JOM, Vol. 64, No. 12, 2012
DOI: 10.1007/s11837-012-0486-y

Opportunities and Barriers to Resource Recovery and Recycling from Auto Shredder Residue – A CR³ Communication

N. Nayak, D. Apelian, B. Mishra, and B. Blanpain

TMS has forged cooperative agreements with several carefully selected organizations that actively work to benefit the materials science community. In this occasional series, JOM *will provide an update on the activities of these organizations. This installment, by the Center for Resource Recovery & Recycling (CR³), focuses on auto shredder residue.*

Worcester Polytechnic Institute (WPI), Colorado School of Mines (CSM), and the University of Leuven (KU Leuven) in Belgium have established a collaborative research Center for Materials Resource Recovery and Recycling (CR³). Thirty corporations, with support from the National Science Foundation's Industry & University Cooperative Research Program, are sponsors of the Center. TMS and CR³ have forged a strategic alliance, as the work of the center is well aligned with TMS's initiative in Materials and Society.

When automobiles reach the end of their lives in the United States, which is typically after 15 to 20 years, they are sent to parts dismantling facilities where fluids are drained and parts of value such as the engine, hubcaps, radio, alternator, etc. are removed. Tires are also often removed for recycling. The automobile is then flattened with an industrial press and sent to a shredder. Automobile shredders were first introduced in the early 1960s. Prior to that, automobile recycling was carried out via open-air incineration that burned combustible parts, leaving usable metals behind.[1] This type of incineration is environmentally unacceptable, and would be in violation of present environmental regulations; open-air incineration has not been practiced in North America since shredders were introduced.

Automobile shredders consist of large-capacity industrial hammer-mills which receive an in-feed of flattened automobiles for crushing or shredding. Fist-sized chunks of material that are the output of this process are further separated into three streams using electromechanical separation and sortation techniques; the streams are: ferrous metals, nonferrous metals, and the remainder, which is known as auto shredder residue. Figure 1 shows the percentage breakdown of typical shredder output by material stream.

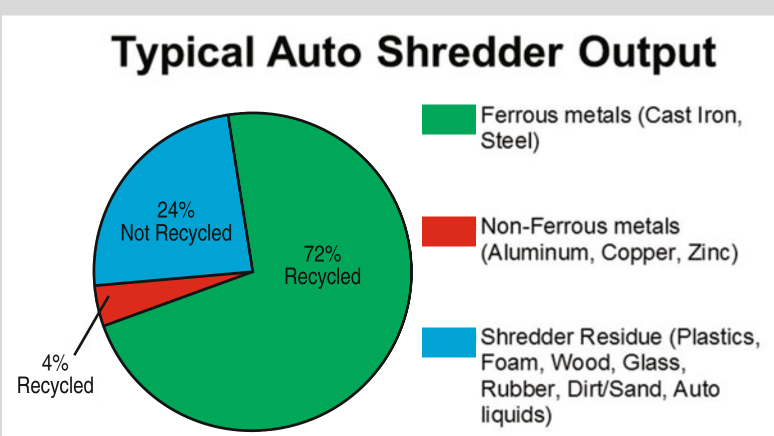

Figure 1. Percentage breakdown of typical shredder output by material stream.

In 2008, there were approximately 185–200 automobile shredders in the United States processing 12–15 million vehicles annually.[2] This would generate approximately 15–21 million tons of ferrous metals, 0.8–1 million tons of nonferrous metals, and 5–7 million tons of shredder residue.

Ferrous and nonferrous metals are sold to steel mills and foundries to produce finished steel and new metal products. These two metal streams are a source of revenue for the shredder operator. The shredder residue, however, is landfilled at a cost, typically to cover odor-producing organic waste as an alternative to dirt. Shredder residue used in this manner is referred to as alternative daily cover. While it serves somewhat of a purpose, its disposal is still at a cost—transportation cost incurred in trucking the shredder residue to the landfill site, and in many states a tipping fee charged by the landfill facility. These costs can amount to approximately $35 per ton of shredder residue disposed.[3] At 5–7 million tons to be disposed every year, the industry as a whole spends approximately $175–$245 million on shredder residue disposal annually.

Advancements in automobile design and manufacturing have led to increased use of lighter materials over metals in automobile construction. When these lighter cars reach the end of their lives, the shredding process can be expected to generate larger amounts of shredder residue than it has done in the past. In today's disposal model, this would reduce the volume of shredder output that contributes to the shredder operator's revenue (ferrous and nonferrous metals) and increase the volume of shredder output that contributes to costs (shredder residue). Decreasing commodity metal demand and prices due to the economic slowdown, increasing fuel (transportation of shredder residue) costs, and decreasing landfill availability will only worsen the situation.

