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HISTORY AND FUTURE OF DROSS PROCESSING

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Abstract

The challenge has always been to melt aluminum at it's highest recovery. As the aluminum industry has developed over the past 60 years the value of the aluminum and the view of the oxidation products has changed from one that was thrown away to one that we look to completely recycle. Aluminum melting generates dross. Dross removal carries out free aluminum. Minimizing these two realities has been the charge of companies developing systems for our industry. The last 60 years has marked real progress in these areas and continues move forward successfully.

Introduction

The paper is going to review the history and origin of dross processing techniques that have been used in cast houses and melt shops around the world. Both hot and cold techniques will be discussed. An effort will also be made to take a look at what the future will bring for processing this material.

I am going to make the assumption that almost everyone reading this paper knows what aluminum dross is and that it is a product of the aluminum melting process. I will not go into any detail on what makes up dross or how it is formed in the myriad of melting processes that are used in our industry. It will suffice to say it is a mixture of aluminum metal and aluminum and various other oxides and sometimes a salt flux. The concentration of aluminum in these materials is what has significantly changed over the development of metal preservation technologies in dross processing. This paper will focus on these improvements.

There are many types of aluminum dross: white dross, black dross, foundry dross, induction furnace dross and primary aluminum dross just to name a few. Each can have special handling techniques but for this paper I will make only three distinctions of dross types and those will revolve around the temperature of the material. The types I will reference are cold dross (800 – 1200°F), hot dross (1200 – 1440°F) and thermiting dross (Very Hot 1440°F +++).

The interest in this topic really centers around figure 1.

Figure 1: Throwing out the Baby with the Bath Water

The aluminum contained in dross is our industries baby. It is a small fraction of the cast houses total aluminum mass balance but it has a significant financial impact. The value of the aluminum at $2000/ton recovered in-house vs. oxide values of 0 - $400/ton puts the emphasis on which material we should maximize in recovering. Aluminum converted to oxides after skimming are dollars lost forever.

The goal of any handling method used in the cast house is to keep the dross from oxidizing any further than when it was removed from furnace. It is normally accepted that aluminum starts rapid oxidation in the air when it's temperature rises above approximately 1440°F. The rate of oxidation increases rapidly as the temperature increases under most conditions.

Historically the dross has been handle as follows:

- Hand Picking
- Floor Cooling
- Stirring
- Shaker Tables/Vibrators/Stirrers
- Rotary Coolers/Vibrators/Stirrers
- Centrifuge (Focon)
- Inert Gas Dross Cooling (IGDC)
- Hot Dross Pressing
- Hot Rotary Furnace Processing
- Cold Mechanical Processing

Hand Picking

The first and most basic form of aluminum recovery from dross is hand picking. It was simply done by looking at the pile of dross and picking out the solid aluminum metallics that could be easily seen. This was originally the only method of recovery. Typical results would be an aluminum recovery of 5 – 10% of the dross weight. This easy step to recovery is widely done even today. This action is often the first line of cast house recovery of a valuable resource. The remaining dross that was shipped out had a very low metal content and was not seen as a valuable product. It was typically landfilled or given away.

Floor Cooling & Picking

The floor cooling and picking combination was the second generation of efforts that was done in this basic form of dross recovery. The dross was spread onto either a refractory, steel plate or aluminum ingot floor. The latter two options, producing better secondary results than the first option. The in house recovered aluminum did not change (5 -10%) but this was the first movement towards good secondary recovery of the aluminum coming in typically at 25 – 35%

The cost of the metal put into the floor could be expensive but was typically old inventory at the site. So it was still on the books even though it was half buried. The system was however only as effective as the operators diligence to do a good job. The dust generated from the process was always significant and fork truck tires were short lived when traveling over the hot dross and molten metal. This was the predominant technology of the 60's and 70's.

In The 60's we started to see a change in the way dross was perceived. It started to become a source for aluminum units and not just a back yard problem. Aluminum values were rising. Stirring, Cooling Tables and Rotary Coolers hit the scene.

Hot Dross Stirring

Stirring was the first physical process to hit the aluminum industry to get wide commercial acceptance. The basic principle was that the hot dross was skimmed directly into a refractory lined cylindrical pot or cast steel pot. This pot was then transferred to a steel frame which contained a paddle. The pot could be raised into the paddle or the paddle lowered into the pot and then stirred. The processing time averaged about 5 minutes. After this period of stirring the hole in the bottom was "tapped" into a sow mold. If the material was hot going into the process and it was not a dry thermited dross high sow recoveries were possible. The recoverable aluminum could range from 35% to 55%. The stirring action of the paddle caused the coalescence of the droplets in the dross/metal matrix, enhancing the drain recovery The stirring action however also caused increased oxidation of the remaining dross and produced a material with a very low secondary recovery. Of all the technologies available in this period, the stirrer did provide the greatest in-house drain.

