Abstract

The aim of the dissertation was to develop and optimise an innovative technology for the recovery of rare earth metals from waste hard disk drives (HDDs) containing neodymium magnets. The technology is based exclusively on physical recycling methods, eliminating chemical processes at the preliminary stage.

Three research hypotheses were verified regarding the feasibility of mechanically recovering pure neodymium alloy, the higher efficiency and lower costs of mechanical methods compared with manual ones, and the scalability of the developed technology.

The methodology involved a comparison of two recycling variants: manual (manual disassembly using a drill-driver) and mechanical (an integrated sequence of physical operations). The mechanical process consisted of shredding in a specially designed disintegrator with non-magnetic elements, magnetic separation, thermal demagnetisation of magnets, multi-stage granulometric classification, gravity, optical, and electrostatic separation, and final planetary milling.

The main results confirmed all research hypotheses. High-quality recovery products were obtained, namely: neodymium alloy with a purity above 97% (71% Fe, 26% Nd), clean ferromagnetic steel, aluminium free of ferromagnetic admixtures, as well as effectively separated plastics and printed circuit boards. The designed disintegrator achieved a throughput of 65.24 kg/h at an energy consumption of 1.29 kWh/kg HDD. The economic analysis demonstrated a threefold cost advantage of mechanical recycling (1,643,903 PLN) over manual recycling (4,554,904 PLN).

The developed technology reached Technology Readiness Level 4 and was secured with three patent applications. The process is characterised by low energy consumption (1.1108 kWh/kg HDD), no need for process water, and controlled dust emissions (0.004–0.027 $g/m^2 \times h$).

The conclusions confirm that the developed technology enables the closure of the material loop in line with the "magnet-to-magnet" concept, offering a technically efficient, economically viable, and environmentally friendly alternative to traditional recovery methods of rare earth metals from waste electronic equipment containing neodymium magnets, with potential for industrial implementation.