Design, Modelling and Analysis of Mini-Motorized Road Cleaning Machine

Abrha Hagazi Tsegay[1], Siva Prasad Dora[2]

[1]*Research Scholar, M. Tech Mechanical Engineering, GITAM Institute of Technology, Visakhapatnam, Andhra Pradesh, India.*
[2]*Associate Professor, Lecturer of Mechanical Engineering, [2]GITAM Institute of Technology, Visakhapatnam, Andhra Pradesh, India.*

---***---

Abstract - *Now a day, people of the world are concerned about environment of the world. Why because, polluted environment is gradually increased and global warming is also increasing. As a result, human health is at a risk. Some causes are unclean vehicle roads, railway stations, airports, hospitals, bus stands, schools, colleges, university etc. So, to address such problems, technologically developed Mini-Motorized Road Cleaning Machine is designed, modelled and analysed. The modelling was done in CATIA V5 and the analysis is done using ANSYS software. From the study, it is concluded that the designed road cleaning machine exhibits low stresses and with negligible deformation and can be confirmed that the design is safe.*

***Key words* - Polluted environment, global warming, road cleaning, life of road, sanitize, time, labor.**

1 INTRODUCTION

A clean environment is one of void form any pollutant. Good sanitizing and cleaning of environment and the surrounding leads to proper health of human beings. Cleaning environment is clean air, clean water, and clean energy, as a result safe and healthy human. Cleaned roads also improves the shelf life of the floor, walls etc due to regular cleaning and maintenance. As we all know, there is no single mechanism that is suitable for cleaning in all locations effectively. It depends upon the type of cleaning machine, cleaning method, its components and user easy operation. Some of vehicle roads, railway stations, airports, hospitals, bus stands, schools, colleges, university are cleaned through manually which consume time and labour. And some roads are cleaned using vehicle machines which is initial costly. Ranjit Kumar and Kapilan [1] designed and analyzed a manually operated floor cleaning machine. A 3D model of floor cleaning equipment was developed in ANSYS and the analysis was done at different load conditions. They concluded that the stresses and deformation developed in the designed model were well within the limits. A systematic qualitative analysis of cleaning method using the cleaner is studied by Sruthi et al. [2]. The developed cleaner eliminates dirt highways, clogged pipelines and manholes, as well as metal particles from the ground and barriers. Praveen et al. [3] fabricated an eco-friendly road cleaning machine with various gears, collecting box etc. They concluded that the fabricated machine is capable of collecting dust particles in a large scale. In terms of area covered, it performs admirably with minimum cost. However, the equipment shows low efficiency when the road was irregular and damaged. Sandeep and Mehta [4] designed and built a cleaning machining system that is powered by a tricycle. They concluded the machine is more effective for cleaning dust and it can provide employment to the uneducated that are in need of such work, as the machine requires human energy to operate. Ritvick Ghosh et al [5] developed a floor cleaner that operates entirely on mechanical power and can be rode at low speeds by the consumer. The cleaning process will be similar to that of a spinning mop, also known as a "magic mop." The mechanism is based on a bevel gear system, which allows for high-speed multiplications with the right gear requirements. By replacing the manual process with a cost-effective system, an effort has been made by Bisen et al [6] to design and create a dust cleaning machine for cleaning dust beside the road divider. This unit has a scrubber brush that sweeps the floor and a vacuum dust collector that cleans the dust. Results demonstrated that the developed model is most effective technique for removing dust from the roadside. Owing to the fact that leaves are difficult to transport because they take up a large amount of space. This problem has been addressed by Mohsen Azadbakht et al [7]. The authors designed and built a tractor-driven leaves collector with a suction-blower mechanism. SolidWorks software was used for the preliminary modeling. The effects of pump suction time, suction pipe size, and PTO intervals on the system's output were also investigated. They concluded that the developed model can hold 1,000 kg of leaves.

2 PROBLEM STATEMENT

The major problem in our environment faces is un-cleanliness. Even though initial work has been done by researchers, but there are fundamental questions that are not clear still now.

