τ, is the maximum allowable shear stress taken to have a value of 55 MN/m2 for commercial steel shafting

Thus $d = \sqrt[3]{\frac{16\times0.174\times10^3\times1.5}{3.142\times55\times10^6}} = 0.0289 = 28.9\ mm$

Selecting the standard value of diameter, d = 30 mm

Fig. 2 magnetic drum

Let T_1 = carrying side belt tension,
T2 = return side belt tension
But $T_1 = T_E \left[\frac{\varepsilon}{\mu\pi-1} + 1\right]$
Where, ε = drive coefficient = 1.66
Since the diameter of both the pulley drive is the same.
Thus, θ = angle of wrap $= 180° = 18 \times \frac{\pi}{180} = 3.1415\ rad$
u = coefficient of friction between the drive pulley and belt = 0.35

Hence $T_1 = 20 \left[\frac{166}{0.35\times3.142-1} + 1\right] = 36.5772\ kW$

$T2 = T1 - TE$
$= 36.5772 - 20 = 16.577\ kW$

2.4.4. Selection of motor:
The helical worm gear motor type is selected considering the availability of the product in the market.
Power = 3.5 kW
Output Speed (N) = 300 rpm, (5:1 of 1500rpm)
Diameter of the motor shaft, dm = 20 mm

Fig. 3 Helical worm gear motor

2.5 Fabrication of Waste Sorting Machine
The fabrication of the waste sorting machine began with the cutting of two inches of pipe and machining the internal diameter to a bearing size which the bearings are fixed and the rollers were made. The centre lathe machine was used in machining the pipes the required dimensions were set and the machining was carefully controlled to avoid manufacturing errors. Figure 4.9 shows the rollers being machined cutting of machine members at the mechanical engineering laboratory. After machining the rollers and other components like the magnetic drum and pulleys, the fabrication continued with the hopper, guide and stand on which the whole setup would be mounted. This involved the cutting of metal sheets, angle iron and flat bars into the required shape and then permanently joining them together by welding. The rollers were then placed into positions with the aid of bolts and nuts to the stand. This made it possible to mount the bearings needed to hold the magnetic drum and the supporting drum into a position in which the belt was also mounted and tensioned screw is also welded and the supporting drum was firmly on the stand, the fan/blower is then mounted and well positioned on the belt then the hopper was mounted to the setup via a permanent weld. The whole setup was brought together after the hopper was constructed to be positioned on the belt; the prime mover was mounted beneath the belt. A switch was added to control the prime mover and the fan/blower and the machine was finally assembled.

3. Testing and Result
The machine was tested with the aid of a stopwatch and a scale. The stopwatch was used in measuring the time in seconds it took the machine to complete the sorting cycle from the activation of the motor to the complete exit of the solid waste. Figure 4 shows the results of the solid waste test. Samples of 2, 3, and 4 kg of dried municipal solid waste obtained from the waste dump were used to test the performance of the machine. Tests on each sample weight were repeated three times (tests 1,2 and 3). These were respectively gradually fed into the machine for sorting and the time taken for the sorting was measured with a stopwatch in a minute. At the end of each operation, the average masses of the sorted wastes were recorded as 2, 3 and 4 kg. The ratios of the light fraction of wastes in the waste stream were evaluated and the results were 0.91 with a time of 1.83 min, 1.30 with a corresponding time of 2.72 min and 1.65 kg with a time of 3.66 min respectively. This shows that the ratio of the light

fraction of waste increases as time increases. Again when ferrous metallic materials were not found in the solid waste, 3kg of ferrous metallic materials was introduced into the waste dump. This was also done to determine the machine's capability of sorting metallic (both ferrous and nonferrous metals), plastics and paper materials. Again, since plastic won't decay, this substance might be recycled for further use. In essence, the waste sorting machine separates the plastic from other elements like paper and metal. The metallic fraction of solid waste of test one (1) results indicated 0 (zero) kg throughout as shown in Figure 4.

