TEST Engineering & Management

January-February 2020
ISSN: 0193-4120 Page No. 8877 - 8888

Design and Analysis of an Hydraulic Trash Compactor

Somade Kolawole David, Jitendra Narayan Biswal, Kamalakanta Muduli, Oyekola Peter, John Pumwa

Article Info
Volume 82
Page Number: 8877 - 8888
Publication Issue:
January-February 2020

Article History
Article Received: *5 April 2019*
Revised: *18 Jun 2019*
Accepted: *24 October 2019*
Publication: *08 February 2020*

Abstract:
This article is focused on the design, analysis and fabrication of a trash compactor which would effectively tackle the issue of large volumes of waste accumulation. Waste generation is one of the major environmental issues affecting the world today. Traditional waste disposal methods are relatively expensive and unhygienic in many developing countries around the world. This brings about the need to provide a more hygienic and cost-effective device that reduces the volume of these household wastes. Thus, this work aims to design and fabricate a motorized trash compactor using locally sourced materials. The machine makes use of a hydraulic system which is connected to a motor to provide the compressing force. Both software analysis and performance evaluation of the machine were carried out to ensure that the design was reliable and efficient.

Keywords: *Compactor, Hydraulic, Solidworks*

I. Introduction

Urbanisation of cities has brought about increase in population which presents a major issue of waste management. Although this issue is prevalent in developing countries as it a recurring event in the Sub Saharan Africa and Nigeria in particular(Nkwocha , Pat-Mbemo, & Dike, Evaluating the efficiency of solid waste collection services in Owerri Municipality, Nigeria, 2011).It is now major cause of concern in European countries in recent times(Mia Rabson)(McGrath, 2019).Generally, waste generation rates around the world are rising and the World Bank in 2016 estimated the volume of solid waste generated as 2 billion ton which amounts to a footprint of 0.74 kilograms per person per day (World Bank, 2019)(Kwaghgee, 2010). The disposal and management of generated waste matter is greatly influenced by the for mentioned growth (Nkwocha & Emeribe, Proliferation of urban solid waste dumpsite in urban and sub urban areas of Nigeria: Need for the construction of regional sanitary landfill, 2008)(Obanigwe, 1999). Availability of land resources makes it susceptible to dumping activities which leads to various health hazards and affects the safety and aesthetics of the environment(Nkwocha & Okoma, Street littering in Nigerian towns: Towards a framework for sustainable urban cleanliness, 2009)(Botkin & Kedley, 1998).These activities encourage secondary issues such as ominous smell of refuse, drainage blockage which prevent the flow of liquid waste. All these affects our ecosystem in numerous ways.(Haward, 2018).Flood disasters and road accidents are results of these dumping activities. This has contributed to flood disasters and road accidents (Davis & Masten, 2004).

Generally, the responsibility for waste management falls on the local or state government which includes both the collection and overseeing framework to protect the health interest of its people and the environment(Perry, Juhlin, & Normark, 2010). And healthy living conditions cannot be realized without the application of proper strategies in waste collection and disposal scheme(RushBrook & Pugh , 1999)(Ogwueleka, 2009).

A study by Yuming et al (Guan, 2011)on vibrating compact or points showed that the vibrator motion may cause irregular distribution of materials and therefore proposes a new method based on finite element analysis on ANSYS.(Jimoh, 2005)also studied the performance analysis of waste management where they discussed various types of models as well as the accurate workload data needed. The garbage compactor is therefore designed to reduce the volume of waste with the requirement of minor human effort. In order to compact a reasonable volume of garbage, the model is designed and fabricated for generic usage such as in hospitals, offices, stores, restaurants etc. for more efficient use in countries with unstable power, the design has been made eco-friendly with the addition of a solar power source as an alternative. The compactor is designed to be operate in both automatic and manual mode and it is expected to minimize frequent disposal requirements as the trash compactor holds in excess of multiple times the volume of the normal waste container prompting the disposal of in any event three out of each four assortment trips. This not just diminishes working costs, litter flood and natural unsettling influence yet additionally emanations from squandering conveying vehicles, further profiting the environment(RushBrook & Pugh , 1999).

Prevailing motorized waste compacting system often use compressed air or inert gas (pneumatic systems) controlled through manual or automatic solenoid valves that can provide the necessary power in an economical, benign, flexible and consistent way which cannot be said for electric motors and actuators. The key benefit of this system is the infinite availability of the working fluid (air). Also, the utilization of compacted air isn't restricted by separation, as it tends to be effectively shipped through channels (small, long or winding)(Beer, Russel Johnson , DeWolf, & Mazurek, 2009). After use, the working fluid can be discharged without further processing thus they are safer. Its limitations, however, is that it demands the establishment of air-creating hardware. Compacted air must adjust to institutionalized prerequisites, meet certain criteria, for example, dry, clean and contain the basic grease for pneumatic gear. In this manner, the establishment of pneumatic frameworks is generally costly because of hardware, for example, blowers, channel, lube cylinder, dryer, and controllers.

The crank mechanism on the other hand is associated with an electric motor. The linear movement is created by a turning wrench through a circular movement and can be changed over to a circular motion and vice versa(Wagner & Singh Chhatwal, 1997). In crank mechanisms the diameter characterises the stroke. additionally, calculations are perplexing contrasted with the straightforward productive pressure driven framework. Motors are difficult to control and operate clockwise and anti-clockwise.

