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OPTIMIZING SCRAP REUSE AS A KEY ELEMENT IN EFFICIENT ALUMINIUM CAST HOUSES

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Abstract

In the last decades, the market share of secondary aluminum is slowly replacing primary aluminium. However, as the demand for aluminum is still considerable larger than the collection of used aluminium, primary aluminium will also be needed for the coming decades. This paper will address the current position of this development and the possibility to further increase the part of used aluminium scrap as the source for production of new aluminium to come to a durable production.
The second part of the paper will concern the melting facilities for recycling used scrap.

Introduction

Remelting of used aluminum takes only 5 percent of the energy that is needed for producing primary aluminium [5]. Recycling is therefore not only interesting from an environmental point of view, but also commercially attractive. The growth of the worlds recycling capacity has led to a structural shortage of aluminium scrap, which even in today's economic crises still exists.
The structural shortage led to a high scrap price that is an important incentive for the collection of used aluminum scrap [2]. Together with the stimulus from many governments, the collection of used aluminum is steadily growing. Aluminum can be recycled indefinitely and is a durable solution for many applications.

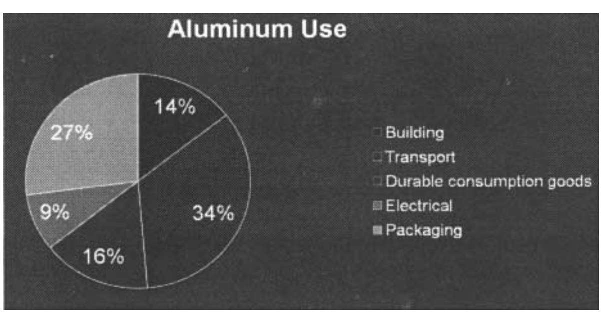

Figure 1: Aluminum use. Source: Aluminium Association

Stimulus

The high scrap price is an important incentive to collect used aluminium from buildings, automotive and used appliances. However, with regard to packing materials, additional stimulus is required. With improved production techniques, there are too many cans in a kilogram of UBC to make it worthwhile to collect all of them [5]. A nickel refund per can makes the difference and leads to almost full recycling. In Germany used Tetra pack is separately collected. With a recycle rate of 65%, many tons of aluminium, paper and plastic is recovered from these packages, while in the rest of the world these packages, that consists of valuable components surely will end up in the incinerators [5]. Worldwide only about 45% of the aluminium packaging material is recycled. In tonnage aluminium, there is still a treasure to be recovered.

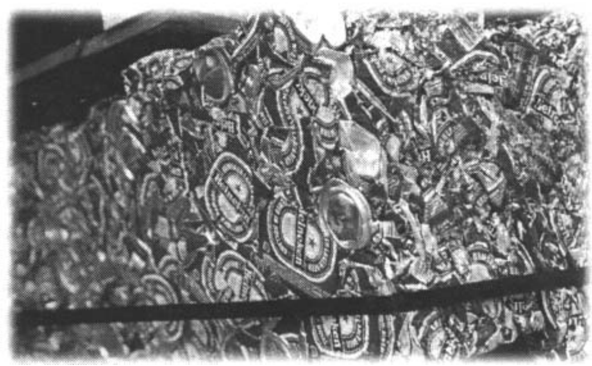

Figure 2: UBC scrap

Cycle

For recycling of used aluminum there are two main approaches, referred to as the "closed cycle" and the "open cycle". A typical example of a closed cycle is producing can stock from UBC (Used Beverage Cans). The scrap has already the right composition and is supplied in a uniform shape. In the closed cycle the material can be re-used endlessly without change of alloy or quality. This is a durable way of operation.
Can stock is a material with a short life-cycle. Only about eight weeks after production, the material is back in the factory in the form of UBC (see Figure 2). Aluminium from the automotive sector takes about twelve years to return, while it takes more than a human generation for material from the building sector to return.