It's negative features revolved around the stirring mechanism. The thermiting reaction caused by the stirrer ate away the stirring blades. Large amounts of fumes and smoke were generated and were very difficult to deal with. The remaining material after stirring was hot and hard to handle.

Cold materials would not stir. Sometimes fluxes were added to colder material to get the thermite reaction to occur losing aluminum units and generating fumes.

Shaker Cooling Tables/Vibrators/Stirrers

Water cooled shaker tables made their appearance in the market about the same time as the stirrer. The most well know was the Ajax/Newark model. Some melting facilities combined the stirrer with the shaker tables others combined a vibratory motion to coalesce the aluminum particle to facilitate free metal drain into a sow mold. The process started by hot dross being skimmed into cast steel posts and then transferred to the water cooled shaker system by fork trucks. Once loaded into the system the pots are moved into the portion of either stirring or vibrating device which ended in "tapping" into a sow mold. After "tapping" process, the pot is dumped onto a series of covered water cooled vibratory tables. The hot dross moves down these tables. The tables are hooded so the fine dust is evacuated into a bag house. The material was typically screened at the end conveyor.

The drain recovery by the stirring action was in the range of the 10 – 20% or a bit less by the vibratory action. The cooling action however allowed for a secondary recovery that was not available by the stirring action alone. Secondary recovery would range from 15% - 40% for a total recovery ranging from 35% - 55%.

The systems however were high in maintenance and difficult to keep running. Colder dross would not drain and large chunky dross would not flow well or cool well thru the system.

Rotary Coolers/Vibrators/Stirrers

Rotary coolers replaced the water cooled table system and made their first commercial appearances in the 1970's and are still sold on rare occasions. The major manufacturers were Remetal, MFS, and Waagner-Biro. The Alumax Aluminum Group had also developed their own in-house processing units. MFS and Sanwa (Japan) still produce and sell this type of system.

The rotary cooler generally consists of a large drum which is externally water cooled, a charging device, a trammel screener on the discharge end of the system and a pollution control system. For safety reasons a back up power supply was always highly recommended. The skim pan designs, set some manufactures apart from others. A good pan deign facilitates dross cooling and draining of the material before the rotary processing. Other items that set the various systems apart were the use of stirrers, vibratory chargers and ball milling sections.

The dross was skimmed into skim pot/sow mold combinations. There was no longer the need to "tap" the pots because holes in the pots allowed draining as soon as the skimming procedure. The skim pots were placed into the charging device and tilted into the water cooled drum while it rotated. Several methods were used to cool the drum shell ranging from submergence, spray nozzles and lifting flights. The system was good at handling a range of material from cold dross to very hot thermiting dross.

The free drain recovery was in the range of the 10 – 15%. Slightly higher if the stirrer was used. The cooling action provided by the contact with the drum allowed for a very good secondary recovery that was not available by the stirring action alone. Secondary recovery would range from 35% - 50% for a total recovery ranging from 40% - 60%.

The mixing action of the drum kept the recovered aluminum in a finer size range than other processes. This was good for overall metal content but limited the secondary recovery process.

The safety record of the rotary cooler was not good. Poor maintenance or operating procedures left the process open for the possibility of molten aluminum being poured on top of water or of having contact with rusty steel. Both of these scenarios opened up the potential for significant explosions. Several units failed in the field with catastrophic results. Maintenance of the systems was very high.

The Waagner-Biro and Sanwa systems were a latter spin offs of the original European rotary cooler designs. These systems had unique features of utilizing a ball mill/autogenous mill and in the case of Sanwa a more focused stirring device. The process starts after skimming when the hot dross is charged into the water jacketed cooling drum via a scoop or tilt mechanism. The dross was cooled with contact with the drum. The dross then passes thru into a ball mill / autogenous mill section. Finally material is passed over a screen for sizing. In house recovery were a bit higher, secondary recovery lower than standard design rotary coolers because of fines generation of the milling action.

Inert Gas Dross Cooling

Inert Gas Dross Cooling (IGDC) an ALCAN developed process was made commercially available by STAS in the early 1990's. Several " home made" in-house designs have also been developed, both are now used and are typically now seen world wide. The process starts with skimming into well designed multi chamber cast steel skim pots that are transferred to "cooling stations". These stations are then closed and ether argon or nitrogen is pumped into the chamber to cut off oxygen to the dross. The cooling process is long and several units are required for a large melting facility. Some of the pan sets are designed with free drain holes others are not. In house recovery will vary from 0% - 12% and secondary recovery range from 30% - 60%.

