paper ICAMME2

by Amelia Sugondo

Submission date: 22-Oct-2021 02:37PM (UTC+0700)
Submission ID: 1680884997
File name: Household_Trash_Compactor_Using_a_Static_Simulation_rev3_1.docx (7.02M)
Word count: 3161
Character count: 16349

Design and Analysis of a Double Lead Screw Household Trash Compactor Using a Static Simulation

T. Kevin Ronald Santoso[1], Amelia Sugondo.[2]

Abstract: Waste is a serious problem, especially household waste. Therefore, an idea was developed to overcome the existing household waste problem in the form of a trash compactor. This research proposes on designing the trash compactor using a double lead screw mechanism. The trash compactor uses an electric motor for its driving force and a set of gearbox for speed reduction. The trash compactor was designed, modelled, and simulated by using Autodesk Inventor Professional 2022. The simulation is based on a static simulation. The results show that the design of lead screw, frame, and ram size has overcome the 20000N of trash compactor capacity are according to the material strength and displacement for each components with safety factor more than 1.4. The trash compactor has a total capacity of 245.76 liter.

Keywords: Household waste, lead screw, static simulation, Von Mises stress, displacement, safety factor

Introduction

Lately, waste has become a problem that arises in the society. Over time, the amount of waste continues to increase, ranging from plastic waste, toxic waste, to household waste. Based on the Indonesian Environmental catalogue, in 2018 the estimated waste production per day in Surabaya reached 2206 m^3, but the volume of waste transported per day was only 1666.84 m^3 (Widya *et al*., 2019[13]). Based on these data, it means that only 75.56% of waste is transported. From the volume of waste transported in the city of Surabaya per day, 905.26 m^3 is organic waste and 761.57 m^3 is inorganic waste (Widya *et al*., 2019[13]). According to the Central Statistics Agency, in the city of Surabaya in 2018 there were 1571 city cleaning service employees, 173 units of garbage trucks, 468 garbage carts, and 183 temporary disposal sites (Widya *et al*., 2019[13]). With so many employees and units of the city cleaning service, there is still garbage in the city of Surabaya that is yet to transported.

Household activity is one of the production sources of various types of waste. National data in 2018 shows that 62 percent of waste in Indonesia is generated from the household sector (Wulandari, 2020[14]). Referring to the Indonesian Environmental Statistics data released by the Badan Pusat Statistik (BPS), only 1.2 percent of households have recycled their waste so far. Around 66.8 percent of households still handle waste by burning (Wulandari, 2020[14]). From the data on the percentage of household's treatment on sorting decomposable and non- decomposable waste, it was found that 9.91% of the people from East Java sort their waste, 10.01% of waste is sorted and then disposed of, and 80.07% of waste is not sorted (Badan Pusat Statistik, 2017[2]).

Therefore, a trash compactor was developed to overcome the existing household waste problem. (Weyuma, 2021[12]) studied for certical baler machine that operated by using hydraulic system. (Bharath, 2020[3]) studied trash compactor bin using scisscor mechanism that connected to lead screw. It can compress waste about 60% until 100%. (Vroom, 2016[11]) studied movable waste compactor bin by using wheel. It achieved compaction ratio is 4:1. Horizontal waste paper baling machine was developed by (Osamwonyi *et al*., 2018[6]) and found that mechanism is also simple management waste. (Mwinuka & Nyichomba, 2017[7]) also studied various types of models for waste compactor prototypes. The prototypes in that paper use 3 types of mechanism, which are horizontal power screw, hydraulic, and bevel gears.

In this research, the trash compactor design is intended for the community, where the device will be placed in the box of a pick-up car or three-wheeled motorcycle cargo truck. These vehicles will go to the villages and housing estates at certain hours, where people can put their household waste that has been sorted. With this idea, it is hoped that the government and the

[1,2] Faculty of Industrial Technology, Mechanical Engineering Department, Petra Christian University. Jl. Siwalankerto 121-131, Surabaya 60236, Indonesia Email: c12180001@john.petra.ac.id, amelia@petra.ac.id

community can work together in dealing with the existing household waste problem.

