary aluminium). Between 1990 and 2002, the share of primary aluminum metal in the US, dropped by 23% with shutting down of 10 smelters and 40.8% of the US domestic metal supply was met by imports [5]. Though smelters were getting closed in the USA and Europe, the output of finished items is on the increase. On the other hand, Canada, a G-7 country and Iceland with cheaper energy are increasing their smelter capacities [6]. Canada also has an efficient recycling system in place and ships out part of the scraps to others for recycling.** The estimated global demand of aluminium in 2005 will be 31.2 million tons, with most of the supply for the increased demand being met from Asia. The price of aluminium is also on the increase. The estimated global shortages of aluminium are expected to be of the order of 0.4 and 1.0 mill. Ton in '04 and '05 respectively [6].

Changing Pattern of Area-wise share of Primary Aluminium production [8]

Year	AREA						
	Africa	N. America	S. America	Asia	W. Europe	E/Ctrl Europe	Oceania
1992	3.2	31.0	10.4	15.1	11.0	21.2	8.1
2002	5.1	21.2	8.2	26.2	10.0	21.3	8.0

High price of primary aluminium pushes up the demand for the secondary/recycled metal. Recycling of aluminum practiced since early 1900's gained prominence in the 1960's from recycling of used beverage cans (UBC). . Beverage cans are made both of steel and aluminium and their respective market shares are 50:50 globally. Magnetic separators take out steel cans if present in Aluminium UBC.

Eddy current separators are used to separate UBC made of aluminium from other foreign materials. Systems for decoating of paint /lacquers from UBC are available for reducing environmental hazards during remelting.

Iron can be separated from aluminum alloys by centrifuging/zone refining/ electromagnetic separation. Recently developed vacuum refining technique claims more effective removal of magnesium and zinc from secondary aluminum compared to methods using Chlorine [10]. The efficiency of recovering Aluminium from scrap is 94% on average on a global basis. The world figure of recycling for aluminium scrap for the year 2003 is given in the following table:

Global Generation of recyclable aluminium scrap in 2003 (in 000, tons) [11]

Type of Scrap	Total Scrap input	Total Aluminium Recovered
Casting Alloys	432.69	415.72
Wrought Alloys	2,295.27	2,159.63
Total	**2,727.96**	**2,575.35**

2.2.2 Closed loop recycling: In closed loop recycling, recyclable aluminium is collected throughout the manufacturing steps at the automobile manufacturers end till the dismantling and shredding process of the scrapped vehicle and remelted for producing the same item with make-up additions for alloys if needed [12]. This recent recycling concept dovetails the aluminium metal processing activities of the user industry like the auto industry and the metal supplier in a closed loop. Inspite of the high cost of fuel, the growth of automobile industry remains unabated globally. Modern cars inspite of the emphasis on achieving greater fuel efficiency thro' weight reduction, weigh more the earlier ones to make them safer and more comfortable. Legislations in developed countries make it necessary to achieve increasing rate of recycling for automobiles with lower emission. Auto manufacturers are joining with the material producers to make items lighter with greater recyclability. It may be of interest to note that, while recycling a car, the value of the plastics and rubber items is negligible, steel scrap comes to about 20 to 25% of its original cost by weight but the cost of aluminium remains unchanged [12].

2.2.3 Future Vision[13]: The following may be the future of aluminium recycling:

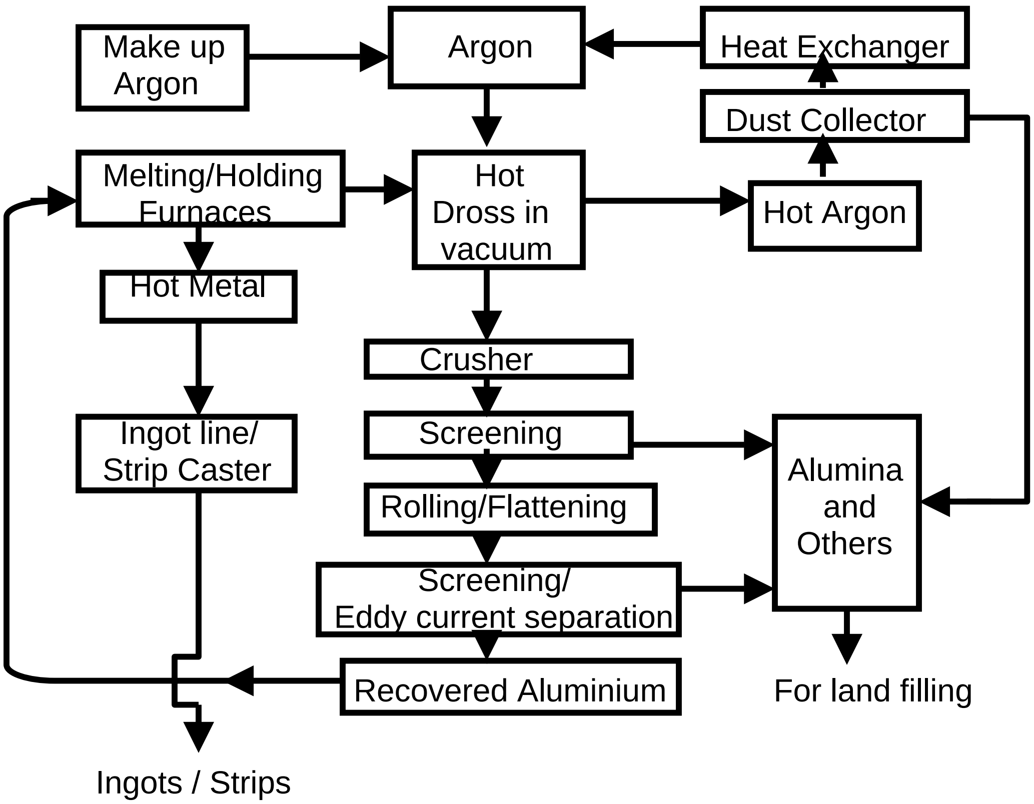
1. Develop process for removing impurities as Mg/Mn/Fe/Si/Ti from mixed scrap.
2. Develop new generation scrap-tolerant alloys.

