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Zinc Recycling in Die Casting Processes Using Industrial Optimization

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Abstract. Zinc is one of the metals existing on the planet too important for the life of this one, it is an element of the essential nature in our development of life of every living microorganism. Agriculture is one of the productive processes of the planet that undoubtedly depends a lot on the quantities of zinc that exist in nature. The pharmaceutical industry has generated thousands of products based on this element to generate medicines for human health. But we must not forget that despite being a necessary element it is also toxic for living beings, and if we wanted to eliminate it from our environment, we would also cause an immense problem to any ecosystem or to our own environment. The excessive use of metals has generated an excessive pollution to the planet, and what is required is to create awareness in the industry to generate a green market. It is required that all companies begin to think about giving back some of what they have taken from the planet, making improvements in their processes to create products with sustainability to have a world without pollution. Technological research has developed new improvements to many applications within the industrial processes that have placed many companies in the first places as recycling plants and generating products based on zinc waste and remain as green companies according to the rules. Generating an evolution to the economy of the main producing and consuming countries of this element, which in spite of being less required than aluminum, in the last years, from 2000 to 20018, more than 45700 million metric tons have been generated all over the world. China is the country with the highest zinc productivity in the world.

Keywords: Die casting, Zamak zinc alloy, zinc recycling.

1 Introduction

In this article we analyze the importance that zinc has in the natural, environmental, after its normal and industrial process cycles as a recycled material. The aspects caused by this type of activity that lead to an increase in the economy in the countries that are dedicated to the collection of this metal are analyzed. Nature on the planet has evolved with the presence of zinc, playing a fundamental role in several biological processes and being an essential element for all forms of life. Small microorganisms, living beings, including human beings, without this material their existence would not be possible.

- Zinc is a natural element, for this reason it cannot be eliminated from our environment, if this happens our ecosystems could have very harmful effects in the long term. This element is indispensable for living beings and it is necessary for humans to ingest it in their daily diet in small doses. It is necessary to know that this element, despite being an important part of life, also becomes toxic when consumed in excessive quantities (Miller, 2002).
- The intoxication can occur by different ways: inhalation, by consumption of drinks or by ingestion. Intakes of 50-60 mg of zinc/day can cause abdominal pain, nausea, vomiting and occasionally pancreatitis, especially if accompanied by inadequate copper intake (Sandstead HH, 2006). Environmental toxicity also exists from elevated levels of zinc released by various human activities.
- Emissions come from municipal and industrial waste, mining, geological activities, and secondary sources not related to zinc production or manufacturing. Current uses of zinc and zinc compounds alone do not lead to the high levels found in some regions in water and sediments. The bioavailability of zinc transport in water, sediment, and soil depends on the chemical characteristics of the environment and organisms on the site (Tejeda S., 2005).

2 Normal Zinc Cycle

Zinc is a common mineral on the planet located in soil, rocks, water and air. Natural emissions to the atmosphere amount to 5.9 million metric tons annually. Sixty percent of the zinc produced worldwide is extracted from mines and the remaining 40% comes from secondary process waste. However, recycling is increasing year by year, with progress being made in zinc production technologies IZA (International, 2014).

- Zinc follows a complex life cycle from extraction as a mineral, through refining and use in society. This life cycle can be characterized by the collection of information at various stages of production, manufacturing, use and waste management to the eventual collection and recycling of products.
- Zinc is an extremely versatile material, which plays a fundamental role in certain industrial applications and products that generate lower costs and a lower environmental impact due to reduced maintenance. In the end, the material recovered from modern products that are discarded can be recycled without deterioration (Martinez J. Roca, 2001).
- Zinc during its normal application is sustainable as it is recyclable at all times of use, playing an important role during the final life phase by consuming little energy, reducing emissions and minimizing waste disposal. Two commonly used approaches to evaluate the percentages of sustainability are the amount contained in the material processed, and the fraction of zinc obtained at the end of its life.
- Zinc is very useful in the chemical and metallurgical industry because its physical and chemical characteristics are very useful for products made from this material. It is a material that can be melted at very low melting point temperatures, 420°C and boiling point of 907°C (SANCHO J., 1999).