The open cycle is using a mixture of all kinds of aluminium scrap to produce new aluminum products. The recycling process, frequently referred to as refining, makes use of low grade, low cost scrap with the purpose to produce high quality aluminium alloy out of it. Low grade aluminum scrap is not only contaminated with all kinds of unknown matter, but in many cases it will consist out of a mix of alloys. For making a useful metal out of it, it will be needed to dilute the metal with primary material or with a higher grade scrap with known composition.

The two types of recycle facilities have different needs with respect to the remelt facilities. The UBC recycler needs an installation that is specially designed for UBC processing with respect to highest recovery and minimum operating cost. The cost price of UBC scrap and can stock is both determined by the market. The recycler must operate a cost effective process, in-between these prices to keep in business.

Looking at UBC, the recycle rate is approximately 45% [5]. This means that still most can stock must be made from primary aluminium. All available UBC should be preferably used for making new can stock as it has the ideal composition for that. Using UBC for other purposes, by changing the composition, is a waste of valuable alloying elements and will be less profitable than re-using it for can stock.

Figure 3: Various types of scrap: Packaging and old coolers

The recycler in the open cycle needs a melting furnace that eats anything. The different types of scrap come in different sizes and shapes. The recycler tries to make an optimum mix with regard to alloys, but the furnace must be versatile to handle any type, composition and shape of scrap (Figure 3). The target of this operation is to produce a useful quality metal with lowest cost input materials. The success of the enterprise depends strongly on the experience of the operators and control of the remelt process.

Durability

The closed cycle recycling is really durable. This is only partially the case for the open cycle. Here are still possibilities for improvement, not only for the melting facilities, but also for the packaging industries. In the filter plant of the remelt facilities, substantial amounts of Chlorine and other noxious substances are found in the additives. The origin of these substances must be in the coatings used on the scrap. Apparently producers of aluminium appliances and even of packaging materials seem still to have little concern for the end of the lifecycle of their products. Noxious components in the used filter dust make the dust useless for any further application such as building materials.

Low grade scrap contains many alloying components that are virtually wasted when making a new alloy out of the scrap. For making the alloy on spec, elements can be leached out with Chlorine or concentrations can be lowered by diluting with primary material. This makes that only part of the material is actually recycled. Another part needs to be supplemented with primary metal.

Garbage to garbage

In scrap remelting a general saying is that one makes garbage from garbage. Remelting low grade aluminum scrap makes low quality aluminium, low quality with regard to high level of oxides, foreign matter and various alloying elements. Recycling is more than just melting. It is the modern variant of alchemy, a true art of transferring a dirty hot soup into precious metal.

There are various means to enhance this operation:

- Separation
- Fluxing
- Dilution
- Holding furnace with porous plugs
- Degasser
- Metal filter

Separation

The first aspect is build into the design of the twin chamber furnace. It has a heating chamber, referred to as clean chamber and a melting chamber called dirty chamber.
The furnace melts contaminated scrap in the dirty chamber with superheated liquid metal from the heating chamber. The concept of the furnace is that the dirt and dross remain in the dirty chamber while the metal that is tapped from the clean chamber is relatively clean. The dirty chamber needs to be skimmed every one or two hours, while the clean chamber needs to be skimmed only once a day.

Fluxing

With fluxing salt, the metal is cleaned from part of the oxides and foreign matter. The reactants will float on the surface of the bath as dross that can be skimmed off. Fluxing is a pre-treatment step in increasing the metal quality. Fluxing salt has negative side effects on the refractory and the filter plant. Many operators today decide to operate the furnace without fluxing salt. The quality of the metal can be compensated with selecting a high end degassing system.

Dilution

Adding primary metal into a twin chamber furnace is in many cases needed to get the metal on spec. As it is virtually impossible to get most alloying elements from the melt, the only way to reduce concentration is to dilute the melt with primary metal. Dilution is a relatively expensive way for increasing the quality. Analyses and pre-selection of the scrap should always have the preference. Controlling the concentrations at the entranced of the process is far more economic than diluting the large content of metal of a twin chamber furnace.