In this research, the trash compactor with double vertical lead screw mechanism and electric motor to generate power is designed. The mechanism is applied considering the compactor capacity, space and weight (Ravi, 2014[9]). The double lead screw mechanism is more compact compared to pneumatic and hydraulic mechanism.

The proposed mechanism is also simulated by using a finite element method. The finite element method is a systematic way to convert the functions in an infinite dimensional function space to first functions in a finite dimensional function space and then finally ordinary vectors that are tractable with numerical methods. The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Many advantages can be obtained by using simulation, such as the location of maximum stress or displacement, stress or displacement at every location we needed, appropriate material, stress or displacement at every location we needed. Finite element method is used to reduce thickness of plate for power press machine design (Chauhan, 2013[5]). (David *et al.*, 2020[4]) designed trash compactor using a hydraulic mechanism rather than lead screw mechanism. The research uses a fatigue analysis using Solidworks for the simulation. In this research, finite element method will be used for the simulation with a static simulation.

Methods

Design Process

To carry out the assignment as mentioned above, the following methodology was used.

Literature Review

This involved review of documents, information, and available data relevant to the assignment to gather any information that could help the design process.

Design Concept

Based on the informations and available data from various sources, the design concept can be made. If the design concept is feasible, then the design process can be proceeded. Meanwhile if the design concept is not feasible, then literature review must be carried out again. The trash compactor was designed and modelled using Autodesk Inventor Professional 2022.

Calculation and Simulation

While desigining the trash compactor, calculation and simulation are required to ensure the material strength. The material strength will be calculated using simulations through software. The simulation results will be analyzed to ensure the design used is safe during operation. The simulation carried out for the double lead screw is based on a static simulation using Autodesk Inventor Professional 2022 software. Lead screw, frame and ram of the trash compactor as important components are chosen to analyze using simulation. From the static simulation, the Von Mises Stress, displacement, and safety factor can be obtained. These two parameters are used to determine whether the design is safe or not. The parameter design for all simulation, the poisson ratio, meshing type and size are 0.3, tetrahedron and 0.1 mm, respectively.

Specification

The double lead screw trash compactor has a total dimension of 1100 mm × 930 mm × 1430 mm. The box in the middle has a dimension of 600 mm × 640 mm × 640 mm with a total capacity of 245.76 liter with average density of waste 311.73 kg/m^3 (Palanivel & Sulaiman, 2014[8]). The box in the middle has a function as a trash bin. The double lead screw trash compactor has a total duration of pressing for 120 second. The device is using a 4 HP electric motor with a gearbox, placed in the back of the box. The double lead screw is placed on both side of the trash bin box.

Working Principle

Figure 1 and Figure 2 show the overall design of a Household Trash Compactor using a Double Lead Screw Mechanism. The important parts are showed in those figures.

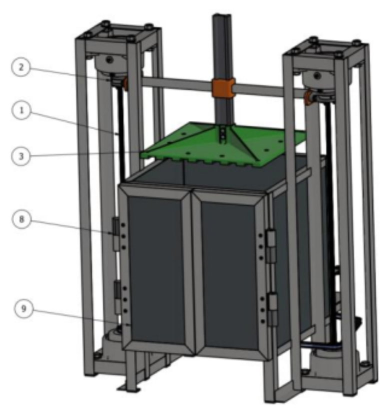

Figure 1. Front view of the double lead screw trash compactor

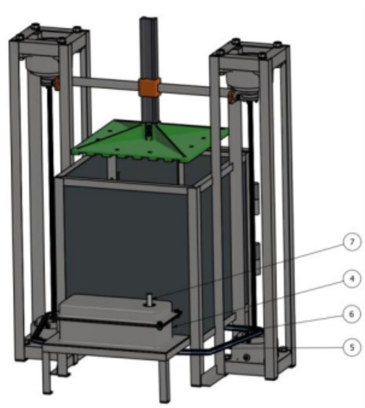

Figure 2. Back view of the double lead screw trash compactor

The electric motor will be placed and connected to the gearbox shaft (7), where the rotation of the electric motor will be reduced by the gearbox (4). The result of the rotation reduction from the gearbox (4) is then transmitted to the sprocket (6) using a rolling chain (5). The rotation of the sprocket (6) will trigger the power screw (1) to rotate, so that the flange nut (2) can move up or down depending on the direction of rotation of the power screw (1).