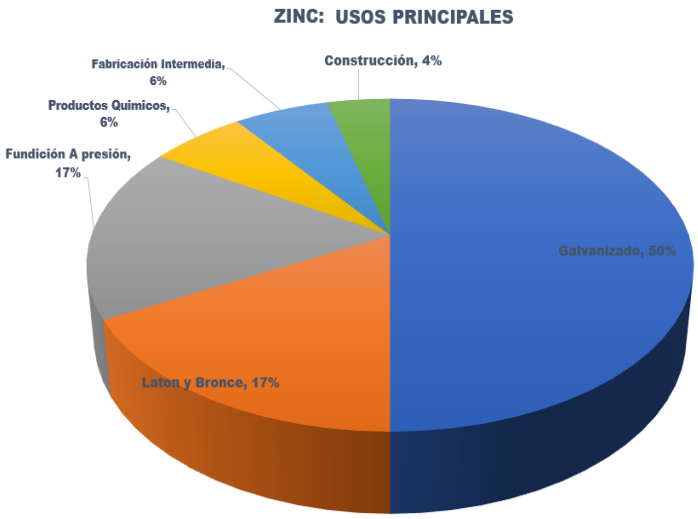

Fig. 1. Zinc as the main metal in the industry (IZA(International, 2014).

– This material is fragile at room temperature, but after 100°C it becomes malleable. Its resistance is higher than that of lead and tin, but considerably lower than that of aluminum, and despite its low nobility it has very good resistance to atmospheric corrosion.

3 Main Uses of Zinc

The International Zinc Association (IZA), in cooperation with Yale University, completed a flow analysis of anthropogenic zinc emissions into the atmosphere based on zinc production and use figures. These analyses and studies have been supported by the industry to understand the extent of environmental impacts beyond the life of zinc IZA (International, 2014).

In this study, the figures produced annually around the world by the transformation industry are presented, which were 11 million tons of zinc use. Of these, the recycling rate at the end of its useful life was 50%, the amount used.

Of the brass and bronze alloy 17% is used for production mainly in the die casting industry. Significant amounts of 4 and 6% are also used in compounds, for example, zinc oxide, zinc sulfate, for the manufacture of sheets required in construction placed on roofs, gutters and downpipes of houses or buildings.

4 Zinc Nonferrous Metal

Zinc is one of the main non-ferrous metals with atomic number 30, an atomic weight of 65.38 and a specific weight of 7.14g. It is a grayish white metal resistant to oxidation and corrosion; once melted it has a high fluidity with a tensile strength of 2kg/mm2,

increasing when processing its lamination. Zinc has a high elasticity in hot of 120-150°C, keeping its malleability, but being harder than tin.

This material is used in manufacturing along with Aluminum, Copper, Magnesium, Nickel, Lead and Titanium. Non-ferrous metals are used in manufacturing processes, as complementary elements to ferrous metals, are also very useful as pure or alloyed materials, which by their physical properties and engineering cover certain requirements or working conditions, for example, bronze (copper, lead, tin) and brass (copper zinc).

Being a non-ferrous metal, it becomes one of the most important natural qualities for use in the coating of steels to prevent corrosion in this type of ferrous material. Steel in any environment if left unprotected corrodes very easily and quickly, hence the use of zinc as a physical and protective barrier (Krúger J., 1990).

Pure steel in its galvanizing process undergoes a caustic cleaning and annealing before the molten zinc coating is applied. A zinc chloride and ammonium flux is used to remove the last traces of oxide. This process must be applied at a speed of 200 meters per minute to avoid the cooling of both metals causing the zinc to not adhere properly to the steel.

Continuously galvanized coatings metallurgically adhere to the steel they protect. This ensures the adhesion of the coating, which is essential for manufacturing processes that bend, stamp, roll or draw the steel into its final product form.

5 Zinc Alloys Used in Die Casting

During the 1930s, many of the alloys we know today were available, but their use was very limited. Modern science and technology, metallurgical controls and research are now making refinements possible that result in new alloys with greater strength and stability.