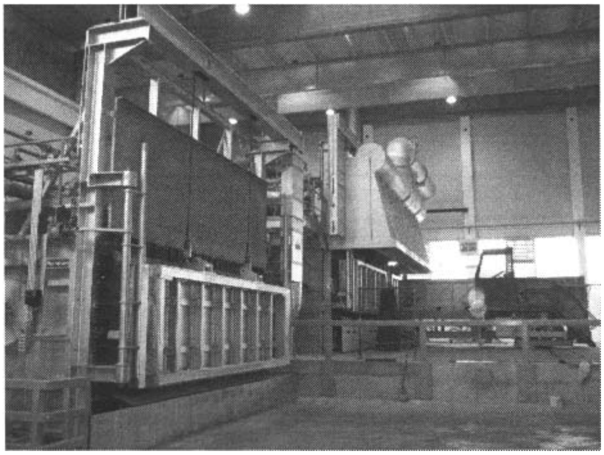

Figure 4: Twin chamber furnace (on back) with tilting holding furnace (on front)

Holding furnace

For casting metal that is produced with a twin chamber furnace, it is in general required using a separate holding/casting furnace (Figure 4). The metal transfer to the holding furnace results in cleaner metal in the holding furnace by retaining dross and sludge in the twin chamber furnace.
Equipped with porous plugs, the holding furnace can directly contribute to an increased metal quality. The gas bubbles from the porous plug system not only take out hydrogen from the melt, but the bubbles take oxides to the surface of the melt as well. Together with the inline degasser and the filter, the metal quality at the casting machine is sufficient for casting extrusion billets or rolling slabs.

Developments to purify aluminium with the partial crystallization process are promising but still in a test phase.

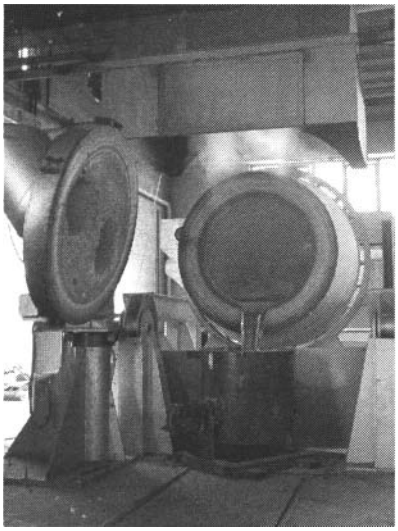

Figure 5:10 Tons rotary furnace

Secondary cast house

For recycling, the larger the amount of metal that is processed, the more economic the operation will be. However, it must be noted that melting and casting 200 MT per day is no big deal, obtaining 200 MT of suitable scrap, every single day, is!
The secondary cast house must therefore be designed for having maximum flexibility in handling various types of aluminium scrap, to respond to the fluctuations on the scrap market.

Both rotary type furnaces as twin chamber furnaces can handle scrap in various shapes, different alloys and are flexible in handling contamination. Rotary furnaces, as shown in Figure 5, are more suitable for small and varying quantities and qualities of scrap. Apart from contaminated scrap, also aluminum dross may be processed in these furnaces.

Twin chamber furnaces are designed for large amounts of scrap with a metal content of 90% and more [3]. Although flexible in type and consistency of scrap, the twin chamber furnace should be used at full capacity most of the time and with not too much variation in alloy. Due to its size, operation at part load results in relatively high fuel consumption per ton of scrap.