If the flange nut (2) moves downward, the ram (3) will also move downward. The ram (3) is used to press the garbage inside the box. Otherwise, if the flange nut (2) moves upward, the ram (3) will also move upward. For loading and unloading trash, the door (9) with hinges (8) can be opened and closed.

Results and Discussion

Material Selection

The major factor on selecting materials for the trash compactor include material strength, cost and availability as shown in Table 1. The best material is one which serves the desired objective at the minimum cost (Weyuma, 2021[12]). After some further research and some careful investigation, the materials are as follows.

Table 1. Materials used for trash compactor parts

Part	Material	Yield Strength	Young's Modulus
Lead Screw	Low Carbon Steel	350 MPa	200 GPa
Frame	Galvanized Steel	207 MPa	200 GPa
Ram	Alloyed Steel	250 MPa	205 GPa

The material of the lead screw is low carbon steel because lead screws are generally made of low carbon steel. For the frame, the selected material is galvanized steel instead of aluminium. Aluminium frame can produce a lightweight trash compactor, but galvanized steel is more affordable but also has a stronger material strength. Last but not least, the ram will use alloyed steel as the material. Based on the materials above, analysis is done by running a static simulation using Autodesk Inventor Professional 2022 stress analysis.

Static Analysis

A Trash Compactor condenses garbage by using compacting ram force. Depending on the model, the ram force ranges from 2,000 to 5,000 lbs (or around 900 kg to 2200 kg) (Ajmadison, n.d. [1]). Therefore, the force used for the simulation is 20000 N. For the static analysis, the following assumptions were made: The force load used in the simulation is 20000 N, the torque used in the simulation is 16 Nm for the double lead screw based on the output torque from the gearbox. For static load, the safety factor of a structure can be 1.4 or above (Szulca *et al*., 2016[10]). Thus, the trash compactor design must have a value safety factor above 1.4 to ensure the design is safe to withstand the 20000 N force and 16 Nm torque. Finite element method is used to reduce thickness of plate for power press machine design (Chauhan, 2013[5]).

Lead Screw

The first simulation is the lead screw. The lead screw must be able to withstand the torque from the electric motor. Based on manual calculation, the torque that occur in the lead screws are 16 Nm. Since there are 2 lead screws for the trash compactor, so the torque for each lead screw is 8 Nm. The torque on the lead screw can be seen through Figure 3. The fixed part is assumed to be on both ends. The specification of the lead screw is M16×4 mm with a length of 1000 mm. On each end, the are 140 mm extension of a rod without thread.

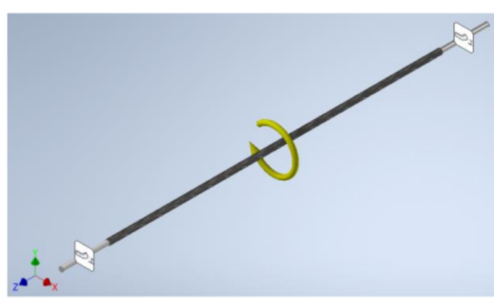

Figure 3. Torque on the lead screw

Figure 4. Mesh view of the lead screw

Figure 4 shows the mesh type that used in the simulation. The total number of the nodes are 88263 and 48817 for the number of elements. Based on the simulation of lead screw, the following results can be obtained (Table 2).

