Upscaling and Advanced Evaluation of Wet and Dry Rod-Milling Processes for Recovering of Cu, PVC, and Plasticizer from Waste Wire Harnesses

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INTRODUCTION

The automotive, and electrical and electronic equipment (EEE) industries have been growing rapidly due to the modernization of society. Since then, the apparent amount of waste from automobiles and EEE has increased significantly. Each small car contains wire harness that weighs at least 15–20 kg. Also, WEEE waste unit consists of about 2% wire harness. Generally, waste wire harnesses cannot be replaced with other vehicles, and it is also difficult to recycle the entire scrap car or WEEE using traditional comminution methods. Therefore, much researches have been done to recover useful materials from waste wire harnesses. However, there are problems with the methods available because the cables are thin and non-uniformed. Since few years, our a research group has been working on the development of suitable techniques for recovering copper, PVC and plasticizers from waste wire harnesses.[1] This study presents upscaling and advanced analysis of wet and dry rod-milling to recover Cu, PVC, and plasticizers from waste wire harnesses.

MATERIALS AND METHODS

Materials

We obtained wire harnesses from end-of-life vehicles. Then, first the cables were manually sorted out from as-received waste wire harness. The swelling organic solvents and other reagents such as *n*-butyl acetate, acetone, and diisononyl phthalate (DINP), and dimethyl sulfoxide-d6 were purchased from Kanto Chemical Co., Inc. On average of 21.4 wt% DINP was determined in the PVC coating.

Methods

In the previous study[1] we studied using lab-scale conventional mill of ~3 liters volume (cable sample, 12.8 g; length of cables, 20 cm; solvent, 100 mL). In this study, we used about 10 times bigger bench-scale mill reactor than before (cable sample, 64–192 g; length of cables, ~60–150 cm; solvent 500–1500 mL). In particular, this mill reactor is equipped with a temperature and pressure sensor, and ambient temperature controlling heat shields. It is used to investigate the pressure and temperature of mill reactor, especially wet milling with acetone. In comparison studies, we studied both wet and dry rod-milling. Figure 1 shows the photographs of employed mill reactors (top) and the process schemes used, namely wet and dry rod-milling (bottom).

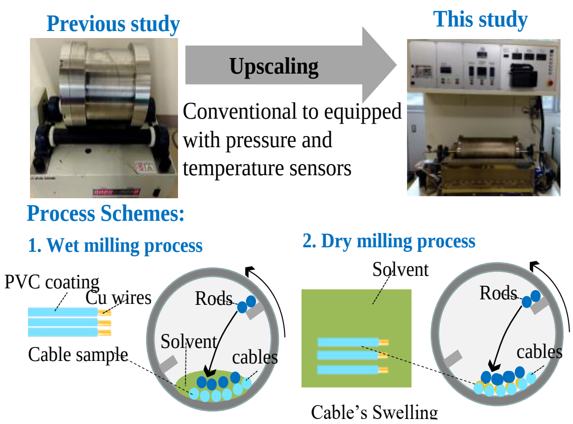

Fig.1 Photographs of mill reactors (top), and the process schemes (bottom)

RESULTS AND DISCUSSION

Analysis of PVC coating swelling at different temperatures

First, cable swelling tests were performed using *n*-butyl acetate and acetone for 80 min submersion at 17±1 °C, 25±1 °C, and 35±1 °C. The results showed that the swelling ratio incresed with increasing temperature with the both acetone and *n*-butyl acetate. The swelling ratio with *n*-Butyl aceate exhibited ~3.6 at 17±1 °C submersion and increased to ~3.9 at 35±1 °C. However, at 35±1 °C, the swelling power of acetone increased dramatically. As results, the swelling ratio exhibited ~3 at 17±1 °C and incresed to ~4.1 at 35±1 °C.

Analysis of wet and dry rod-milling separation yields

In the wet milling process, complete separation of Cu and PVC coating (64-g cables) was achieved in 50 min of milling at 17±1 °C. Increasing the temperature to 35±1 °C, separation rate dramatically improved in the presence of acetone, but not with *n*-butyl acetate. The results of separation was good agreement with swelling ratio. However, the mill reactor pressure of both solvents were further investigated to find out why acetone showed a much faster separation. As results, the reactor pressure increased at a rate of about 2×10^{-4}- and 3×10^{-4} MPa/min at 17±1 °C and 35±1 °C, respectively in the presence of acetone, whereas with *n*-butyl acetate noted from zero and no change was seen. This may be the reason behind the fast separation with acetone. Second, in the case of dry milling (cable sample, 64-g), acetone exhibited low degree of swelling, and it evaporates rapidly as well that causing the acetone-treated cable to de-swell rapidly.Therefore, the separation rate of the acetone-treated cables comparativelly slower than the *n*-butyl aceate-treated cables at 17±1 °C. However, the separation rate improved for higher swelling ratio that is, at 35±1 °C. On the contrary, *n*-butyl acetate-treated cables maintain swelling for a longer period of time. Complete separation was achieved in 45 min of milling. Figure 2 shows separation yields, and the recovered Cu wires and PVC coating are showed for both wet milling and dry milling. Near-quantitave DINP recycled by both wet and dry processes.

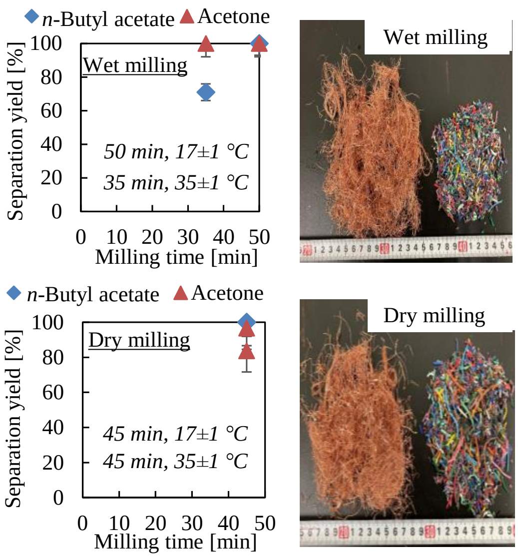

Fig.2 Separation yields (left penal) and the recovered Cu wires and PVC coating (right penal) for both wet milling and dry milling

CONCLUSION

We successfully evaluated the both wet and dry rod-milling methods using *n*-butyl acetate and acetone. Further, we determined that acetone would be suitable for wet milling and *n*-butyl acetate for dry milling.

ACKNOWLEDGEMENT

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REFERENCES

Kumar, H. Kumagai, S. Yoshioka T. et al., Highly efficient recovery of high-purity Cu, PVC, and phthalate plasticizer from waste wire harnesses through PVC swelling and rod milling. Reaction chemistry & Engineering , 5 (9), 1805-1813, 2020.