Over time this research into different alloys has led to significant technological improvements in the basic process of high-pressure zinc injection molding applications (die casting). These alloy improvements have been effective in expanding die casting applications in all known markets.

Among the technological investigations is zamak, which belongs to the 17% zinc-based alloy used in the die casting industry, which is composed of various non-ferrous metals to give the necessary purity to the alloy. Zamak is manufactured in six types and several sub-types and its basic composition contains besides Aluminum, Magnesium and variable amounts of Copper and Nickel, these metals are added with the purpose of improving the mechanical properties of the base metal, in this case zinc.

It is very important for the die casting process that the high-pressure molding designers, before making any application project should consult a table containing the mechanical properties of Zamac alloys. These properties of typical interest are:

- Tensile strength (maximum).
- Production strength.
- Elongation (ductility).
- Modulus of elasticity (MOE).

Fig. 2. Zinc Alloy Ingot (SoloStocks, 2020).

Table 1. Zamak Alloys (NADCA, 2015).

Tipo de Aleación	Aleación de Zamak				Aleación ZA		
	#2	**#3**	**#5**	**#7**	**ZA-8**	**ZA-12**	**ZA-27**
Nominal	Al-4.0	Al-4.0	Al-4.0	Al-4.0	Al-8.4	Al-11.0	Al-27.0
Composición	Mg-0.035	Mg-0.035	Mg-0.055	Mg-0.013	Mg-0.023	Mg-0.023	Mg-0.015
	Cu-3.0		Cu-1.0	Cu-0.013	Cu-1.0	Cu-0.88	Cu-2.25

Each of these is a property which predicts how the alloy will react to a stress condition. A "strong" alloy has high tensile and elastic strength values and low elongation values. A "weak" alloy has low strengths and higher elongation values.

Zinc alloys are referred to as Zamak, which is an acronym for “Z” for zinc, for “a “aluminum, “m” for magnesium and “k” for copper. In the United Kingdom, they are called Mazak Zamak is manufactured only with "Special High Grade" Zinc, with 99.99+% purity, pure Aluminum and Magnesium and electrolytic Copper. Its most common presentation is in ingots of 8 kilograms approximately, the standard stowage handles 132 ingots (although it can be adjusted according to needs) and weighs ± 1100 kgs.

Existing Zamak ingots comply with the following standards: NOM-W-137-85 and ASTM B240-87 and they may contain Nickel, Chrome, Silicon and Manganese in quantities that correspond to their solubility of 0.02%; 0.03%; 0.035%; and 0.5% approximately and respectively at freezing temperature.

The following table shows the elementary specifications for the zinc alloys normally used in die casting. Zamak #3 and #5 were introduced in the 1930's and #7 were introduced about 20 years later.

In this type of productive activity, waste of this metal is generated in three stages that are used to create a good that will generate a production cost. During the processes of melting the zinc ingots in the production equipment, there are several processes of

consumption of this metal in which a percentage of the purity of the virgin Zamak is constantly lost.

The zinc based Zamak alloys, as mentioned above, applied in the industry are 17%, zinc die casting scrap, zinc dust filtered by the steel mill furnaces represents 6% as well as steel plates.

6 Recycling in Die Casting

Slag

The slag is basically formed from the material coming from the furnace or crucible, generated by the high temperature in the melting process, this temperature is normally 800° Fahrenheit and is recovered in an impure form of 50% zinc. This material is a kind of foam that is generated on the surface of the molten metal inside the container (Crucible). Its chemical composition is basically zinc and iron.

Flash

The burr is a material that is generated at the time of molding the main part that is already the finished product. This is a surplus material or an excess that is formed to the figure of the piece and affects the quality of your design, so all parts that come out with this defect are recycled as virgin zinc. The material that is discarded during the injection process in a die casting process does not lose the property of being a pure zinc alloy. This material is still Zamak and for this reason it is returned to the production areas and placed back in the molten zinc container furnaces (crucible) to be recycled during the same process. The special dies used to generate the die castings are provided with several slots that serve to dislodge the injected zinc gases into the die cavities. These grooves generate several excesses of zinc that are not used in the main product, so they are also recycled, as is the burr mentioned above.