- Mostly road cleaning machine are manually operated road cleaning machine: those works by pushing or pedal operating. So, they are time consuming and human power consuming (shoulder pain).
- And some road cleaning machines are diesel operated machines which are very costlier.

Now, let's open our eyes and to come up with scientific and mechanical solution, that is design, modelling and analysis of "Mini-Motorized Road Cleaning Machine".

3 METHODOLOGY

3.1 Modelling and Analysis

The actual three-dimension (3-D) modelling structure of the motorized road cleaning machine is carried out using CATIA V5 software as shown in Fig. 1 and numerical analysis is carried out in ANSYS. The machine carries maximum weight of 100 Kg (initially 20 Kg of dead load). It has mainly consisted of 6 units. The motor unit, supper gear system unit, the chain drive unit, the roller brushes unit and the trash bin collecting unit. The whole assembly is mounted on a frame made up of ASTM-A36 (Structural) steel which is light in weight. The motor unit is source of power used to rotate the chain drive unite and roller brush unit. The chain drive unit contains roller chain and supper gear system unit contains gears, which are used to transfer power from the input motor shaft to roller brush and to bucket elevator. The roller brush is used to clean the road, which is supported in the frame. The trash bin collector unit contains the bucket and the bucket elevator, which is used to collect the trash or the dusts.

3.2 Materials and Components

Selection of appropriate material is significant for the safe and reliable functioning of a part or a component. In this work, the design of components are based on design engineering book [8] and some parts are selected from indiamart [9].

a. Frame: It is square hallowed cross-sectional of ASTM-A36 (Structural) steel material (50x50 mm thickness of 5 mm) to support overall weight.
b. Motor: It is source of power having maximum of 10 KW with 1440 rpm speed.
c. Shaft: It is a solid circular cross section of ASTM-A36 (Structural) steel material having 20 mm diameter and 1000 mm length.
d. Super gear pair: It is used to transmit power/ or reverse direction of power, having material of mild steel C45 with i=2, Z_1=20, Z_2=40, centre distance = 90 mm, face width = 27 mm, module = 3 mm.
e. Bearing: A roller bearing is used to transfer load, having a SKF6004 bearing type with shaft diameter 20 mm and outer diameter 42 mm.
f. Chain drive: To transmit power between larger center distances of shafts. The chain is having pitch 12.7 mm, roller diameter 7.95 mm, maximum center distance 1300 mm. The sprocket is having transmission ratio= 2, Z_1=27, Z_2=54, pitch 12.7 mm.
g. Round horizontal sweeper brush: is used to clean dusts. The brush is a material of mixture of steel wire, wave/flat polypropylene and Nylon. It has 20 mm interna diameter with 1000 mm length.
h. Elevating bucket: is a stainless-steel material used to collect, carry and throw the dust particles to trash bin collector.
i. Trash bin collector: is a material of polypropylene used to collect dusts coming from elevator bucket. It has 1000 x 500 x 500 mm dimension.
j. Caster wheel: It is a material of rubber to enables relatively easy rolling movement of the object. It has wheel diameter 300 mm and 150 Kg load capacity.
k. Bolt and nuts: A mild steel material is used with diameter 8 mm.

3.3 Modelling

The concept is generated for low-cost, minimal human effort, easy operation and low time-consuming floor cleaning machine. And the three-Dimensional (3-D) was developed in CATIA V5 software tool as shown in the Figure 1.