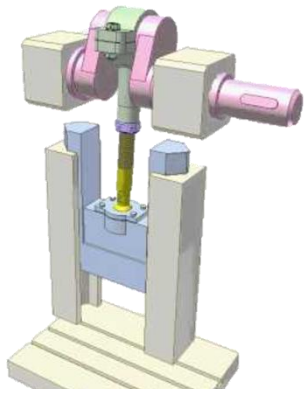


Figure1: Crank Mechanism

The manual compaction mechanism is more economical and free standing as it can operate on most flat surface and compatible with most trash container. The lever control is used for compressing the garbage in the vesse land it is designed to be adjustable for different scenario like amount of trash being compacted or diverse waste containers(Harari, 2011).

The hydraulic mechanism as opposed to the pneumatic system uses incompressible fluid(Sammons & Sammons, 2005)(Lacobucci, 2006)which results in more efficient and steady power in compression. It also includes high ratio of power to weight, hence allowing compact designs. the high torque-mass and force-inertia ratio allows

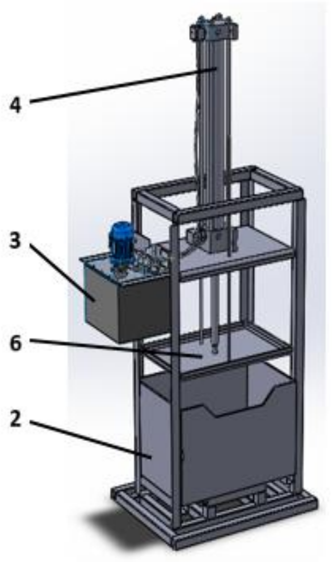
January-February 2020
ISSN: 0193-4120 Page No. 8877 - 8888

for increased acceleration and swift response of the hydraulic motors(Chapple, 1999).

II. MATERIALS AND METHOD

The trash compactor was first drafted and modelled using solid works software. Analysis of the compactor was also carried in order to determine the choice of materials to be used in the trash compactor fabrication. After fabrication, tests were carried out on the compactor to determine the compression ratio of the machine with respect to various types of wastes.

There are several components that makes up the trash compactor. The Housing Frame is the body structure of the machine while the remaining parts are divided into the upper section and the lower section as seen in Figure 3.



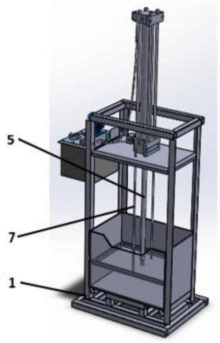


Figure 2: Trash Compactor Design

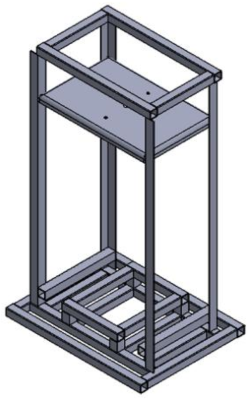
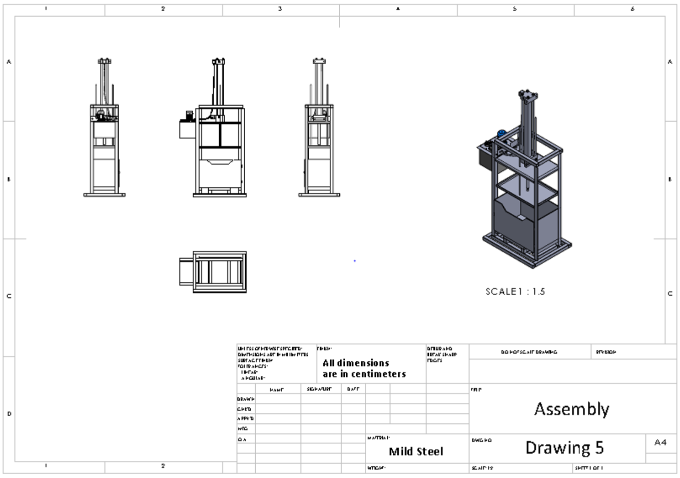
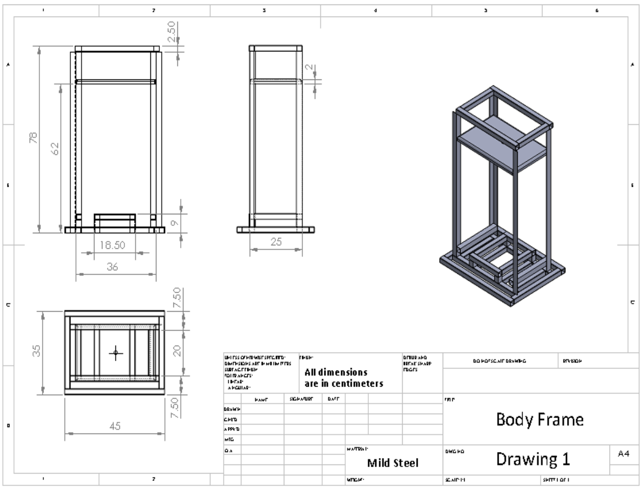