Injected material

The amount of leftover material that is used at the time of injection in the mold dedicated to the molding of specific parts, not all this material is used and this is returned to the furnace (crucible) and this zinc waste is also collected by the company and sent for recycling.

Material with Quality Defects

Another very important waste in this recycling activity is the pieces that have a final finish, this means that they are pieces that after being manufactured go through other processes required by the customer's design, such as machining, polishing and sanding. During these processes, the pieces suffer damage and are rejected by the quality area and become useless material. There are already finished materials that, take secondary processes such as painting, which is a finish required by the customer.

This material commonly comes out with defects in the quality of the paint, 'so it is rejected and sent to companies dedicated to the recycling of this material to give them their proper process and generate the new alloy with the properties of Zamak again.

The parts already finished and available as scrap, like all the burr and dust generated in secondary processes, which are the machined, these can be placed directly in the ovens (crucibles) as this material still has all the characteristics of a completely virgin zinc alloy.

Companies that perform these zinc-based processes are committed to the principle of sustainability, and this commitment is rooted in the sustainability charters and guiding principles. The companies believe that protecting the environment, openly engaging in sustainability issues, and supporting sustainable development practices not only drives long-term prosperity for the industry and enables customers to become more sustainable through the use of zinc products.

The processing industry knows that nature is the main medium that exists as a supplier of raw materials for the production of the different processes in the industry, and for this reason the consumption of these materials requires their use in the productive areas.

These activities generate waste that, sooner or later, will return to the natural environment and depend on the handling of these, when they are discarded as they normally produce pollution.

It is necessary to know that, the productive sector will reuse some waste in the form of recyclable products, and that there are other materials from production that will not be recycled being thrown into the environment, so that it will behave in its role as a sink when receiving the waste (Martinez, 2013).

The environmental aspect and sustainable development have had a great influence on the metal recycling industry, without forgetting that this has been important in generating growth in the economy of countries. Due to the exploitation of natural resources and the scarcity of exploitable mineral reserves, the recovery of zinc from industrial waste is very important because zinc values can be obtained at very low costs. This increase is due to the fact that the recycling of metal waste is a truly lucrative activity for the world economy (Martinez J. Roca, 2001).

In the U.S. since 1970 30,000 jobs were created marking the economic and ecological importance of recycling until 1985. During this time, the American society annually discards around 35 million aluminum cans, generating $200 million dollars due to the collection of this metal waste, which is indispensable for society's consumption (Sergio Augusto Fernández Henao, 2010).

7 Main Zinc Producing Countries

A growing production of zinc in recent decades was due to its increased demand, especially in the construction sector, given the economic inclusion of China in India. During 2000 to 2018 zinc production increased by 53% to 13.7 million metric tons worldwide (GERENS, 2020).

In terms of world zinc production, the leading producer of this metal in 2018 was China, followed by Peru, as shown in the graph. At regional level, and during this year, the region of Ancash showed the highest production, with 36.8%, followed by the areas of Ju-min and Pasco which were in second and third position. The three regions together represented 71.5% of the national zinc production.

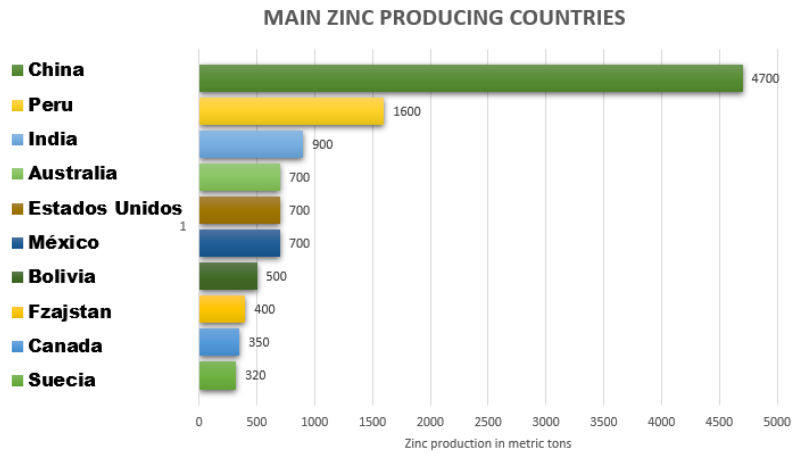

Fig. 3. Main countries in zinc production (GERENS, 2020).