Twin chamber furnace

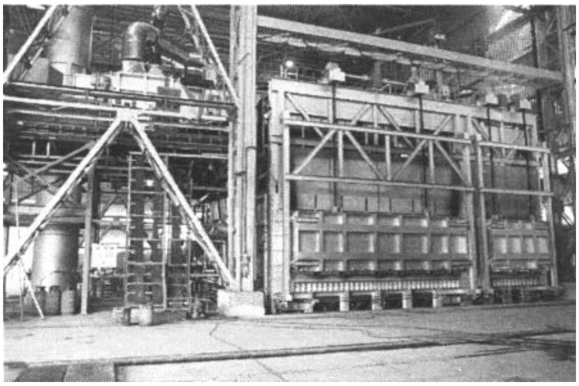

Figure 6: Twin chamber furnace for Hindalco

Aluminum has always been a valuable material. As the production of aluminium product goes with quite some production of internal scrap, there was always a need for furnaces that remelts the internal scrap. Internal scrap is mostly clean and pure material that can be processed easily. Further the amount of internal scrap is the smaller part of the total production.

Part of internal scrap is formed by cuttings and thin foil. Processing this type of scrap is best with an (open) side well furnace by indirect melting. For processing contaminated scrap, the open side well type of furnace was further developed into the closed side well furnace with closed (electromagnetic) pump, also referred to as twin chamber furnace.

A bottleneck in the development of these furnaces, during a long time, was the pumping capacity of both the electromagnetic as the mechanical pump. Only since a couple of years, larger pumps exist on the market that allowed scaling up twin chamber furnaces to melting capacities beyond 10 tons per hour [3]. The types of twin chamber furnaces that were developed by Otto Junker mainly serve the "open" cycle remelt facilities. It makes no sense to optimize these furnaces for a certain type of scrap as they will be fed with different scraps from day to day.

Description of the furnace

The furnace has two chambers, connected via a metal pump with LOTUSS bowl [3]. The main heat source is formed by regenerative burners. Heat for pre-heating is supplied by a hot gas circulation system that transports contaminated fumes to the thermal oxidizer and brings back hot flue gas to the melting chamber.

A docking type charging machine charges the scrap into the melting chamber with minimum emission of fumes to the cast house environment. Finally a bag house filter plant cleans the flue gasses from dust and dirt. Due to volatility of the scrap market, the furnace is designed in a way that has maximum flexibility with regard to alloy, scrap shape and contamination.

Large volume scrap recyclers mostly used baled scrap as these have logistical advantages. Loose scrap has such volume that it becomes impossible to charge it into a modern furnace in the required production rate of the furnace. Flexibility has its price with regard to the downstream processing of the fumes. Thermal oxidizer and filter plant needs to be prepared for unknown fume supply.

Figure 6: Twin chamber furnace with docking type charging machine

The twin chamber furnace separates the burner flames from the combustible scrap. In a large heating chamber, the heat from the burners is transferred into a bath of liquid metal. The superheated liquid metal is pumped into the relatively cold melting chamber, where the thin gauged scrap is molten by submerging into the liquid metal. Before the scrap is submerged, it is preheated with almost inert flue gas in order to dry the metal from organics.

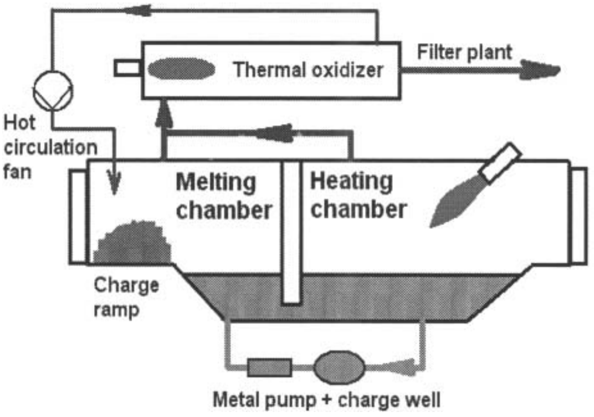

Figure 7: Simplified schematic of a twin chamber furnace

The scheme shows a twin chamber furnace with a thermal oxidizer for combusting the volatile contaminants that are released during the melting process. Alternatively these contaminants can be combusted in the heating chamber of the installation. The latter has both advantages as disadvantages. The major advantage is a reduction in fuel consumption. Keeping the external thermal oxidizer on operating temperature requires fuel while combusting the fumes in the heating chamber make optimum use of the energy content of these fumes.