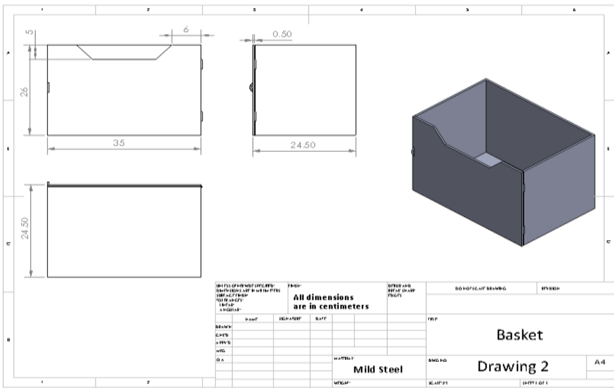
Figure 3: Model of Housing Frame

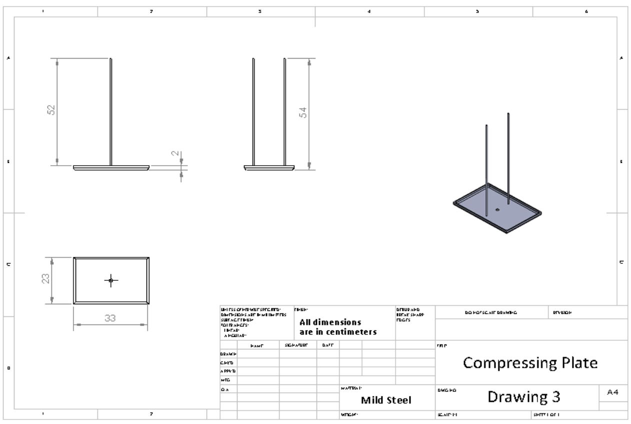
S/N	Part	Section
1	Housing Frame	Frame
2	Basket base	Lower
3	Hydraulic unit	Upper
4	Cylinder	Upper
5	Piston Rod	Upper
6	Compressing Plate	Lower
7	Guide	Lower

ISSN: 0193-4120 Page No. 8877 - 8888

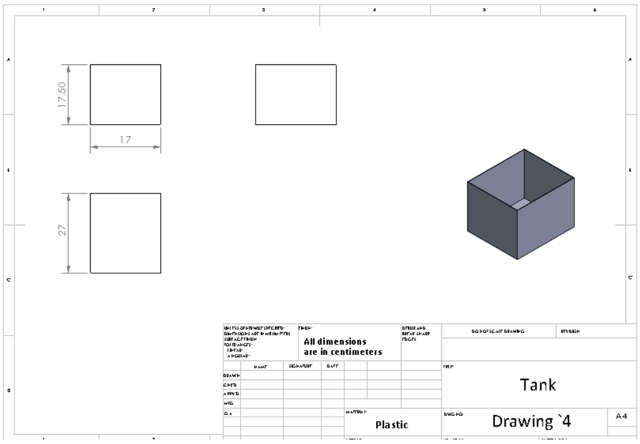








January-February 2020
ISSN: 0193-4120 Page No. 8877 - 8888



The upper section houses the hydraulic Jack (which weight 6kg and produces a maximum pressure of 3000psi), cylinder, piston rod, and the hydraulic Unit which house a tank and pump connecting the hydraulic jack with hydraulic hoses.

The Tank (Reservoir)stores the hydraulic fluid and heat dissipater. And a motor rating of 0.75 horsepower, 220volts was used.

The Lower Section contains the accessory basket used to hold the trash during and after compression and the compressing plate which transmits the force generated by the hydraulic unit to compress the trash.

III. Design and Modeling

For proper analysis, the following assumptions were made:

a) PET (Polyethylene terephthalate) materials makes up most of the trash.
b) The bottom base of the trash is taken to be a fixed geometry while the sides are taken to be frictionless constraints.
c) The trash is a perfect cuboid whose volume is equal to that of the basket base.

IV. Results and Discussions

A. Materials Selection for the Plate

The major factors governing the selection of materials for this part include cost and availability. The aim of this exercise is to obtain a material which can be found as scrap in the environment and can also serve the purpose of compressing trash effectively.

After careful investigation three materials were obtain which include aluminium alloy and AISI 1089 low carbon steel (mild steel). In order to determine the best material option to select, fatigue analysis was done.

B. Fatigue Analysis

For the fatigue analysis, the following assumptions were made:- The trash compactor is used three times a day, the pressure exerted by the compacting plate on the trash is 20.684 MPa (3000psi), the reaction of the trash on the compressing plate is 1057710 N (which was obtained from the analysis on the trash), the sides of the compressing plate are fixed geometries and lastly, the fatigue analysis is carried out for cycles corresponding to the periods of 1yr, 5yrs, and 20yrs (i.e. 1095, 5475and 21900 cycles respectively). The reason for the large number of cycles is to obtain an accurate result from the simulation software.