2.2.4 Estimated quantity of recycled aluminum in India: Assuming a life cycle of aluminum products of 25 years before being scrapped and taking the annual production of the amount produced 25 years back i.e. in 1980 and multiply this with an assumed factor of 0.85 as recycling rate and collection efficiency during that period, the figure comes to about 120,000 tons/year. Now with a different approach, taking share of global recycled aluminium being 12.42% of primary aluminium production, the current estimated tonnage of recycled aluminium in India is about 113,000 tpy. Now applying the law of average, the estimated tonnage of recycled aluminium in India comes to about 116,000tpy approximately and is in agreement with the global trend.

2.2.5 Energy required for remelting of aluminium: Re-melting of aluminum scrap requires about 5% (≅700/750kWh/ton) of the energy for making primary aluminium. Secondary steel making by the EAF/LRF/VD* route needs same or less specific energy. It is expected that in future aluminum re-melting will have lower specific energy requirement with reduced emissions with improved technology and equipment.

2.2.6 Per capita consumption of aluminum metal: It is estimated to be about 0.70 kg in India, which is low even when compared to less developed countries. With the average per capita income of about US$ 650/- and the LME price of aluminium being nearly three times than that, aluminium is beyond the reach of majority of the population. Stainless steel utensils with considerably longer life and used widely by Indian households is also one of the reasons for low per capita consumption of aluminium.

2.3 Recovery of aluminium from dross: Dross, a product of aluminium melting/remelting, is formed @ 5% of metal weight by oxidation of aluminium. While removing dross, some metal also get drawn out. A ton of metal is expected to generate 50 kg of dross yielding 15 kg of aluminum. The metal recovery rate from the dross can be improved with better processes as suggested herein. A schematic diagram for an improved process to better recovery rate of aluminum from dross follows:



Schematic flow diagram for improved recovery of aluminium from dross

2.4 Recycling/reuse of Iron and Steel Plant slag: Slag from steel melting high in Calcium Oxide is being recycled back into blast furnaces as a part substitute for the flux/limestone. Blast furnace slag on the other hand, can be used for the following:

1. Coarse aggregates for acting as abrasion elements on roads.
2. As ballasts in rail tracks, replacing the stone chips.
3. Coarse aggregates in the concrete for building construction.

Crushed and screened blast furnace slag will accrue the following benefits:

1. Reduce destruction of natural hills used for sourcing stone chips.
2. Prevent occurrence of silicosis of people working in the crushing units.
3. Provide aggregates for road-making/building construction.
4. Improve environment by reducing clearing the slag dumps.

2.5 EAF/ESP* Flue Dust and mill scale: The flue dust from the bag-houses and ESP's and mill scale from hot rolling mills with high iron oxide content and can be used for the following:

1. Feedstock for DRI* units after being mixed with iron ore.
2. Feedstock providing a source of iron and oxygen when fed into EAF.

2.6 Recycling of plastics: India leads in recycling of plastics. A technology has been developed for converting plastics to lube oils for automobiles by the Fischer Tropsch process developed in WW II for converting coal to oil. It has been claimed that 60% of the plastics could be converted by this process to high-grade lube and transmission fluid for automobiles. Incidentally IIT Khargpur established a pilot plant for Fischer Tropsch process in the early 1960's for converting coal to oil [14].

3.0 Hazards and Limitations of recycling: The emission from paints and lacquers of aluminium UBC during remelting is harmful. Toxicity due to degrading of items made from recycled plastics is of concern. Stainless steel scrap with copper cannot be recycled in the EAF freely as the copper content in alloy steel is to be restricted for automotive applications. Scraps containing moisture and organic matter like rubber increase hydrogen level, which is to be kept below 2/2.5 ppm for most steels. In Mexico, scraps used for remelting had a Co 60 source resulting in radioactive steel, which was buried in desert to avoid human exposure. Similar incidents were stopped in India by detecting an Iridium 192 pencil and unexploded grenades in scrap meant for EAF. Sometimes hazardous wastes from recycling generated in other countries are shipped to and accepted in developing countries for dumping/reuse [15].

4.0 Conclusions:

4.1 Modified Pederson process can improve recovery of components of redmud.

4.2 Redmud can be used as road topping and hard industrial floors.

4.3 Design of future aluminium alloys is to be made more recycle friendly.

4.4 Process involving vacuum and argon can improve yield of metal from dross.

4.5 Steel melt shop slag can be recycled into Blast furnace to reuse the lime.

4.6 Blast Furnace slag can be used in construction and as ballast in rail-track.

4.7 Flue dust and mill scale can be recycled for use as feedstock in DRI/EAF.

4.8 The pilot plant at IIT can be revived for recycling plastics to make lube oils.

4.9 Ferrous scrap for EAF is to be used with care to limit undesirable elements/hazards.

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*EAF: Electric Arc Furnaces; LRF: Ladle Refining Furnaces; VD: Vacuum Degasser; DRI: Direct Reduction Iron; ESP: Electro Static Precipitators