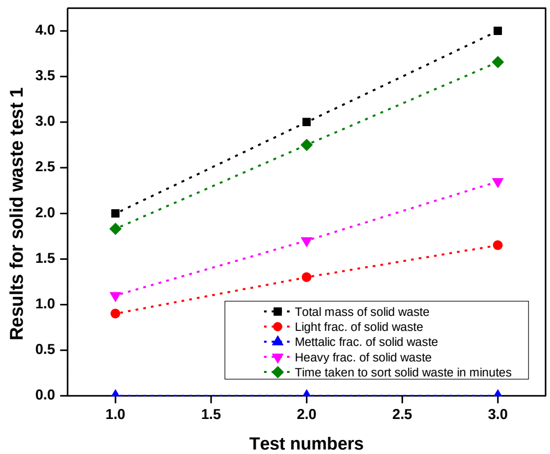

Fig. 4 Results for solid waste test 1

Figure 5 shows the results of solid waste test 2. Samples were 3, 4, and 5 kg of the dried municipal solid waste containing the added ferrous metallic materials obtained from the waste dump and also used to test the performance of the machine, using the same procedure. The ratios of the light fraction of wastes in the waste stream were evaluated and the results were 1.65 kg with a time of 2.8 min, 1.85 kg with a time of 3.73 min and 2.08 kg with a time of 4.8 min respectively. The results indicated that the total mass of the solid waste increases with respect to time. The metallic fraction of solid waste of the test for two (2) results indicated 0.25 kg, 0.45 kg and 0.95 kg as the time increases as shown in Figure 5.

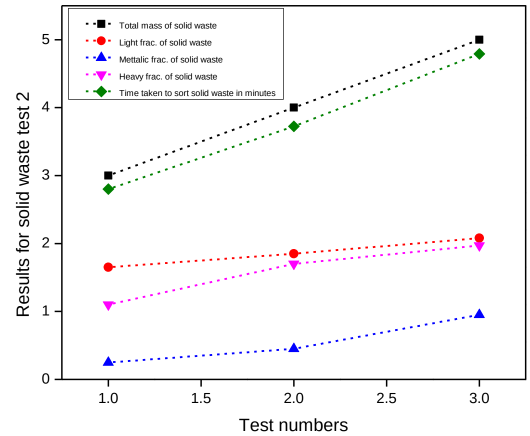

Fig. 5 Results for solid waste test 2

4. Conclusion

The management of solid waste has become one of the issues of great concern in most developing countries like Ghana. The need for concerted efforts to manage these solid wastes cannot be over-emphasized. This study was based on the design of an institutional solid waste sorting device that can lessen human effort in waste sorting and separate waste disposal into various components that can be used for producing electricity, recycling, or other beneficial uses. The system was assembled and tested. The result in test one indicated that the ratios of the light fraction of wastes in the waste stream were evaluated and the results were 0.91 with a time of 1.83 min, 1.30 with a corresponding time of 2.72 min and 1.65 kg with a time of 3.66 min respectively. This shows that the ratio of the light fraction of waste increases as time increases. Again when ferrous metallic materials were not found in the solid waste, 3kg of ferrous metallic materials was introduced into the waste dump. In addition, the result in test 2 indicated that the ratios of the light fraction of wastes in the waste stream were evaluated and the results were 1.65 kg with a time of 2.8 min, 1.85 kg with a time of 3.73 min and 2.08 kg with a time of 4.8 min respectively. The results indicated that as time increases, the masses of the solid waste also increased. The metallic fraction of solid waste of the test for two (2) results indicated 0.25 kg, 0.45 kg and 0.95 kg as the time increases.

References

[1] M. Liboiron and J. Lepawsky, *Discard studies: Wasting, systems, and power*: MIT Press, 2022.

[2] T. B. Payberah, *Specifications and evaluation guidelines for the use of recycled materials and byproducts in roadway construction and maintenance activities*: The University of Texas at Arlington, 1999.

[3] S. Mani, L. G. Tabil, and S. Sokhansanj, "Effects of compressive force, particle size and moisture content on mechanical properties of biomass pellets from grasses," *Biomass and bioenergy,* vol. 30, pp. 648-654, 2006.

[4] S. O. Nelson, S. Trabelsi, and A. W. Kraszewski, "RF sensing of grain and seed moisture content," 2001.

[5] D. Hoornweg and P. Bhada-Tata, "What a waste: a global review of solid waste management," 2012.

[6] S. Kaza, L. Yao, P. Bhada-Tata, and F. Van Woerden, *What a waste 2.0: a global snapshot of solid waste management to 2050*: World Bank Publications, 2018.

[7] D. Hoornweg and N. Giannelli, "Managing municipal solid waste in Latin America and the Caribbean: Integrating the private sector, harnessing incentives," 2007.

[8] Y. Dhokhikah and Y. Trihadiningrum, "Solid waste management in Asian developing countries: challenges and opportunities," *Journal of Applied Environmental and Biological Sciences,* vol. 2, pp. 329-335, 2012.

[9] E. Amo-Asamoah, D.-G. Owusu-Manu, G. Asumadu, F. A. Ghansah, and D. J. Edwards, "Potential for waste to energy generation of municipal solid waste (MSW) in the Kumasi metropolis of Ghana," *International Journal of Energy Sector Management,* vol. 14, pp. 1315-1331, 2020.