January-February 2020
ISSN: 0193-4120 Page No. 8877 - 8888

Aluminium 6061 alloy

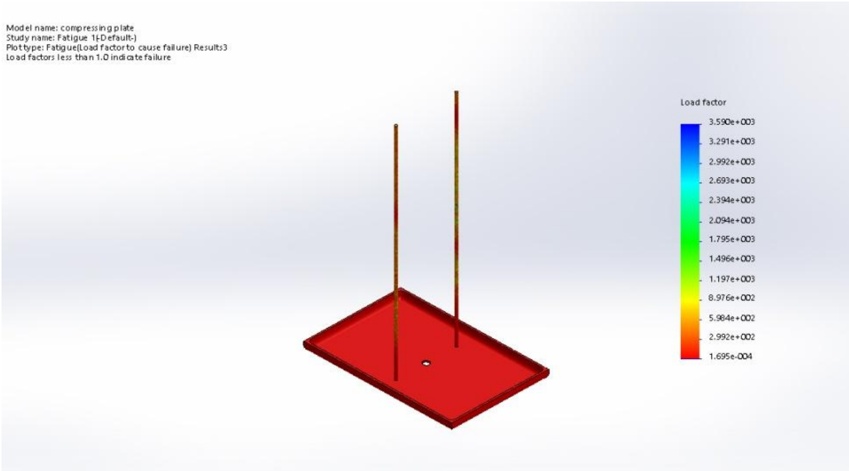


Figure 4: fatigue analysis for Al 6061

Year	Cycle	Loading factor
1	1095	0.000169519
5	5475	0.000108727
20	21900	0.00007976

AISI 1089Low carbon steel

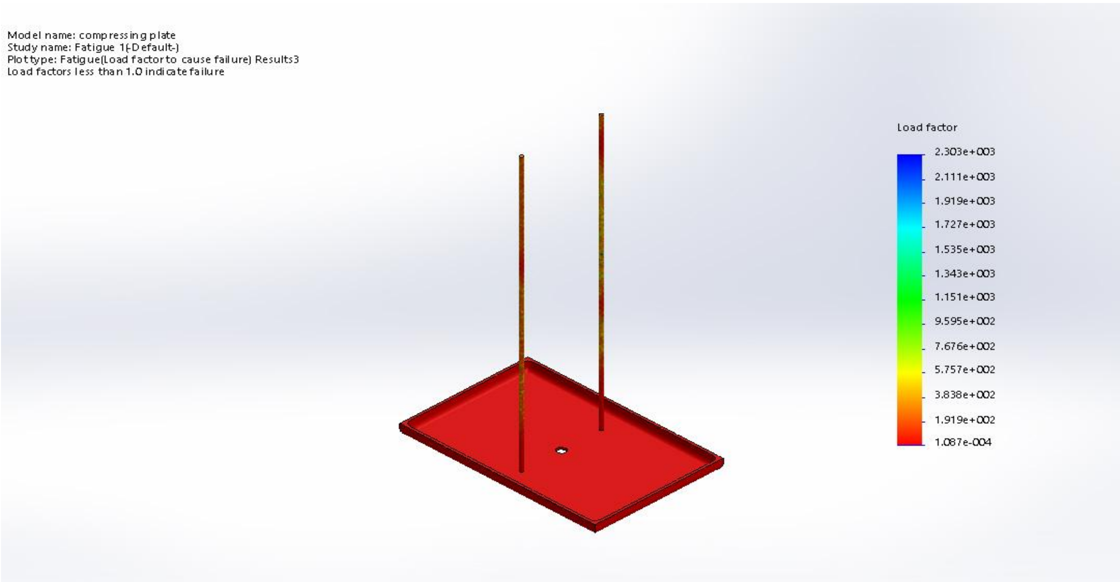


Figure5: Fatigue analysis for AISI 1089

Year	Cycle	Loading factor
1	1095	0.000493741
5	5475	0.000316678
20	21900	0.000232312

The load factor of the Aluminium alloy reduced drastically from 1.087e-004 for 5475 cycles to 7.976e-005 for 21900 cycles. This goes to show that the load effect on the aluminium alloy increases over time. As for the low carbon steel the reduction in the load factor is not as drastic as it reduces from 3.167e-004 for 5475 cycles to 2.323e-004 for 21900 cycles. This analysis led to the selection of low carbon steel for the compressing plate.

C. Compression Ratio

The experiment for compression ratio of the machine was done by compressing two plastic trash bags with the first containing PET bottles while the second contained food packs made of polystyrene.

Table 1:Experimental results of compression

	Before Compression		After Compression	
Experiment	Mass (kg)	Volume (m^3)	Mass (kg)	Volume (m^3)
1	0.38	0.014421	0.38	0.005237
2	0.09	0.012144	0.09	0.003112
Total	**0.47**	**0.026565**	**0.47**	**0.008349**

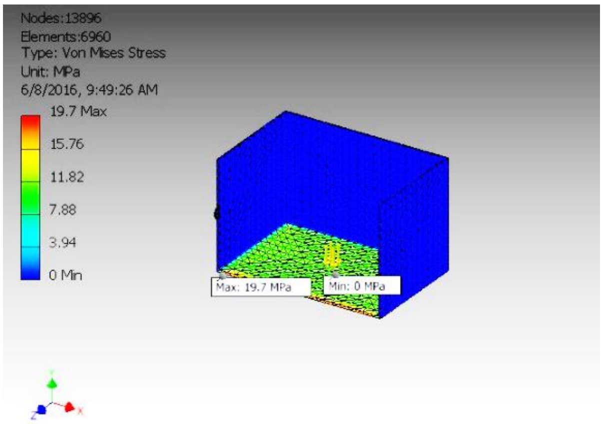
$$\text{Compression Ratio} = \frac{\text{Total volume before compression}}{\text{Total volume after compression}}$$