Peru is the second largest producer of zinc in the world and in 2018 the companies Antamina, Volcán, Nexa and Nexa el Porvenir. They were responsible for 62% of the year's production. This resulted in zinc exports worth more than U.S. $2,563 million, representing 9% of Peru's mining production (ANTAMINA, 2020).

At present, zinc is one of the most widely produced industrial metals and is only surpassed by iron, aluminum, and copper, with China, Australia and Peru being the main zinc producers. China is the largest producer of zinc in the world, generating 4,57000 tons of metal used to galvanize steel.

Even though in recent years there have been reductions of 10% due to low prices of this metal, companies in the Asian giant have managed to increase this price by 5.3% in the sale of this non-ferrous metal. Complexity is a characteristic in the process of recycling metals, but the main objective of this activity is the enormous savings in production costs.

This is reflected in the 95% of the little energy that is used to recycle aluminum and zinc, different from that used to create them again. Over time, the increase in new technologies will allow the process to be fast, efficient and with renewable energy. Products that are not only recyclable, but also produced with a maximum of renewable substances and energy, are certified as Cradle-to-Cradle, (C2C) (Business, 2020), (IZA International, 2014).

The concept of Cradle to Cradle aims to close the life cycle of every product, making the end of life a beginning of the next production. This type of economy has created one of the greatest barriers to sustainability due to the current linear economic model of "take-manufacture-dispose" (Business, 2020).

This is done using the model of a circular economy, first used by (Pearce and Turner 1990), which aims to redefine growth by focusing on positive benefits for all of society. New markets are experiencing a rapid change and boom in eco-design, which helps companies stand out from the competition. Today there is a new generation of entrepreneurs concerned about environmental issues that focus their processes thinking

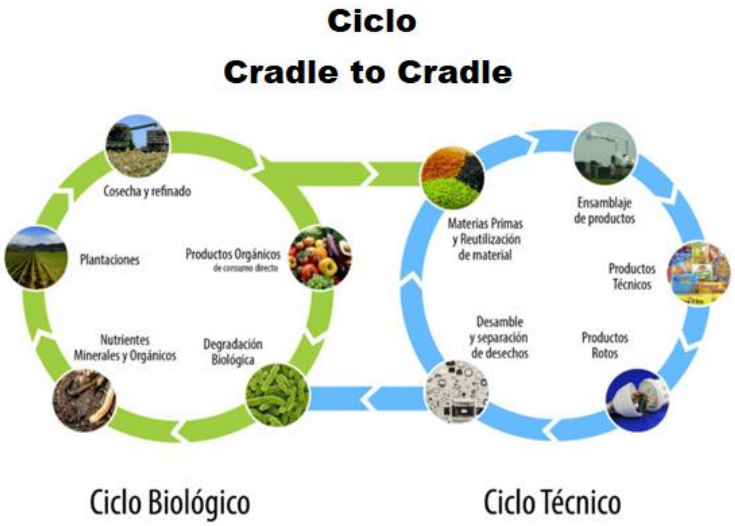

Fig. 4. Life cycle of a product (Miller, 2002).

about the entire life cycle of the product, from the manufacturing process, until the end of the life of a product (Martinez J. Roca, 2001).

These markets need companies to be sustainable and to show the world the need to build non-polluting factories that produce green products called eco-design, safe for the environment and recyclable, developing new industrial methods and analyzing all the raw materials used for manufacturing (Business, 2020).

It is necessary that the products manufactured under this new process have to go with a new brand, which will certify that the company that is elaborating it cares about what happens with this product since it is created until it is discarded by the final user.

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