Popular Science Summary

Thesis Title: AI-Based Insert Classification via Acoustic Emission Signal

Author: Sihong Yu

Teaching Recycling Systems to "Listen" to the Inner Secrets of Metal Scrap

Every year, millions of high-performance cutting tools made of "cemented carbide", a super-hard material, are discarded. These tools contain tungsten and cobalt, rare and precious metals that the European Union classifies as "Critical Raw Materials" due to severe supply risks. While we can recycle these metals, the scrap must be sorted perfectly by its exact chemical recipes. Mixing them up ruins the recycled product.

Today's industrial sorting systems face a frustrating choice: they are either too slow to be practical or too inaccurate to be reliable. The magnet method can only roughly distinguish the percentage of Cobalt, laser codes wear off, and existing X-ray technologies can only scratch the surface, failing if the scrap is dirty or worn. This thesis introduces a breakthrough solution: giving recycling systems a pair of "digital ears" to look deep inside the metal using sound.

By using a technique called Acoustic Emission (AE), we tapped a metal insert with a tiny pulse and recorded the wave after the transmission through the material. Because different metal recipes change how sound waves travel, each tool grade produces a unique acoustic "fingerprint." We then fed these sound recordings into an Artificial Intelligence (AI) brain.

Initially, the AI performed brilliantly, identifying the metal types with 92.5% accuracy. But we uncovered a hidden trap. In machine learning, AI loves to take shortcuts. We discovered that the AI wasn't "listening" to the subtle metal composition; instead, it was judging the *shape* of the tools. Because bigger shapes muffle sound differently, the AI mistook geometric shapes for material types—a phenomenon we call "feature masking."

To fix this, we forced the AI to train on only one specific shape. Once it could no longer use the shape as a shortcut, the AI truly learned to decipher the internal material structure, achieving a robust 83.2% success rate on completely unseen, randomized test samples. However, when we asked this same AI to sort entirely different tool shapes, its accuracy dropped to 41.8%, proving that shape and material are deeply entangled in the world of sound.

This research marks a vital steppingstone for green manufacturing. It proves that sound-based AI sorting is highly capable. Still, it also warns future engineers that they must first "decouple" the shape of an object from its material before AI can be safely deployed in industrial recycling plants.