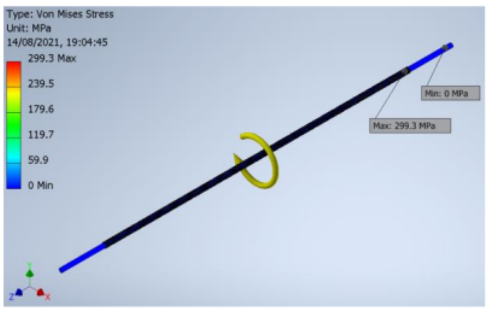

Figure 5. Von Mises Stress on the lead screw

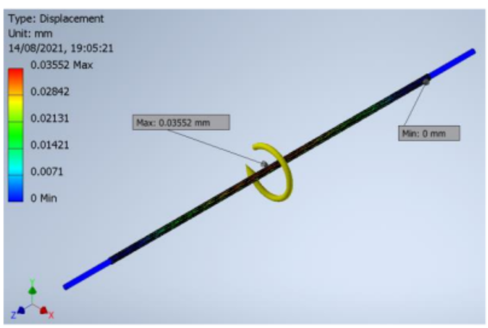

Figure 6. Displacement on the lead screw

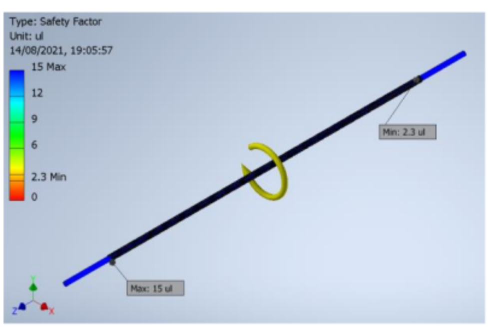

Figure 7. Safety factor on the lead screw

Table 2. Frame simulation result

Lead Screw	Min	Max
Von Mises Stress (MPa)	0	299.3
Displacement (mm)	0	0.03552
Safety Factor	2.3	15

As seen in Figure 5, the maximum stress that occurs in the lead screw is 299.3 MPa which was located on the pitch of the screws. Figure 6 shows the location maximum deflection. The minimum safety factor is 2.3 according to figure 7, which means the lead screw is safe to be used at 8 Nm.

Frame

The next simulation is the frame for the trash compactor. The frame must be able to withstand the force from the pressing process. Therefore, the force given on the frame for the simulation is the same as the reference force, which is 20000 N. The force will be divided by six according to the shape of the box, which is a cube. The force on the frame can be seen through Figure 8. The fixed part is assumed to be on bottom of the frame. The frame has a length of 1100 mm, width of 930 mm, and 1430 mm of height.

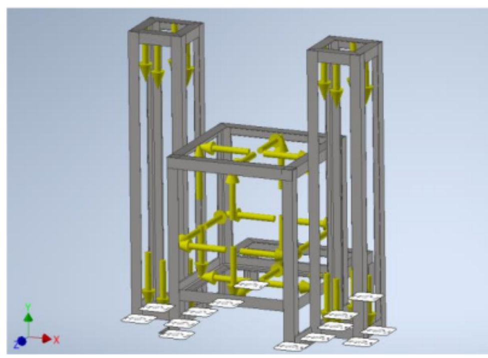

Figure 8. Forces on the frame

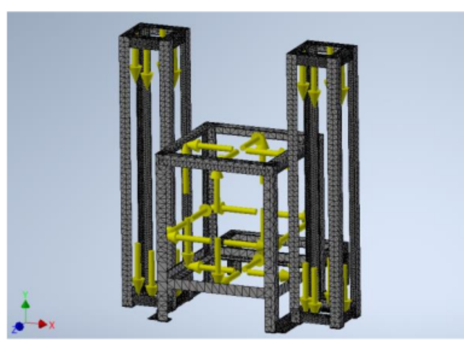

Figure 9. Mesh view of the frame

Figure 9 shows the mesh view of the frame. The total number of the nodes are 210531 and 97073 for the number of elements. Based on the simulation of the frame, the following results can be obtained (Table 3).