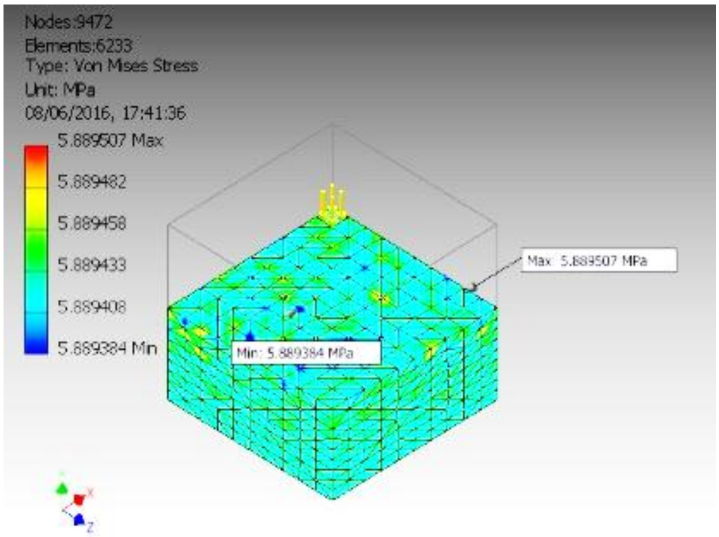
A compressing ratio of 3.18 to 1 of the initial volume of garbage compacted was obtained from the conducted experiment. Also, the stress and strain analysis are shown in the table 2 below

Table 2: simulated stress values

	Basket Frame		PET trash		base support	
Name	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Von Mises Stress (MPa)	0	19.699	5.88938	5.88951	0	4.47759
1st Principal Stress (MPa)	-9.50221	2.47087	-14.7946	-14.7945	-0.95257	3.83981
3rd Principal Stress (MPa)	-27.4967	0.74323	-20.6841	-20.6839	-5.29357	0.3676
Displacement (mm)	0	0.00639	0	0.06051	0	0.0293

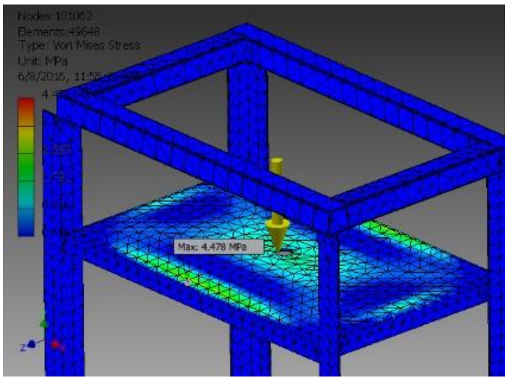
D. Von Mises Stress



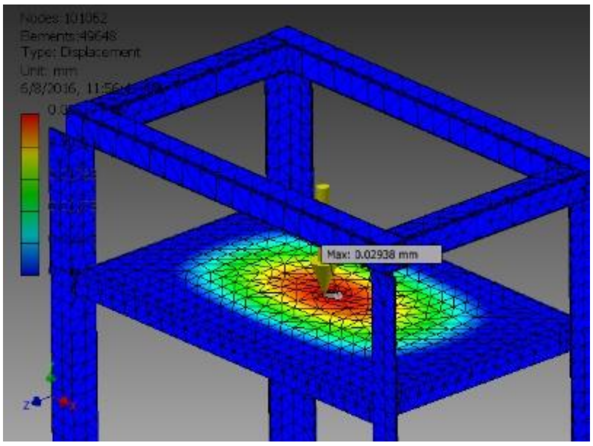


(a)(b)

January-February 2020
ISSN: 0193-4120 Page No. 8877 - 8888

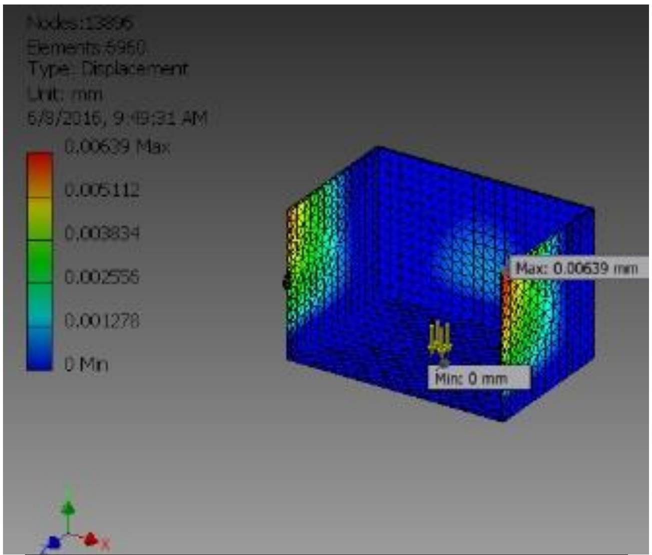


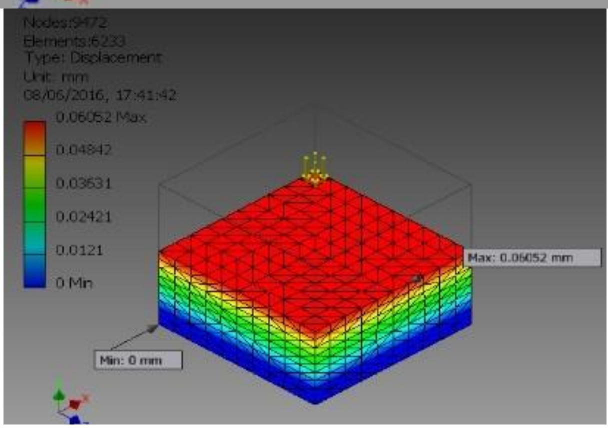
(c)
Figure 6: Von Mises Stress of (a) basket frame (b)PET trash face (c) Support