[10] E. Ankrah, "Challenges faced by Zoomlion Ghana Limited in the Management of Solid Waste in Ghana," Ghana Institute of Journalism, 2017.

[11] R. Agyapong, "Residents' perceptions and attitudes towards urban solid waste management in the Berekum Municipality," University of Cape Coast, 2012.

[12] B. K. Sovacool, "Toxic transitions in the lifecycle externalities of a digital society: The complex afterlives of electronic waste in Ghana," *Resources Policy,* vol. 64, p. 101459, 2019.

[13] J. Petts, "Effective waste management: Understanding and dealing with public concerns," *Waste management & research,* vol. 12, pp. 207-222, 1994.

[14] A. Baabereyir, "Urban environmental problems in Ghana: A case study of social and environmental injustice in solid waste management in Accra and Sekondi-Takoradi," University of Nottingham, 2009.

[15] M. Oteng-Ababio, J. E. M. Arguello, and O. Gabbay, "Solid waste management in African cities: Sorting the facts from the fads in Accra, Ghana," *Habitat International,* vol. 39, pp. 96-104, 2013.

[16] A. Ghosh, S. Kumar, and J. Das, "Impact of leachate and landfill gas on the ecosystem and health: Research trends and the way forward towards sustainability," *Journal of Environmental Management,* vol. 336, p. 117708, 2023/06/15/ 2023.

[17] C. Sutter and J. C. Parreño, "Does the current Clean Development Mechanism (CDM) deliver its sustainable development claim? An analysis of officially registered CDM projects," *Climatic change,* vol. 84, pp. 75-90, 2007.

[18] S. Wainaina, M. K. Awasthi, S. Sarsaiya, H. Chen, E. Singh, A. Kumar*, et al.*, "Resource recovery and circular economy from organic solid waste using aerobic and anaerobic digestion technologies," *Bioresource Technology,* vol. 301, p. 122778, 2020.

[19] A. C. Woolridge, G. D. Ward, P. S. Phillips, M. Collins, and S. Gandy, "Life cycle assessment for reuse/recycling of donated waste textiles compared to use of virgin material: An UK energy saving perspective," *Resources, conservation and recycling,* vol. 46, pp. 94-103, 2006.

[20] X. Zeng, J. A. Mathews, and J. Li, "Urban mining of e-waste is becoming more cost-effective than virgin mining," *Environmental Science & Technology,* vol. 52, pp. 4835-4841, 2018.

[21] Y. Wang, H. Shi, M. Sun, D. Huisingh, L. Hansson, and R. Wang, "Moving towards an ecologically sound society? Starting from green universities and environmental higher education," *Journal of Cleaner Production,* vol. 61, pp. 1-5, 2013.

[22] G. Zilahy and D. Huisingh, "The roles of academia in regional sustainability initiatives," *Journal of cleaner production,* vol. 17, pp. 1057-1066, 2009.

[23] R. T. Watson, M.-C. Boudreau, and A. J. Chen, "Information systems and environmentally sustainable development: energy informatics and new directions for the IS community," *MIS Quarterly,* pp. 23-38, 2010.

[24] G. Hilson and B. Murck, "Sustainable development in the mining industry: clarifying the corporate perspective," *Resources policy,* vol. 26, pp. 227-238, 2000.

[25] D. R. Reinhart and A. Basel Al-Yousfi, "The impact of leachate recirculation on municipal solid waste landfill operating characteristics," *Waste Management & Research,* vol. 14, pp. 337-346, 1996.

[26] J. T. Powell, T. G. Townsend, and J. B. Zimmerman, "Estimates of solid waste disposal rates and reduction targets for landfill gas emissions," *Nature Climate Change,* vol. 6, pp. 162-165, 2016.

[27] R. P. Singh, P. Singh, A. S. Araujo, M. H. Ibrahim, and O. Sulaiman, "Management of urban solid waste: Vermicomposting a sustainable option," *Resources, conservation and recycling,* vol. 55, pp. 719-729, 2011.

[28] P. Anand, R. Jain, and A. Dhyani, "Knowledge, attitude and practice of biomedical waste management among health care personnel in a teaching institution in Haryana, India," *Int J Res Med Sci,* vol. 4, pp. 4246-50, 2016.

[29] G. Robert, P. Marcin, and M. Marek, "Analysis of picked up fraction changes on the process of manual waste sorting," *Procedia Engineering,* vol. 178, pp. 349-358, 2017.