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# SCRAP CHARACTERIZATION TO OPTIMIZE THE RECYCLING PROCESS

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## Extended Abstract

Managing the secondary production process for aluminum auto-shred scrap is of prime importance considering the projected demand increase for aluminum alloys in the transportation, electronic and packaging industries. Aluminum auto-shred scrap is a major end-of-life, mixed metallic stream that must be recovered and recycled effectively and efficiently to ensure infinite lifetime involving a broad distribution of re-use applications determined by specific alloy chemistry [1, 2]. Currently, secondary recyclers that dilute the melt chemistry using primary aluminum minimally only produce A380.1 as this alloy has broad alloy chemistry specifications [3]. Downgrading mixed auto-shred scrap streams is a significant waste of intrinsic value and re-use applicability. Downgrading here is defined as not utilizing all sortable chemistries within this mixed auto-shred. This, paired with scrap export, are the two major present day options for mixed aluminum scrap.

One issue preventing a wide secondary alloy spectrum is the lack of knowledge concerning sortable chemical compositions in these mixed scrap classes. In addition, proper commercial equipment capable of intelligently sorting into the consumer dictated chemistries while maintaining profitable throughput specific to aluminum and it's alloys needs to be properly developed and installed in the secondary recycling process. Steinert manufactures an XSS F (x-ray fluorescence sorting system) capable of sorting based on the heavy metals (Zn, Cu, Fe) in solid solution however more work needs to be completed to understand the extent of achievable sorting capabilities. Understanding of the varying scrap bulk chemistries as a function of time, region of origin, shredder feedstock and processing parameters will aid in proper allocation of scrap mixtures with or without intelligent sorting system exposure. Regardless of sorting mechanism, cleaning and removal of organic and polymeric content is necessary for proper downstream recycling [4]. These processes must be environmentally acceptable and exercise waste-to-energy removal methods of carbon-based impurities in the form of free polymers, oils, lubricants, paints and coatings. Another issue combating this industry is the unnecessary transport of recovered scrap particulates to be charged at external secondary smelting or casting facilities. The developing Aluminum Integrated Mini-mill process will utilize a proper inline process to sort, clean, re-melt and cast multiple secondary aluminum alloy types from this mixed scrap stream [5]. This work is focused on characterizing aluminum auto-shred in terms of metallic chemistry and through thermal analysis of the organic content to aid development of intelligent sorting systems and waste-to-energy cleaning processes, respectively.

Through a three phased approach, the research team will present an overview landscape of a complicated industry by: (i) investigating market relations domestically in the U.S. and with international consumers; (ii) financial fluctuations to expose margins for developing business

models; (iii) and auto-shred scrap composition characterization for intelligent sorting and cleaning systems. Automotive shredder scrap is an above ground aluminum ore that needs to be utilized in the USA as so much is produced with high amounts intrinsic energetic and metallic value. The export of scrap aluminum will continue to occur, but a higher volume should be maintained domestically so primary import and energy-intensive bauxite extraction can be avoided. The two auto-shred scrap classes analyzed in this work are Zorba and Twitch. Zorba is the non-ferrous auto-shred scrap containing aluminum, copper, zinc, magnesium, nickel, titanium and even some stainless steel. Twitch contains predominantly aluminum alloys (typically 90-98 wt. %) [6]. Twitch is derived from Zorba via sink-float separation or optoelectronic technology focusing on atomic density (*i.e. x-ray transmission*) [6].

Phase 1 of this project focuses on the market dynamics of the aluminum scrap industry and covers auto-shredder scrap specifically and aluminum scrap as a whole. The amount of auto-shred scrap, or Zorba/Twitch, that is exported from the USA to external markets is estimated. Upon further investigation, however, this estimation has been proven to be a significant underestimation and this will be discussed in the presentation. Due to the latter, a further analysis was conducted at a macro-scale covering the entire aluminum scrap market. One objective of this larger scale study is to compare scrap export with the international trade of other forms of aluminum (*i.e. mill products and ingots*). A second objective is to determine the amount of scrap consumed vs. how much is available for consumption in the U.S. and Canada; similar to the original auto-shred analysis. Finally, the amount of non-UBC (used beverage container) aluminum scrap metal traded to and from the U.S. on a country by country basis is to be determined for the most recent data available; 1996-2015 (YTD).

Phase 2 analyzes the margin between the cost of recovered auto-scrap classes and the value of secondary aluminum alloys. The value quantified is considered an initial margin as the calculation does not account for labor cost, capital cost, energy costs or any other accrued cost during the processing of this material.

Phase 3 seeks to quantify three distributions to support developing intelligent sorting systems. The distributions are: Major Category, Alloy, and Bin/Chemical. The six major categories are aluminum cast, aluminum wrought, other metals, mixed metals (*i.e. aluminum cast with a rusty steel bolt*), mixed material (*e.g. metal piece with significant amount of adhered polymer*), and free solid polymeric particulates. Oils, lubricants and paints are not considered to be significant adhesions. The alloy distribution includes cast 319, 356, 360, 380, 384, 390 and 413, specifically, and 2000, 3000, 4000, 5000, 6000, and 7000 series for the wrought portion. Distribution of the 6000 series to 6061, 6063 and the other 6000 alloys was achievable due the variance in the electrical conductivity measurements recorded, this was not possible for the 5000 series, however. The final distribution was determined based upon the chemical composition of the individual scrap pieces and a threshold criteria set by the research team upon discussions with professionals within the recycling industry.

Additionally, three thermal analysis techniques were performed on the organic and polymeric components found within these auto-shred scrap mixtures to aid in the optimization of proper cleaning techniques. Thermogravimetric analysis (TGA) to determine vaporization temperature and quantify residual mass values for free polymers, paints and coatings, adhered polymeric materials and cutting oil in an inert atmosphere. Cone calorimetry was utilized to determine heat of combustion values and residual mass value for free polymers in air. Finally, a burn off study, in air, paired ultrasonic cleaning, in water, was conducted to quantify the amount of oils/paints/coatings/lubricants that can be removed as a function of temperature and char removal.

Finally, an evaluation of the sorting criteria set in Steinert's automated sorting systems, XSS T and F, was conducted. A 100 lb. Zorba sample was tested on the companies' XSS T (x-ray transmission) to determine its ability to sort Zorba into its material constituents. Also, a 100 lb. Twitch samples was run through the XSS F (x-ray fluorescence) system to determine the possible chemical composition outputs when sorting on the lowest sorting threshold for Cu, Zn and Fe.

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