(c)
Figure7: Displacement of (a) basket frame (b)PET trash face (c) Support

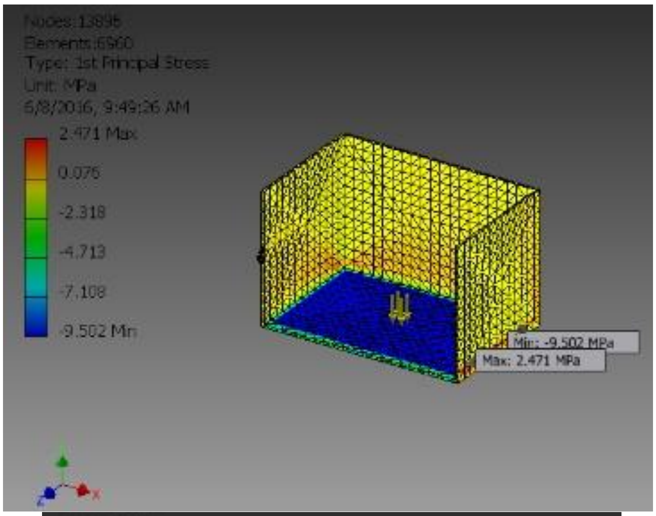
E. Displacement

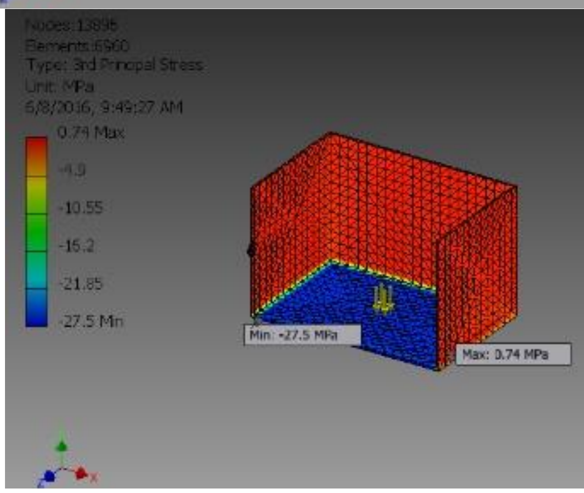




(a) (b)

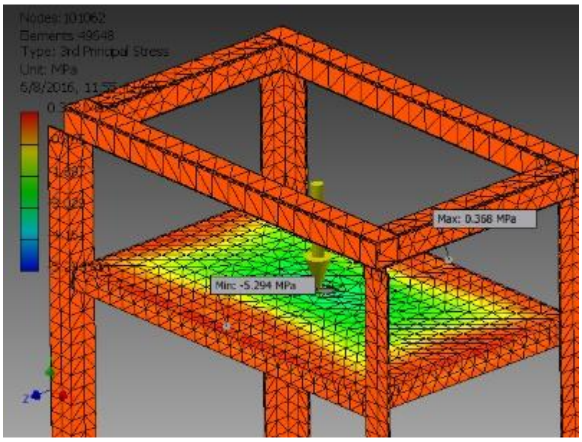
F. Principal Stress





(a) (b)

January-February 2020
ISSN: 0193-4120 Page No. 8877 - 8888

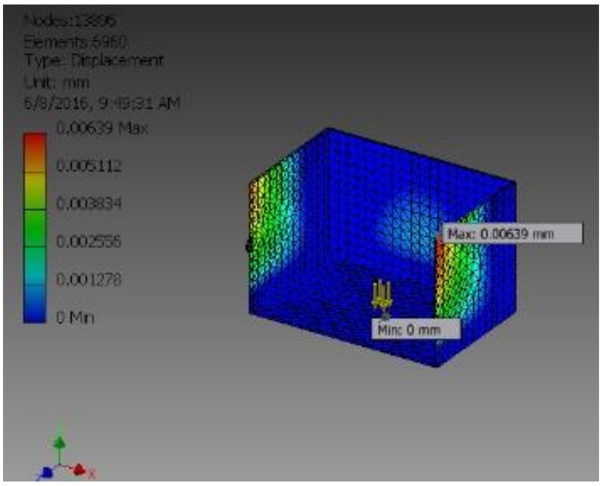


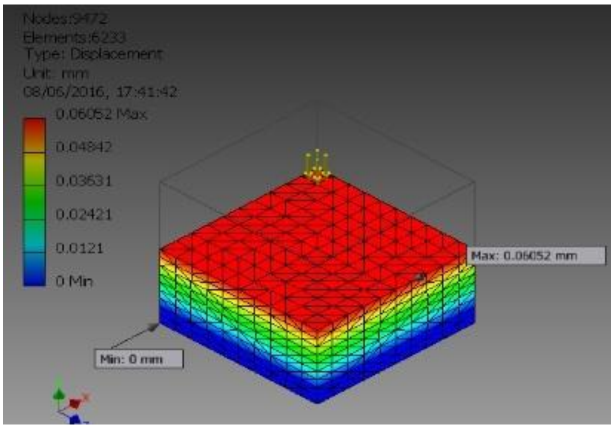
(c)