While these costs might currently not be prohibitive to the margins of the U.S. shredding industry, a material recovery and recycling solution that is cost effective and environmentally friendly is needed for the metal recycling industry, environmental agencies, and the U.S. public. The cradle-to-cradle approach mandates that we do not landfill but rather use the various pieces of the whole at the end of useful life of the product. Furthermore, the potential to generate revenue from what is currently a waste stream is already starting to attract the attention of proactive, forward-thinking members of the shredding industry.

The average polymer concentrate in auto shredder residue is estimated to be 36–43% by weight. At 5–7 million tons of shredder residue, that is up to 3 million tons of polymer material equivalent in energy content to 16 million barrels of oil per year.[4] Regulations preventing the commercial distribution and use of polymers contaminated by polychlorinated biphenyls (PCBs)—which can be the case with auto shredder residue—have been a barrier to the development and implementation of recycling initiatives in this area. The guidelines surrounding PCB levels are unclear but it is believed that recovered polymers need to have PCB levels below 1 ppm to pass these guidelines.

Certain entrepreneurial organizations in the United States have taken the initiative to develop technology which, in addition to separating and recovering materials of value (polymers, foam, rubber), involves pre-processing or processing steps to cleanse the feedstock or recovered material of PCBs to acceptable levels. There are optimistic expectations that these companies will receive or have already received regulatory approval for their processes.[5] With available technology, recovered polymers can be used to produce finished-plastic products or synthetic crude oil with qualities comparable to their virgin equivalents. Recovered polyurethane foam (PUF) can be sold as an alternative to virgin PUF.[6]

At CR^3, we are leading an effort to evaluate the economics of shredder residue recycling with the objective of providing specific strategic recommendations to the auto-shredder industry. It is often difficult for a "green" initiative to gain traction unless there is an economic case that supports it. It must be emphasized that the business model must be a viable one for it to be sustainable. Specifically, the work at CR^3 involves examining the following aspects of commercializing shredder residue recycling:

- Capital expenditure of an operational shredder residue recycling facility (for recovery and recycling of material into reusable plastic resin, PUF, or crude oil)
- Operational capacity, modularity in construction, and operating costs of such a facility
- Operating leverage to utilize potential economies of scale
- Process efficiency
- Market demand and pricing for recovered material and synthetic crude oil
- Possible business models
- In-house recycling at a shredder operator
- Off-site recycling by a recycling operator who buys pre-processed shredder residue from the shredder operator
- Revenue-sharing partnership between the recycling operator and the shredder where the recycling operator recycles at his/her own site but receives pre-processed feedstock from the shredder operator for no cost in exchange for a share of the revenue generated

Ultimately, from a societal perspective, we must recover and reuse the materials that are used in our manufactured products. The concept of 24% of shredder residue going to landfills is not sustainable; our motivation is to develop both technologies as well as the business model framework in order to have a closed loop cycle, and with minimum waste.

References

1. E. Daniels, B. Jody, P. Bonsignore, and E. Shoemaker, "Automobile Shredder Residue: Process Developments for Recovery of Recyclable Constituents" (1991), *www.osti.gov/bridge/servlets/purl/6294535-nfGadc/6294535.pdf* (accessed 6 September 2012).
2. B. Hook, "Auto Shredder Residue Recycling *Researched*" (2008), *www.americanrecycler.com/1008/auto.shtml* (accessed 5 September 2012).
3 . C. McCarthy and N. Nayak, Interview with Schnitzer Steel personnel (interview conducted January 2012).
4. C. Duranceau and J. Spangenberger, "All Auto Shredding: Evaluation of Automotive Shredder Residue Generated by Shredding Only Vehicles" (2011), *www.es.anl.gov/energy_systems/crada_team/publications/all_auto_report.pdf* (accessed 1 August 2012).
5. Green Envirotech PR Newswire, "Green EnviroTech Holdings Corp. Tire and Plastic to Oil Sample Meets Specification for Resale" (2012), *www.greenenvirotech.com/news/120514news.html* (accessed 15 June 2012).
6. B. Jody and E. Daniels, "End-of-Life Vehicle Recycling: The State of the Art of Resource Recovery from Shredder Residue" (2006), *www.es.anl.gov/energy_systems/CRADA_Team/publications/Recycling_Report_(print).pdf* (accessed 6 September 2012).

N. Nayak is a graduate student with the CR^3 at Worcester Polytechnic Institute, Worcester, MA; D. Apelian is a Professor and Center Director of the CR^3 at the Worcester Polytechnic Institute, Worcester, MA; B. Mishra is a Professor and the Center Co-Director of the CR^3; and B. Blanpain is a Professor & Center Co-Director of the CR^3 is at KU Leuven. Dr. Apelian can be reached at dapelian@wpi.edu.