The overall results were very comparable to rotary coolers but without the large maintenance expense. High argon gas expense was one of the drawbacks of the system. This is the reason some users have gone to nitrogen for a cover gas. I cannot comment on the results of that change. The system is good for all dross temperatures. The system is widely used in the aluminum industry.

Centrifuge

A company named Focon from Europe marketed centrifuge system in the late 1990's. I have only heard rumors of it's use and have not seen or heard actual results from anyone using the system. The unit was made up of a charging device, "converter" or heating chamber and a centrifuge device. The process design was to take the hot dross and charge it into the converter and heat the dross for charging into the centrifuge unit. Then the centrifugal force would separate the molten metal from oxides. The molten metal agglomerated into a ring on the interior surface of the centrifuge. The oxides would be the discharge product with essentially no aluminum content. Temperature of the dross was very important, the user had to adjust temperature in the heating section with a burner and by the use of exothermic fluxes. Cold dross must be heated for it to work in this system.

According to it literature the centrifugal force would allow for very high in house recoveries. It would seem however that the exposure at elevated temperatures by the burner flame and exothermic fluxes would promote oxidation and reduced overall metal units. Dealing with the hot by product I am sure was also challenge.

Hydraulic Pressing

The hot dross pressing technology was first invented for the zinc industry in the 1920's. The first commercially marketed pressing system for aluminum was available in the late 1970's and manufactured by Pechiney. In the mid 80's Anaconda Aluminum develop a dross press system that was used in several of it's operations. The first commercially successful dross presses were developed and marketed by ALTEK in the early 90's. Since that time there have been many commercial manufactures and home made versions of the dross press found around the world. Dross pressing is the most widely used system for hot dross processing used through out the aluminum industry.

The process of hot dross pressing is based on the observation that if dross is placed under pressure, the liquid aluminum will separate from the solid oxides and flow to the area of highest pressure (drain hole locations & top head surface). The press system consists of a steel frame, hydraulic unit, press head and skim set. Some presses have attached pollution control units.

Dross press technology is really not about the press but about good skim pan and head designs. High grade steel castings allowing for optimal pressing configurations have made the process what it is today. The skim pot has holes to allow for the natural drain and pressed drain. Good casting designs also promote dross cooling and newer designs optimum sizing for down stream processing.

The process starts when dross is skimmed into the skim pot set. The most important free metal drain starts here. The skim pots are brought to the press by fork truck, where the press head is pressed into the dross. This pressure forces additional metal out into the sow mold and coalesces the fine particles of liquid aluminum into large solid plates of aluminum within the dross matrix. The mode of the press cycle is very important to get the separation of the aluminum from the oxides for down stream processing. These plates of aluminum recover at a much higher melt recovery than the typical – ¼" aluminum particles that you see in non processed dross. Typical press cycle times range from 4 – 12 minutes. Large dross generators would require multiple presses. Cold dross does not press well or drain well. Thermiting dross gives good drains but the press is not the answer to stopping a wild thermite reaction.

Dross pressing provides a good in house drain but not as high as stirrers for hot dross. The maintenance however is much lower and therefore the up time much higher than the stirrers. Pressed dross is rapidly cooled preserving metal units in the process vs being heated up as in the stirring operation.

The in-house recovery will range from 15% - 40% and the secondary recovery ranges from 30% - 70%. This process gives the best overall recovery of any of the preceding hot processing modes.

HDP with Rotary Furnace

In plant hot dross processing with a combination of one or multiple tilt rotary furnaces has been a common method of in house dross processing in Asia for many, many years. The system uses, cast steel skim pans for movement of the dross and molten metal, a tilt type rotary furnace, a combustion system (sometimes used and sometimes not used). A pollution control unit for the fume control and some method of containing and cooling the hot oxide product after the aluminum is removed. In the 90's a few companies in the US and Europe installed systems for their melting and casting facilities.

The process is designed around bringing the hot dross directly from the melting furnaces to a rotary furnace. The hot dross after charging will tumble with the rotation of the rotary furnace. This rotating action essentially vibrates the dross and once again coalesces the molten aluminum droplets into the bath of the rotary. The operator has ultimate control of this process controlling the processing time and the input of extra the heat via the combustion system if requited. When the molten aluminum is separated from the oxides the operator carefully tips the furnace, holding the oxides in and pours the aluminum out. This recovery method produces a recovered aluminum unit of exactly the same alloy that was just removed from the melting furnace. This metal is more valuable than that which would have been returned from a secondary processor. There have been no flux additions so that the oxides produced have a market value or at least have a zero disposal value. Care does have to be taken not to over heat the remaining oxide materials. It is easy for the process to start to thermite and then significant fumes are generated before it is removed from the furnace and some type of slag cooling equipment cools down the remaining material.