Figure 8: (a)1st Principal Stress on Basket Frame (b) 3rd principal stress on Basket Frame (c) Support

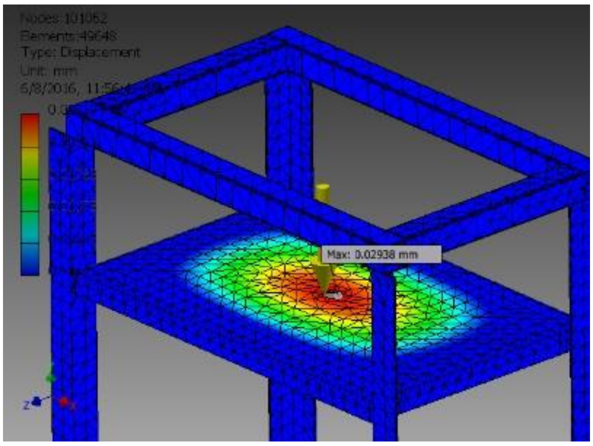
The first principal stress gives the estimation of stress typical to the plane (the shear pressure is zero). This shows the most extreme tractable pressure prompted in the part because of the stacking conditions. From the analysis, the basket frame has a maximum yield stress of 2.47087MPa induced while the base support is 3.83981MPa.

Additionally, the 3rd principal stress acts at a normal angle to the plane where shear stress is zero. This shows the most extreme compressive stress instigated in the part because of the stacking conditions. Thus, the basket frame has a maximum compressive stress of 0.74323MPa while that of the base support is 0.3676Mpa based on these results, the principal stresses are lower than the tensile strength of AISI 1080 low carbon steel which is 440MPa and as such, its probability of failure is highly unlikely. The same deduction can be made for the Von mises stress criterion. Both values for the basket frames and base support respectively are lower than the Yield strength of the material and thus, failure is unlikely.





(a) (b)

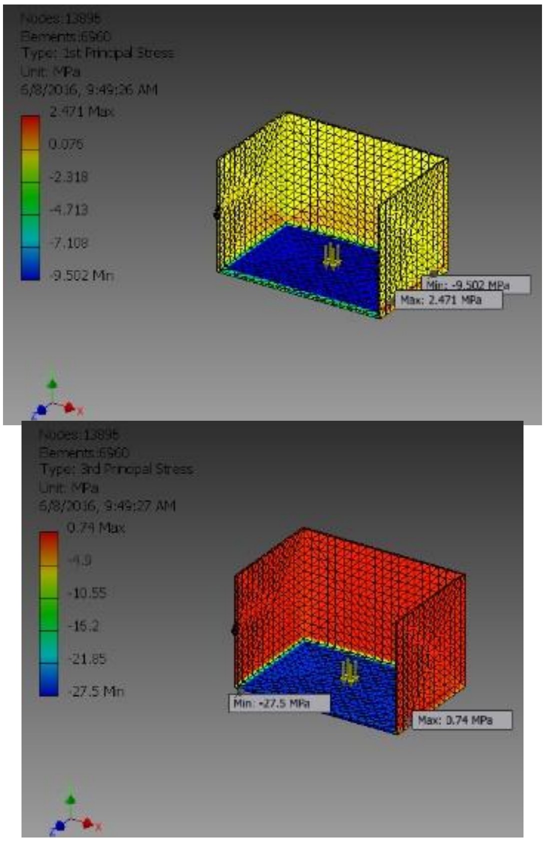


(c)

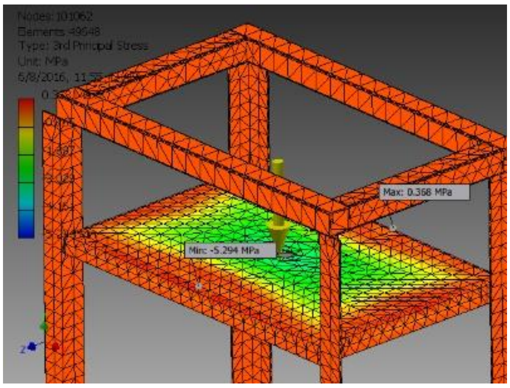
Figure7: Displacement of (a) basket frame (b)PET trash face (c) Support

January-February 2020
ISSN: 0193-4120 Page No. 8877 - 8888

G. Principal Stress



(a) (b)



(c)

Figure 8: (a)1st Principal Stress on Basket Frame (b) 3rd principal stress on Basket Frame (c) Support

The first principal stress gives the estimation of stress typical to the plane (the shear pressure is zero). This shows the most extreme tractable pressure prompted in the part because of the stacking conditions. From the analysis, the basket frame has a maximum yield stress of 2.47087MPa induced while the base support is 3.83981MPa.

Additionally, the 3rd principal stress acts at a normal angle to the plane where shear stress is zero. This shows the most extreme compressive stress instigated in the part because of the stacking conditions. Thus, the basket frame has a maximum compressive stress of 0.74323MPa while that of the base support is 0.3676Mpa based on these results, the principal stresses are lower than the tensile strength of AISI 1080 low carbon steel which is 440MPa and as such, its probability of failure is highly unlikely. The same deduction can be made for the Von mises stress criterion. Both values for the basket frames and base support respectively are lower than the Yield strength of the material and thus, failure is unlikely.