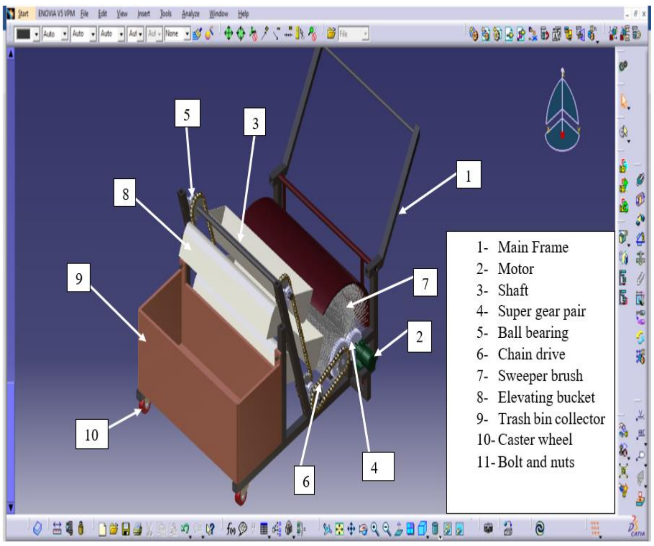

Figure 1: 3-D Assembled modelling

3.4 FEA Numerical Analysis

Here, the FEA analysis tool is used to find the deflection and stresses on frame. The frame model was checked for the effects of self-weight (deadload frame) and for the whole combination (dead load assembled) and live load. The maximum deflection and stresses were checked, and maintained within the allowable limits of material. Finally, the factor of safety is checked from Von Mises stress.

During the numerical FEA analysis, there are some assumptions listed below.

- Assumed material is homogeneous, isotropic and obeys Hooke's law
- Assumed all materials are ductile in nature and Von-Mises stress theory is used for comparing induced yield stress values to check safety.
- Only structural parts are considered for FEA analysis. Other components are considered as lumped masses at their center of gravity and as dead load assembly 20% extra loads is added.
- The plane cross sections of the frame-beam remain plane during bending.

3.4.1 Element Type

ANSYS function defines by element type. For the structural frame, BEAM188 is selected from library element type. Beam188 is suitable for analyzing and it's two nodes beam element in 3-D.

3.4.2 Material type

The material type for the structural frame is square hallowed cross-sectional of ASTM-A36 (Structural) steel. It is linear, elastic and isotropic. Its mechanical properties are shown in table 1.

Table 1: Mechanical properties of ASTM A36 steel

Material type	Yield strength	Allowable deflection for 3 m under 1 KN pin support beam experimentally
ASTM-A36 (Structural) steel	250 MPa	19 mm

3.4.3 Boundary and loading conditions

The boundary condition for the structure of frame is considered as pin support. The load is constantly varying to maximum 1000 N/m as shown in Fig. 2.

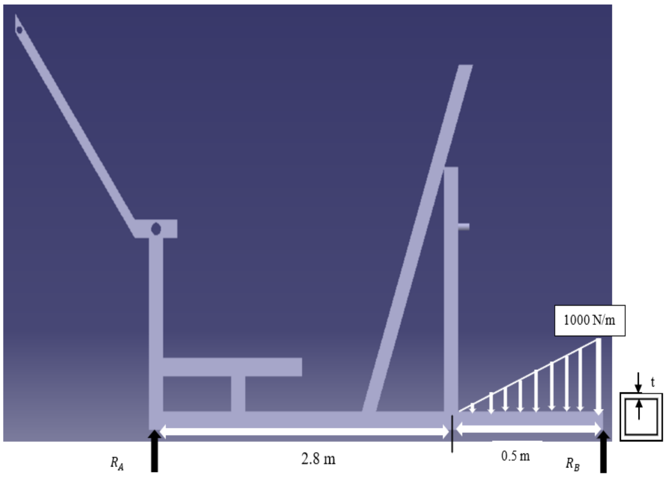

Figure 2: Boundary condition for load applying

Fig. 3 shows the load (1000 N/m = 1 KN/m) distribution in 20 section elements on ANSYS mechanical APDL. The counter plot in Fig. 3, the blue and red colour shows minimum (0.05 KN/m dead load) and maximum (1 KN/m carrying load) is constantly applied in to 20 element division sections. The boundary condition for the beem188 model is applied to both side pin support and then maximum deflection and maximum von Mises stress is checked.