The basic recovery results for processing in this method are very good, nearly 98 + % of the available free aluminum. The only caveat being that the recovery will range with the aluminum content of the dross. It is without saying that if the aluminum is not in the dross in the first place it will not be recovered.

Another very unique feature of the process is that thru observation of the metal content and quality of the dross that is generated from the melting furnaces and being locally processed, operational improvements can be made to lower dross generation and improve dross quality. None of the previously mentioned processes allow for this significant advantage.

The system is the most expensive capital expenditure of all the processes listed with the highest annual maintenance and operating cost. It also requires the highest level of skilled operators to work in a reliable manor.

Mechanical Processing

Cold mechanical processing has had two time periods of popularity in the aluminum industry with dross generators. First, in the 60's with the use of ball mill systems provided by various manufactures and for the past 5 years with the use of DIDION Tumbler processing systems.

A few dross generators that were typically secondary aluminum melters attempted mechanical processing in ball mills. There goal was to get some level of aluminum recovery from the dross they generated and at the same time add value to the oxide products that they would have had to pay to dispose of. The dross would come from the internal melting processes and would have to be pre-sized to go into the mill. Typically mill openings would accept a dross piece no more than 10 -12" in size. The ball milling process would produce concentrates of aluminum and "ball mill fines". The concentrates were typically in the 60 - 70 % aluminum content range. The system was not good at producing high aluminum concentrates because of "rolling in the oxide". The system produced high grade "ball mill" reactive fines which were popular with those companies purchasing these types of materials. The basic systems were relatively low cost to run but for the balls that needed replacing on a regular basis. Mechanical difficulties and "rolling in of oxide" limited their productiveness. Rotary furnace melting was still required for most of the materials that they produced. There use with dross generators was short lived.

The DIDION Tumbler system had been used successfully at various secondary dross processors since the mid 90's. The first unit was sold for use by a dross generator in 2010. The system was the first a single piece of equipment that allows for total dross processing in the dross generators facility. The system is a unique rotary impact crusher and classifier in one unit. The system is typically feed by a motorized vibratory feeder. A pollution control unit is required for the systems operation. The properly sized Tumbler requires no presorting of the incoming dross. It works well on normal white dross, black dross and slat cake. It is not effective on cold skimmed white dross the "ice cream" type materials.

The process starts with dross that has been removed from the furnaces that may be hot but contains no molten aluminum. The Tumbler is typically sized for the largest piece of dross produced at the dross generators facility. The system is based on impact crushing the aluminum / oxide matrix separating the aluminum from the oxides around it. The aluminum, free of most of the oxides is classified by size for in house melting. Producing concentrates of aluminum typically greater than 85% is possible on the +1/4" material in the Tumbler. The -1/4" material if not suitable for in house melting are sold on the open market for their aluminum content. The low grade aluminum fines separated from the metallic aluminum in the process are also used in various by product industries. When processing primary dross the oxide products that are detached from the aluminum are becoming suitable for reintroduction into the pot lines.

The system is simple to operate and does not require highly skilled operators. One system is sized for the operations total dross generation. The capital cost is in the medium level, maintenance and manpower cost are very low.

Mixed Technologies

The best technologies are often a mix of existing technologies. In my opinion the best combination of technologies is the use of the dross press with properly designed dross pans, achieving a large in house drain, plating action of the aluminum droplets into larger +1/4" metallics and rapid cooling of the dross for maximum metal preservation. The DIDION Tumbler would then give a clean separation of the maximum amount of metallics for in house melting. This combination would achieve the highest in house recovery keeping the metal at its highest value for the dross generator. It would also produce a high quality oxide product for various by-product uses.

Future Technologies

Those of us who work in this area of dross recycling have to continually to ask ourselves how can we make things better. What could we do to be even more effective in dross handling, saving energy units, aluminum units and minimizing our industries CO_2 generation.

TT Tomorrow Technologies of Italy is working on a system to minimize the amount of metal pulled out of the furnaces with the dross. Their goal is to cut the amount removed in half from the current averages. Imagine cutting the plants dross generation in half by the use of a unique skimming machine. A significant amount of the dross removed from the furnace is aluminum that should remain in the furnace. This development has the power to significantly reduce melt losses, energy consumption from remelting metallic concentrates and cause a significant contribution to real CO_2 reductions in the area where dross is processed and handled.

These are the type of steps we need to take to achieve the goal of 100% in house recycling and zero dross shipments to outside recycling resources.

Summary

There is an industry need to keep moving forward in its dross processing technology development. The first step is keeping as much aluminum as possible inside the melting furnace. The next step is keeping as much recycled aluminum in house for use in the facility that generates it and producing by products that are by nature saleable and not a landfill liability. It has been a long trip but the end is in sight. We have moved forward over the past 60 years to understand and keep close to our industry the baby that we use to discard.