V. DISCUSSION

The reaction at the base of the waste during compaction exerting a pressure of 20.684 MPa on a composition of trash consisting of PET plastics is 1057710 N. This value was needed for the fatigue analysis of the parts.

A maximum pressure of 3000psi produced by the compressing plate will result in a maximum displacement effect of 0.00639039 mm on the body of the Basket frame. This value is negligible therefore the hydraulic unit can be used for construction. Also, the exertion of a force of 60N exerted on the Base support by the Hydraulic Jack will result in a maximum displacement effect of 0.0293824 mm. This value is negligible therefore the specifications for the support can be used for construction.

The compression ratio of the trash compactor is 3.18.

VI. CONCLUSION

This project was constructed to solve the problem of the large volume of waste produced that is constantly being produced. The compression ratio of the compactor is measured experimentally using common trash substance like PET plastics, nylons etc.the result of this experiments shows a compression ratio of 2.75 (for plastic bottles) to 3.9 (for extrude polystyrene food packs) of the initial volume of garbage compacted. This implies increased savings in transportation costs, fuel cost, labour cost as well as vehicle maintenance. For recycling centres, waste compaction encourages waste sorting and as such recyclable waste can be taken to these centres for recycling. For the waste management crew, it reduces the time spent on waste disposal as 3 trips to the dumpsite can be reduced to 1 and as such it allows for adequate waste management. All these savings give an indication that the trash compactor has attained its goals

VII. References

[1] E. E. Nkwocha , E. C. Pat-Mbemo and M. U. Dike, “Evaluating the efficiency of solid waste collection services in Owerri Municipality, Nigeria,” International journal of Science and nature, vol. 2, pp. 89-95, 2011.

[2] Mia Rabson, “Canada violated international law by dumping garbage in the Philippines: lawyers,” National Globalnews, [Online]. Available: https://globalnews.ca/news/5179164/canada-philippines-garbage-law/..[Accessed 10 July 2019].

[3] M. McGrath, “US top of the garbage pile in global waste crisis,” BBC News, 2019. [Online]. Available: https://www.bbc.com/news/science-environment-48838699. [Accessed 10 July 2019].

[4] World Bank, “Solid Waste Management,” 1 April 2019. [Online]. Available: https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management. [Accessed September 2019].

[5] A. Kwaghgee, “National Economic Empowerment and development Startegy NEEDS,” 2010.[Online]. Available: https://www.academia.edu/9469457/National_Economic_Empowerment_and_development_Startegy_NEEDS. [Accessed 2016].

[6] E. E. Nkwocha and C. A. Emeribe, “Proliferation of urban solid waste dumpsite in urban and sub urban areas of Nigeria: Need for the construction of regional sanitary landfill,” Journal of Environmental Systems, pp. 315-331, 2008.

[7] S. Obanigwe, “Wasting Wastes and Wealth,” The National Guardian, pp. 18-22, July 1999.

[8] E. E. Nkwocha and I. O. Okoma, “Street littering in Nigerian towns: Towards a framework for sustainable urban cleanliness,” African Research Review, vol. 3, pp. 147-164, 2009.

[9] D. B. Botkin and E. A. Kedley, Environmental Science: Earth As A Living Planet, 2nd ed., New York: John Wiley and Sons Inc, 1998.

[10] M. Haward, “Plastic plollution of the world's seas and oceans as a contemporary challenge in ocean governance,” Nature Communications, vol. 9, no. 1, pp. 1-3, 2018.

[11] M. L. Davis and S. J. Masten, Principles of environmental engineering and science, New York: McGraw-Hill, 2004.

[12] M. Perry, O. Juhlin and D. Normark, “Laying Waste Together: The Shared Creation and Disposal of Refuse in a Social Context,” Sp. Cult, 2010. [Online].[Accessed 2019].

[13] P. RushBrook and M. Pugh , “Solid Wasteadfills in middle and lower income countries: A technical guide to planning and operation,” in The World Bank, Washington DC, 1999.

[14] T. Ogwueleka, “Municipal solid waste characteristics and management in Nigeria,” Journal of Environmental Health Science & Engineering, vol. 6(3), pp. 173-180, 2009.

[15] Y. Y. B. Z. S. X. Y. &. D. X. Guan, “Analysis on vibrator of vibrating compactor based on ANSYS.,” in Second International Conference on Mechanic Automation and Control Engineering , 2011.

January-February 2020
ISSN: 0193-4120 Page No. 8877 - 8888

[16] I. A. Jimoh, "A new Approach to Municipal waste Management in Nigeria," in International Conference on Energy, Environment and Disasters- INCEED, Charlotte N.C. , USA, 2005.
[17] P. Beer, E. RusselJohnson , J. DeWolf and D. Mazurek, Mechanics of Materials, New York: McGraw_Hill, 2009.
[18] W. E. Wagner and K. N. Singh Chhatwal, "Manual Trash Compactor". US Patent 5619915, 15 April 1997.
[19] A. Harari, "Universal Manual Trash Compactor". US Patent 8001887 B2, 23 August 2011.
[20] D. A. Sammons and E. W. Sammons.US Patent 6959643 B1, 1 November 2005.
[21] E. Lacobucci, "Waste Compactor". US Patent 7089852, 15 August 2006.
[22] P. J. Chapple, "Using simulation techniques in the design of actuator cushionin," in Drives and Controls Conference, Telford, 1999.