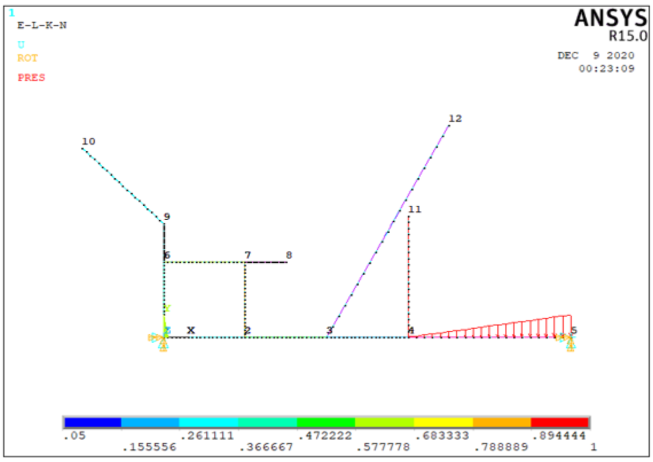

Figure 3: load distribution and boundary condition in ANSYS

4 RESULTS AND DISCUSSIONS

4.1 Maximum deflection

Figure 4 shows the maximum and minimum deflection of the frames under load case. From the counter plot, the blue colour is for minimum deflection (0.112E-14 mm) and red colour is for maximum deflection (4.0314 mm). So, the maximum deflection is less than from the allowable deflection of material in table 1 that can withstand.

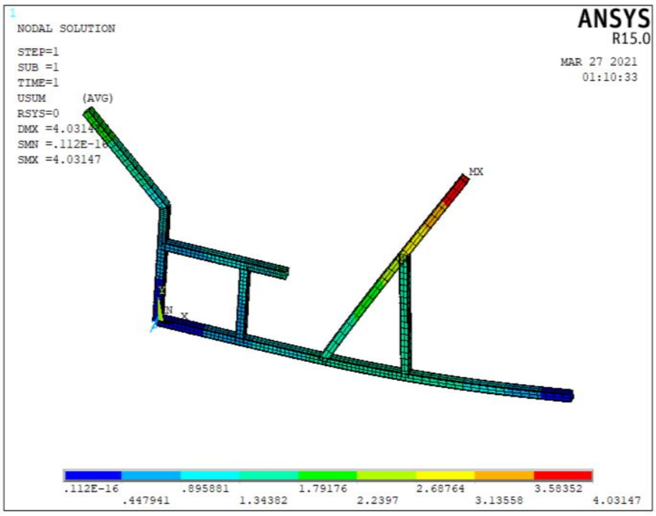

Figure 4: Maximum deflection

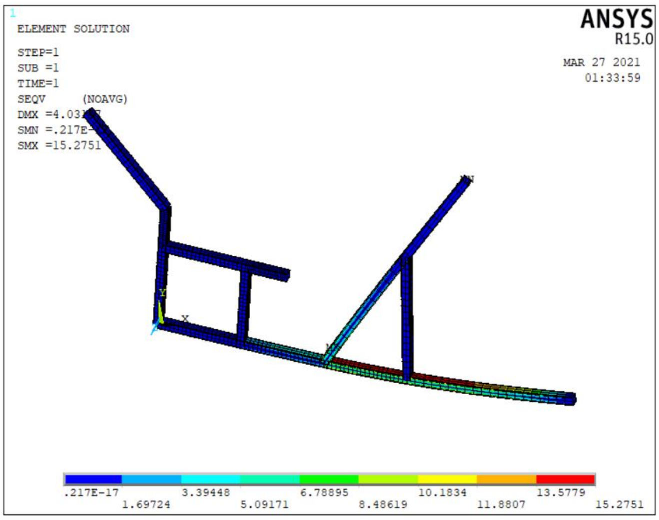

Figure 5: Maximum Von Mises Stress

4.1.1 Maximum Von Mises Stress

Figure 5 shows the maximum and minimum von Mises stress of the frames under load case. From the counter plot elemental solution, the blue colour is for minimum von Mises stress (0.217E-17 MPa) and red colour is for maximum von Mises stress (15.275 MPa).

