Estimating Electric Power Requirements for Mechanically Shredding Massage Chairs and Treadmills at a Recycling Plant

Jihwan Park[1*], Jun Soo Yoo[1], Choongwoo Lee[1], Jonghyun Choi[1]

1: Korea Electronics Recycling Cooperative (KERC), 17 Daehak 4-ro, Suwon16226, South Korea

*corresponding author: jh.park@k-erc.or.kr

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INTRODUCTION

Since 2008, South Korea has operated an Extended Producer Responsibility (EPR) system for collecting and recycling the Waste of Electrical and Electronic Equipment (WEEE). Starting in 2020, EPR targeted products included massage chairs and treadmills. Due to continuous economic growth and the development of advanced leisure electric products, the distribution rates for massage chairs and treadmills have increased in South Korea. Nevertheless, these products have been recycled by manual dismantling and component sorting in the recycling stage. Manual dismantling work is not only operationally inefficient but also can also cause worker fatigue. The main purpose of this study is to calculate the proper electric power required to mechanically shred massage chairs and treadmills that were manually recycled. Accordingly, basic data was collected based on previous studies related to the shredding (crushing) theory. The possible crushing power of the two products was calculated with practical shredder design empirical equations utilized in the WEEE recycling industry in South Korea. To carry out this study, the hardness of steel components used in massage chairs and treadmills was measured and converted to shearing strength. Based on the above data, we calculated the shredding electric power and compared the estimated electric power with the actual power of the recycling center shredder when crushing two products.

MATERIALS AND METHODS

Research Assumption

The calculation of the proper shredding power is focused on the 'primary crushing machine' or 'pre-shredder' machines. In other words, the result of this study is applicable to the first crushing (primary crushing) process. The processing power criteria was considered at 10m^3/hr (volume basis). Considering a density of one, the study was conducted assuming a shredder has a processing power of 10 tonnes per hour. The proper power for shredding a massage chair and a treadmill was estimated based on the empirical equations for designing the shredder to crush refrigerators or washing machines, these products have been recycled by shredders mechanically, in actual recycling plant.

Hardness Measurement

To calculate the shear strength for steel structures comprised of key parts from massage chairs and treadmills, the Vickers hardness was measured and converted to tensile strength through actual dismantling and decomposition samples. In the sampling process, five sampling and measured for each product, calculating the mean value from the data onto the Vickers hardness scale.

RESULTS AND DISCUSSION

Hardness and Shear Strength

The calculation of the mean value of the Vickers hardness shows that the hardness of the massage chair iron components are relatively higher than those of the treadmill. As a result, the average hardness of the massage chair is 186.4 and the average hardness of the treadmill is 159.8. On the other hand, Vickers hardness of the refrigerator iron averaged 161.9, which is lower than the massage chair and higher than the treadmill.

Using the Vickers hardness measurements, the values converted to shear strength were 0.54 kg/cm^2 (massage chair), the treadmill was 0.46 kg/ cm^2, and the refrigerator was 0.47 kg/cm^2. However, since the thickness of the experimental samples for the massage chair and the treadmill were three to four times thicker than that of the refrigerator, the difference was considered by applying the correction factor when finally calculating the proper power of crushing.

Proper Electric Power

The crushing power was determined based on the previously calculated processing capacity (10 tons/hour), shear strength data obtained through hardness measurement, and thickness correction factor. At this time, the power was calculated as horsepower (HP). Also, the torque was first calculated for this purpose, and the number of revolutions (14.5 revolutions) and 1.5 times of safety factor (as a working allowance) were applied equally to the massage chair and treadmill power calculation formula based on the refrigerator shredder.

Table 1 Torque and horsepower for shredding the massage chair, treadmill, and refrigerator.

	Massage Chair	Treadmill	Refrigerator
Torque (kgf·m)	2363.774	151.189	514.339
Horsepower (HP)	717.850	458.620	156.200

CONCLUSION

The calculation of shear strength by Vickers hardness was 0.54 (massage chair), 0.46 (treadmill), and 0.47 (refrigerator). However, the iron thickness of the treadmill (three times) and the massage chair (four times) were thicker than the refrigerator. It is analyzed that more power is needed for crushing massage chairs and treadmills than refrigerators. Conclusively, based on the shredding capacity of 10 tons per hour, the electric power required for shredding is approximately 717 HP for massage chairs and 458 HP for treadmills.

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REFERENCES

Gong, J., Wu, J., & Guan, Z. (1999). Examination of the indentation size effect in low-load Vickers hardness testing of ceramics. Journal of the European Ceramic Society, 19(15), 2625-2631.