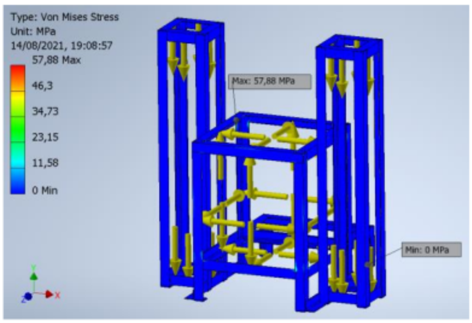

Figure 10. Von Mises Stress on the frame

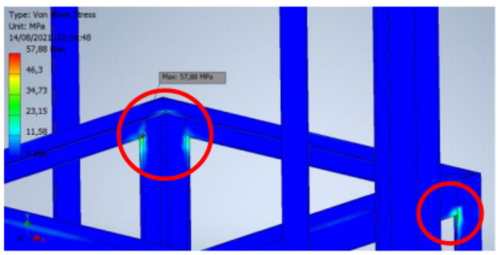

Figure 11. Stress concentration at the corner

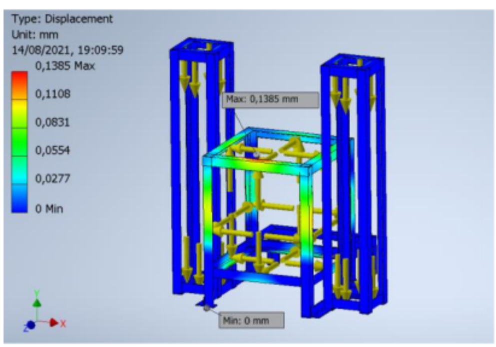

Figure 12. Displacement on the frame

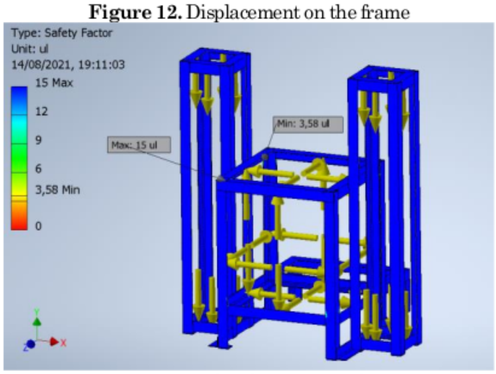

Figure 13. Safety factor on the frame

Table 3. Frame simulation result

Frame	Min	Max
Von Mises Stress (MPa)	0	57.88
Displacement (mm)	0	0.1385
Safety Factor	3.58	15

In Figure 10, the maximum Von Mises stress of the frame is 57.88 MPa. Based on the simulation, Von Mises stress are high at the corners. The detail view of the Von Mises stress at the corners of the frame can be seen through Figure 11. The phenomenon caused by the stress concentration at each corner. A stress concentration is a location in an object where the stress is significantly greater than the surrounding region. Figure 12 shows that the largest displacement is around the box. Bracing can be added to increase frame strength. As seen in Figure 13, the minimum safety factor is 3.58. It means the designed frame is safe to be used for 20000 N.

Ram

The last simulation is the ram, which receives a force of 20000 N from below as a reaction from the trash. The force on the ram can be seen through Figure 14. On the simulation, the force is assumed to be distributed force. The fixed part is assumed to be on top of the ram, assuming the ram is being held from above. The ram has a dimension of 500 mm of length, 500 mm of width, and 90 mm of height. The bottom surface of the ram is designed with a jagged surface to increase grip while pressing.

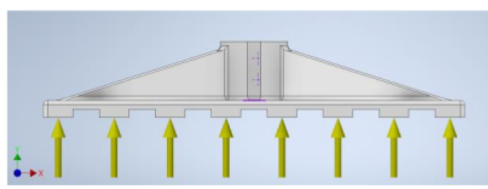

Figure 14. Force on the ram

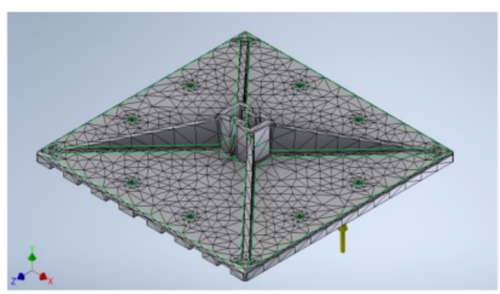

Figure 15. Mesh view of the ram

Figure 15 shows the meshing view from the ram. The total number of the nodes are 13700 and 7216 for the number of elements. Based on the simulation, the following results can be obtained. Figure 16-Figure 18 shows Von Misses stress, displacement and safety factor of the ram results, respectively.