From the stress contour, it is found that induced maximum Von-Mises stresses on the frame (beam188) is less than the maximum yield stress of material of construction. Finally, Design for factor safety is checked according to the distortion-energy theory.

The factor of safety is expressed

$\sigma' = \frac{\sigma_y}{n}$, where, σ' is von Mises stress and σ_y is yield stress of material.

So, the factor of safety $n = \frac{\sigma_y}{\sigma'}$

$$n = \frac{250 Mpa}{15.2751\ Mpa} = 15.625 > 1$$

Therefore, the factor of safety is greater than unit, so the frame design is safe.

5 CONCLUSIONS

Since, peoples of the world are concerned about environment of the world a mini-motorized road and floor cleaner machine is necessary. In this project, the machine is successfully designed, modelled, analyzed. The main objective is to avoid uncleaned road or floor, to reduce human effort, to save the time, to reduce cost and to decrease environment pollution. It cleans the road by sweeper brush and collects dust by elevator bucket to trash bin collector by itself.

Throughout analysis of frame, it is checked by failure criteria theory. The frame is designed using distortion energy theory failure criteria, $\sigma' = \frac{\sigma_y}{n}$, in which the total Von Mises stress is calculated by ANSYS mechanical APDL. Finally, design for factor of safety is checked. Since, the factor of safety is more than unit, the design is safe.

6 Future scope and Recommendation's:

From our design we have recommended for individual society to concern the problems and to apply the scientific solution of our design.

Due to various constraints such as technical, financial, environmental, material availability etc. the project could not achieve 100 percent efficiency. Someone can further work on this project to improve the performance of the machine. Some future modifications

- Adding advanced mechanism
- Proper material selection reducing cost and weight
- Use of pressure vacuum can also be made for collecting micro dusts.

REFERENCES

[1] M. Ranjit Kumar and N. Kapilan, Design and analysis of manually operated floor cleaning machine, International Journal of Engineering Research & Technology, 4(4), 828-831, 2015.

[2] K. Suruthi, K. Pradheepan, T. Gopalakrishnan, Manually operating sweeper machine to collect dust particles & grains, International Journal for Scientific Research & Development, 6(2), 816-818, 2018.

[3] Praveen H, Harish Gowda GR, Anil G Ramageri, Arunkumar Kallammanavar, Prasanna P Kulkarni, Girish B Kallihal, Design and fabrication of multipurpose eco-friendly cleaning machine, International Journal for Research in Applied Science & Engineering Technology, 6, 2333-2338, 2018.

[4] J. Sandeep, G. Meshram, .D. Mehta, Design and development of tricycle operated street cleaning machine, Journal Of Information, Knowledge And Research In Mechanical Engineering, 4, 702-706, 2016.

[5] Ritvick Ghosh, H R Vinay Kumar, Dattatraya, Pavan Kumar B. Hiremath, Pradeep Kumar K.V,

[6] Reshav Bisen, Akshay Ukey, Mohit Manohare, Yogesh Bharti, Khushal Burande, Smitesh R. Bobde, Design and development of dust cleaning machine for cleaning of dust beside the road divider, International Research Journal of Engineering and Technology, 7(5), 1055-1059, 2020.

[7] Mohsen Azadbakht, Ali kiapey, Ali Jafari, Design and fabrication of a tractor powered leaves collector machine equipped with suction-blower system, Agric Eng Int: CIGR Journal, 16(3), 77-86, 2014.

[8] Achchagam, Kaliakathir ''Disign Data Book for Engineeriners 2019, India''.

[9] B. A. Dinesh Agarwal, “indiamart,” IndiaMART InterMESH Ltd, 1996. [Online].

BIOGRAPHY:

Abrha Hagazi Tsegay,

M. Tech Research Scholar, Mechanical Engineering, GITAM Institute of Technology, Visakhapatnam, Andhra Pradesh, India.