Major disadvantage of combustion in the heating chamber is that with the combustible fumes an amount of dirt and noxious components come into the heating chamber. The clean chamber now gets polluted with dirt and dust, which also may end up in the metal and have to be removed in the downstream processes. The dirt also collects in the regenerators of the burners of the heating chamber, which results in increased maintenance time and cost.

Melting process

Objective of the recycle facility is to have a high as possible metal recovery. In addition to separating flames from thin gauge scrap, it was learned from observations that the highest recovery is obtained with quick melting of the scrap. In the first generation of twin chamber furnaces, especially melting of baled contaminated scrap took a long time. It seemed that the longer the melting time took, the higher the metal loss.

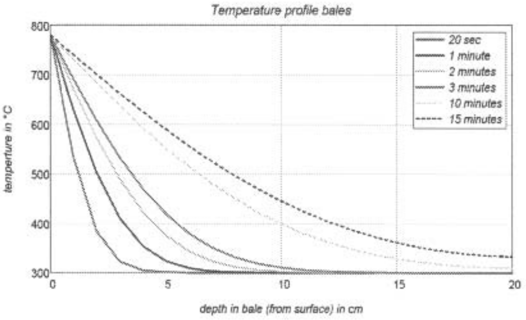

Figure 8: Temperature profile in submerged bale

For improving the furnace performance, the melting process had to be improved. We needed to have better understanding of the physics of the melting process. Mathematical models of heat and mass transfer in combination with temperature measurement of full sized bales in a test furnace showed that in the melting process in a twin chamber furnace are governed by metal velocity rather than by heat transfer.
Figure 8 shows the metal temperature in a bale, calculated with the method of Euler [3]. From the figure it may be evident that the outer skin is already melting while the inner part of the bale is still relatively cold. In a stream of superheated liquid aluminum, the viscous forces will take the melting outer skin and dissolve the material. Further calculations resulted in a quantification of the dissolving of the bales, as shown in Figure 9.

By melting with high metal velocity, the heat transfer value goes up and the bale will be peeled off quickly. The blocks quickly dissolve, rather than slowly melt [3].

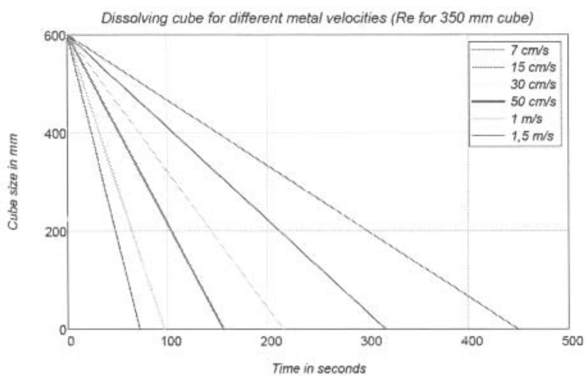

Figure 9: Dissolving time for different metal velocities

In the new generation twin chamber furnaces, we keep the metal velocity in the melting chamber at a level that all metal is molten before the next charge. The highest recovery is achieved with high liquid metal temperature and high metal velocity.

For further improving the melting velocity and – at the same time – recovering heat, the bales are preheated on the charging ramp of the furnace. By keeping a charge of relatively cold metal on the ramp all the time, waste heat from the flue gasses is transferred into the metal.

Improvements

It has been proven that governmental stimulus has a major success on the recycling rate of used aluminium packaging materials. The recycling of used aluminum scrap is not only beneficial for energy consumption and the associated carbon dioxide production, but at the same time it reduces the amount of waste that is produced and will result in a durable economy. When, for packaging materials, only coating materials would be used that contain no noxious substances, the recycling process would be more durable. In that case the dust from the filter plants would have a further application as building materials.

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