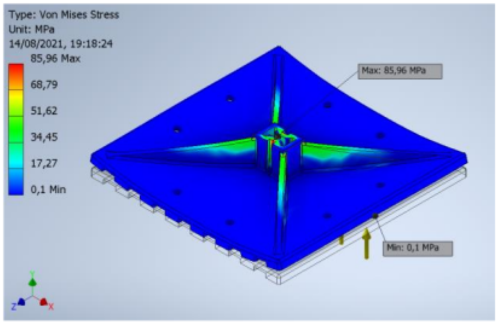

Figure 16. Von Mises Stress on the ram

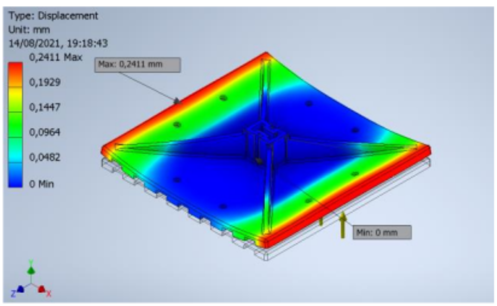

Figure 17. Displacement on the ram

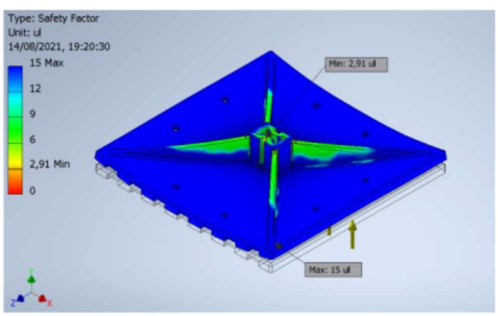

Figure 18. Safety factor on the ram

Table 4. Ram simulation result

Ram	Min	Max
Von Mises Stress (MPa)	0.1	85.96
Displacement (mm)	0	0.2411
Safety Factor	2.91	15

Maximum stress on ram is 85.96 MPa, which occurs in the middle. The ram is equipped with 4 ribs in each diagonal. Ribs are a thin-walled support shape used to strengthen a plate without increasing the plate thickness. As seen in Figure 16, the ribs are experiencing a high stress during the pressing process. Figure 17 shows that the maximum displacement is 0.2411 mm. The minimum safety factor based on Figure 18 is 2.91, which means the designed rame is safe to be used for the pressing force of 20000 N. Table 4 shows the simulation result of the ram.

Conclusion

The double lead screw household trash compactor design has a large capacity, simple construction, and easy to operate. Based on the static simulation analysis using Autodesk Inventor Professional 2022 stress analysis, parts of the double lead screw household trash compactor are safe to operate. In the simulation, the loads for testing are 20000 N for load force and 16 Nm for load torque. The lead screw can withstand a 16 Nm torque with a minimum safety factor of 2.3. The frame and the ram can withstand a 20000 N of force with a minimum safety factor of 3.58 and 2.91. All these numbers indicates that the trash compactor has a safe-to-operate design. The following is a rendered view of a double lead screw household trash compactor using Autodesk Fusion 360.

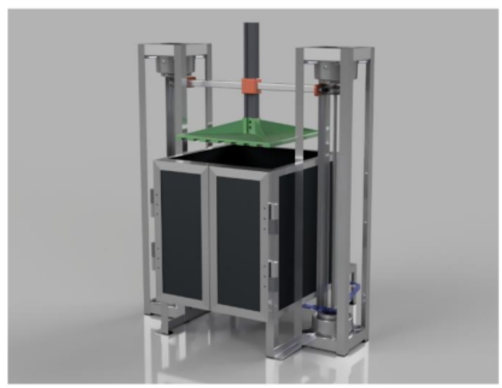

Figure 19. Rendered view of a double lead screw household trash compactor

References

1. Ajmadison. (n.d.). *Trash Compactor & Food Disposer Buying Guide*. Retrieved August 15, 2021, from ajmadison: https://www.ajmadison.com/learn/trash-compactor-food-disposer-buying-guide/#:~:text=A%20Trash%20Compactor%20condenses%20garbage,volume%20by%20up%20to%2080%25.
2. Badan Pusat Statistik. (2017, March 7). *Persentase Rumah Tangga Menurut Provinsi dan Perlakuan Memilah Sampah Mudah Membusuk dan Tidak Mudah Membusuk, 2013-2014*. Retrieved from Badan Pusat Statistik: https://www.bps.go.id/statictable/2014/05/02

