FAST X-RAY SORTING FOR RECYCLING LIGHT METALS

UPDATED: JULY 18, 2016

PROJECT TITLE: Low-Cost High Throughput In-Line X-Ray Fluorescence Scrap Metal Sorter
PROGRAM: Modern Electro/Thermochemical Advances in Light Metals Systems (METALS)
AWARD: $2,021,189
PROJECT TEAM: *UHV Technologies (Lead)*; Phinix, LLC; OmniSource Corporation
PROJECT TERM: January 2014 – September 2016
PRINCIPAL INVESTIGATOR (PI): Dr. Nalin Kumar

TECHNICAL CHALLENGE

Reducing automobiles' weight by using more aluminum and other light metals in their construction is an effective way to improve fuel efficiency. In principle, lighter cars and better fuel economy are global benefits. However, there is a challenge with these cars at their end-of-life. Many different light metal alloys are used in cars, and they must be accurately separated during recycling to preserve their strength and economic value. The problem is magnified because the alloys can be difficult and expensive to separate. For instance, the aluminum alloy used in a car frame differs by only a few percent from the alloy used in the car's body. Cost-effective separation and recycling of the different alloys could dramatically reduce the cost of light metals and lower the environmental impact of manufacturing with them. To be commercially attractive, a sorting system should be able to evaluate 10 pieces of scrap per second, and the sorting should cost less than about 2 cents per pound of accurately sorted material.

TECHNICAL OPPORTUNITY

Currently, aluminum alloy scrap is sorted by hand, using a special X-ray fluorescence (XRF) gun. With this gun, a worker shines X-rays at a piece of scrap metal, and measures the energy spectrum of the X-rays emitted back from the scrap's surface to determine the type of alloy. This process can take up to a minute for a single piece of scrap. This is due both to the low intensity of the X-ray source and the inconsistency when sorting thousands of metal pieces by hand.

One of the difficulties in automating XRF sorting of metal alloys is that the X-rays currently come from "point" sources like those used for medical X-rays. Point sources emit X-rays from small regions, which is needed for good quality medical X-ray images, but yields a low intensity over the large areas needed for industrial sorting. As a result, automating sorting systems require a mechanical positioning system built into the X-ray source, which is costly and slow. New proprietary X-ray tube technology, X-ray optics, position sensitive detection, and rapid data acquisition and analysis systems now make it possible to address these problems.

INNOVATION DEMONSTRATION

Working within the METALS program, UHV Technologies set out to develop a high throughput, fully automated sorter for light metal alloys, as illustrated in Figure 1. To accomplish this, the company addressed three major challenges: (i) developing a high intensity, linear X-ray tube for parallel elemental composition measurement on a tenth of a second time scale; (ii) developing low cost X-ray optics and silicon detector arrays to continuously resolve real time XRF signals from at least 10 elements (Al, Mg, Si Ti, Cu, Fe, Cr, Ni, Mn, Zn) with sufficient sensitivity to distinguish different alloy compositions; and (iii) developing intelligent software to correlate the XRF data with optical images to identify the unique elemental composition signature for each piece of scrap.

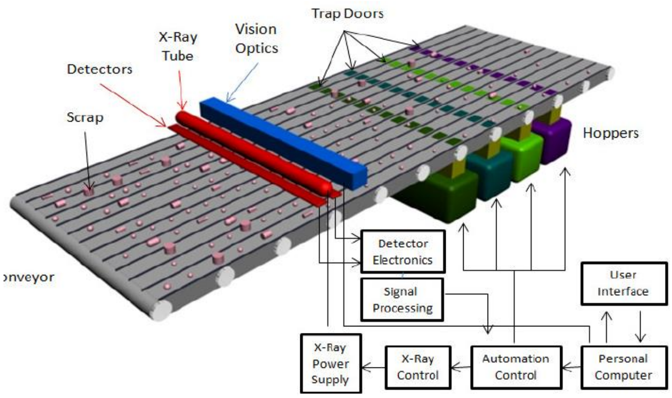

Figure 1. Schematic diagram of the sorter. The long linear X-ray source bombards up to 12 scrap pieces simultaneously, the emitted fluorescence X-rays are measured for more than 10 elements to determine alloy composition of each piece. The pieces are then sorted in to their appropriate containers using a combination of XRF data and a vision system.

UHV has developed a linear X-ray tube (Figure 2, top panel) which uniformly illuminates the entire width of the conveyer with X-rays. This innovative X-ray source reduces the tube power requirements by a factor of 10, thereby reducing cost, and enhancing reliability and lifetime. This source contains no moving parts, and is simple enough that the source can be overhauled on-site by a technician, rather than being returned to the manufacturer for refurbishment.

The detector system has been constructed using multiple arrays of commercial silicon avalanche photodiodes, paired with proprietary X-ray optics to record spatially resolved X-ray fluorescence spectra. The team has demonstrated the ability to discriminate and quantify the concentrations of Al, Mg, Si, Ti, Cr, Fe, Ni, Cu, Mn and Zn with accuracies better than 99%.

The project team has developed software that uses the array of fluorescence spectra evolving in real time to match each piece passing underneath the X-ray system with the fluorescence fingerprint of an alloy. This software is the first of its kind, able to analyze the shape and reflectance of each metal piece, determine the best place to analyze it, and then use standard spectra to identify, and send instructions to the sorting hardware for correct alloy shunting in milliseconds. Software also calculates the percentage and weight of each element in a batch of sorted scrap ready for melting during recycling. This avoids an extra melting step in current recycling process resulting in an additional 5-8 cents/lb reduction in overall costs.

Figure 2. (top) 30 kV, 36" wide X-ray source. (bottom) The UHV pilot scale aluminum alloy sorting system.

In a double-blind test, the proof-of-concept system has demonstrated a better than 99% sorting accuracy, including the ability to separate 5000 and 6000 series aluminum alloys. This has been repeated in real-world testing at an automotive scrap sorting facility. The team has demonstrated separation of 5xxx and 6xxx automotive alloy scrap at speeds exceeding 120 ft/min and a potential throughput of 40 million pounds/year, using a medium scale commercial prototype designed and constructed during this project.

PATHWAY TO ECONOMIC IMPACT

The project team has carried out extensive techno-economic analysis and supply-chain customer discovery. UHV's system, incorporating its new linear X-ray source and automated processing, can enable businesses to profitably sort light metal alloy pieces, and to improve the sustainability of the light metal industry.

UHV has established commercial connections and an agreement for field testing a prototype unit in a commercial setting. In May 2016, UHV installed its first test sorting line with a potential throughput of 40 million lbs/year at an industrial partner's (OmniSource) scrap processing yard. UHV's pilot installation has been used to test the system's throughput and reliability under actual industrial conditions. The pilot phase for this work will be completed in 2016, and negotiations for scale up to a full industrial installation are ongoing.

LONG-TERM IMPACTS

UHV's sorting diagnostics provide a commercial option to reduce energy consumption and costs associated with manufacturing light metal components from recycled light metal scrap that is typically discarded or downgraded by blending. As few as 30 metal sorting lines using UHV technology would sort most of the scrap generated in the United States. Two million tons of these light metals would no longer need to be exported for hand sorting, with the potential to expand the revenue of the U.S. light metal recycling industry by $120 million/year.