International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
doi : https://doi.org/10.32628/IJSRST229366

Study and Analysis of Various forces acting on developed Automated Lake Cleaning Robot Model - A Review

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Article Info
Volume 9, Issue 3
Page Number : 306-313
Publication Issue
May-June-2022
Article History
Accepted : 10 May 2022
Published : 30 May 2022

ABSTRACT

Analysis on an (Pre-designed) Automated lake cleaning robot is conducted and the optimization of various critical components is done. The robot is a prototype model for a lake cleaning machine which collects surface waste and debris from the water surface with the help of conveyor mechanism which is built with it. Some critical components of this machines are analysed on ANSYS 18.1 software to study deformations and stresses induced on them due to external forces. The forces acting on the components are first identified, followed by theoretical calculations of the forces. Parts where forces need to applied and constraints are parameterized. Four types of results are studied firstly the Von-misses Stress, Strain, Deformation and the Factor of safety. The obtained results are studied and are used for further prototype models.

Keywords: ANSYS 18.1, von-misses stress, parametrized, forces, factor of safety

I. INTRODUCTION

India is a land of beautiful and diverse landscapes, rich in natural resources, and an attractive tourist destination. Nowadays the country faces the grave challenge of large-scale environmental pollution such as water pollution. Water is our source of life. The first species to live on earth arrived from water. Water is present abundantly on our planet Earth. About 71% of total land area is covered by water bodies, including oceans, lakes, river, ponds, etc. About which 97% of it resides in oceans and the remaining 3% is stored in various sources like glaciers, lakes, rivers, etc. Over 140000 species including 55% of fishes rely on freshwater directly. Including us i.e. Humans. We need water for omnivorous reasons. Drinking being the primary one; power generation, natural habitat, etc. It used for irrigation which ultimately leads to food production. In India specifically, rivers are treated as goddesses' for example River Ganga, River Yamuna, these are considered to be holy in India. Even after knowing its importance and its value people are misbehaving with it. The condition of rivers and lakes today are devastating. Water bodies today are mostly covered with a blanket of plastics and other waste that is being

fed inside it against its will. The poisonous untreated factory waste is directly flushed into the water bodies which is affecting the life in water bodies on a tremendous high rate.The impurities present in water can cause hazardous diseases. Waste water is defined as the flow of used water from homes, business industries, commercial activities and institutions which are subjected to the treatment plants by a carefully designed and engineered network of pipes. The biggest impact of cleaning the chemical wastes can cause respiratory diseases and it plays a challenging issue for the municipality officers. Water damage is classified as three types of contaminated water. They are clean water, gray water and black water. Clean water is from a broken water supply line or leaking faucet. If not treated quickly, this water can turn into black water or gray water, depending on length of time, temperature, and contact with surrounding contaminants. Gray water is contaminated water that causes discomfort or illness. It includes washing machine overflow; toilet overflow with some urine, and dishwasher overflow. Black water is grossly contaminated and could cause severe illness or death if ingested and avoided such as flooding from rivers or streams, water from beyond the toilet trap, water from the toilet bowl, or standing water that has begun to support microbial growth.

Our Automated lake cleaning robot model brings a hope in such a devastating state of our water bodies. A robot that works on a simple mechanism of a conveyor belt and floating. The base frame supports the main conveyor mechanism over it. The conveyor mechanism is powered by a D.C. Motor supplied with D.C. power through a battery. One end of the conveyor is placed near the water surface which when opera rated pulls in the surface waste. The conveyor disposes of it in a bin with holes in it that let the water drain away and help to reduce the unwanted weight. Analysis is a process of breaking complex topic or substance into smaller parts in order to gain a better understanding of it. The technique has been applied in the study of mathematics and logic since before Aristotle. Analyzing the critical components of the robot mentioned above is the aim of this paper, and studying the following results:[1]Von-misses stress, which is a value used to determine if a given material will yield or fracture. It is mostly used for ductile materials, such as metals. The von Mises yield criterion states that if the von Mises stress of a material under load is equal or greater than the yield limit of the same material under simple tension then the material will yield.[2]Total Deformation, which is the deformation option that you can see all the deformation results related to your model, in three coordinates(X, Y, and Z). [3]Strain is useful in determining the amount of elongation or distortion a structure may experience under various loading conditions. [4]Factor of Safety,A factor of safety is the load-carrying capacity of a system beyond what the system actually supports. Bridges, buildings, safety equipment, and fall protection all start with a factor of safety.