/1360/persentase-rumah-tangga-menurut-provinsi-dan-perlakuan-memilah-sampah-mudah-membusuk-dan-tidak-mudah-membusuk-2013-2014.html

3. Bharath S* a, Sirajuddinb, Chandan S Mudakavic, Allah Pateld, Lokesh N (2020). Design and Fabrication of Solar Powered Trash Compactor Bin using Scissor Mechanism with GSM. *High Technology Letters. Volume 26, Issue 9*
4. David, S. K., Biswal, J. N., Muduli, K., Peter, O., & Pumwa, J. (2020). Design and Analysis of a Hydraulic Trash Compactor. *TEST Engineering & Management*, 8877-8888.
5. H. N. Chauhan, M. P. Bambhania. Design & Analysis of Frame of 63 Ton Power Press Machine by Using Finite Element Method. Indian Journal of Applied Research. Volume: 3, Issue: 7
6. Igbinigie Osamwonyi, I. P. Okokpujie and J. O. Dirisu. (2018). Development And Performance Analysis of Horizontal Waste Paper Baling Machine. International Journal of Mechanical Engineering and Technology. Volume 9, Issue 10. pp. 84–101
7. Mwinuka, T. E., & Nyichomba, B. B. (2017). Design and Manufacture of a Waste Compactor Prototype: A Step Towards Implementing a Non-Burn Health Care Waste Disposal in Developing Countries. *Tanzania Journal of Engineering and Technology, 36*, 1-11.
8. Palanivel, T. M., & Sulaiman, H. (2014). Generation and Composition of Municipal Solid Waste (MSW) in Muscat, Sultanate of Oman. *APCBEE Procedia, 10*, 96-102.
9. Ravi, D. (2014). Computer Aided Design and Analysis of Power Press. *Middle-East Journal of Scientific Research* 20 (10): 1239-1246.
10. Szulca, M., Malujdaa, I., & Talaśkaa, K. (2016). Method of determination of safety factor on example of selected structure. *Procedia Engineering, 136*, 50-55.
11. Vroom, C.B. Bentil, J., Eshun, D. (2016). Design of a Solid Waste Compactor. International Journal of Scientific Research and Innovative Technology. Vol. 3 No. 7
12. Weyuma, Z. (2021, March). Design and Manufacturing Analysis of Multi-purpose Vertical baler/trash Compactor Machine. *International Journal of Emerging Trends in Engineering Research, 9*, 324-334. doi: https://doi.org/10.30534/ijeter/2021/27932021
13. Widya, C., Andianti, R., & Pragesari, N. N. (2019). *Statistik Lingkungan Hidup Indonesia 2019*. Badan Pusat Statistik.
14. Wulandari, R. (2020, September 9). *Perlu Bersegera untuk Kurangi Produksi dan Sampah Rumah Tangga*. Retrieved from Mongabay: https://www.mongabay.co.id/2020/09/09/perlu-bersegera-untuk-kurangi-produksi-dan-sampah-rumah-tangga/#:~:text=Data%20nasional%20tahun%202018%20menunjukkan,tangga%20yang%20mendaur%20ulang%20sampahnya.

paper ICAMME2

ORIGINALITY REPORT

4%	3%	1%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Ateneo de Davao University Student Paper	1%
2	www.ajmadison.com Internet Source	1%
3	www.buy.com Internet Source	1%
4	Submitted to Shanghai Pinghe School Student Paper	1%
5	journals.udsm.ac.tz Internet Source	1%

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		