Calculations of the various forces are done and then the values are fed as an input in ANSYS.

II. LITERATURE REVIEW

Various scientist and authors have worked on the concept of an Automated Lake Cleaning Robot work and its designing and analysis. Analysis considering a separate part to the project various literatures regarding the topic was researched. Some works are as follows:

Shuxiang Guo, et.al., 'Modeling and experimental evaluation of an improved amphibious robot with compact structure'[1].This paper presented the static and hydrodynamic modelling and analysis of a spherical round amphibious robot. This paper aimed to achieve stability and accuracy of prototype built.

Juan A. Ram´ırez-Mac´ıas, et.al., 'Hydrodynamic modelling for the remotely operated vehicle Visor3

using CFD' [2].In this paper hydrodynamic model of a underwater remotely operated vehicle has been presented. Fluid analysis was done.

Sreejith S Nair et.al., 'Design and Fabrication of River Cleaning Robot' [3].In this paper designing and analysisof an autonomous lake cleaning robot is given. Design constraints are parameterized here. Construction of the robot and Structural as well as hydrostatic analysis of the robot is done.

P. Jagadeesh et.al.,'Experimental investigation of hydrodynamic force coefficients over AUV hull form'[4].In this paper, The axial, normal, drag, lift and pitching moment coefficients are determined from towing tank experimental study on Afterbody1 for AUV operating conditions for different angles of attack. Results from this study reveals a maximum increase that is observed in normal force coefficient compared to axial force coefficient for the highest speed and angle of attack.

Emily Wax, "A Sacred River Endangered by Global Warming", Washington post, June 2007[5].This article shows the real side of our holy river Ganga which is polluted by humans and there activities. A comparison with other countries is also briefly mentioned here.

Ganesh S. Khekare et.al., 'Design of Optimized and Innovative Remotely Operated Machine for Water Surface Garbage Assortment' [6].Condition of water sources in India and how it is being hampered by human activities is given here. A prototype model used for cleaning the surficial waste on such water bodies is designed. The methodology applied consists of selection of proper material, designing, and testing of the prototype.

III. METHODOLOGY

This analysis is based on the calculated assumptions of forces acting on the critical components of the Robot. The design constraints are set and accordingly a CAD model for the proposed design is made. This CAD model is then used for the analysis purpose of the Robot.

The following are the steps involved in the process:

1. Design constraints,
2. CAD Modelling,
3. Material selection,
4. Force calculation,
5. Static constraints,
6. Analysis,
7. Results.

The main aim of the complete research is to study the forces acting on the robot and its susceptible failure locations if any, so as to improve them in further iterations.

IV. DESIGN CONSTRAINTS

In mechanical design the components are listed down and stored on the basis of their procurement, designed in two categories namely.

1. Designed parts
2. Parts to be purchased

Mechanical design phase is very important from the view of a designer as the whole success of a project depends on the correct design analysis of the problem. Many preliminary alternatives are eliminated during this phase. Designers should have adequate knowledge about the physical properties of a material, load stresses and failure. He should identify all internal and external forces acting on machine parts. These forces may be classified as,

a) Deadweight forces
b) Friction forces
c) Inertia forces
d) Centrifugal forces
e) Forces generated during power transmission, etc.

Designers should estimate these forces very accurately by using design equations. If he does not have

sufficient information to estimate them he should make certain practical assumptions based on similar conditions which will almost satisfy the functional needs. Assumptions must always be on the safer side. Selection of factors of safety to find working or design stress is another important step in the design of working dimensions of machine elements. The correction in the theoretical stress values is to be made according to the kind of loads, shape of parts & service requirements Selection of material should be made according to the condition of loading shapes of products environment conditions & desirable properties of the material provided should be made to minimize nearly adopting proper lubrication method.

Material Selection- It plays an important role in the rigidity and reliability of the system. If the proper selection of material is not done it may affect the performance of the model drastically. If a material with less desired qualities is used it will hamper the robot's performance and if a much overestimated material is chosen it has its own disadvantages such as increased cost, availability, etc

Table 1. Material used in various components

Sr.no.	Component	Material
1	L- angle	Aluminum
2	Square pipe	Steel
3	Conveyor belt	Rubber
4	Shaft	PVC
5	Hull	PVC

V. CAD MODEL AND DRAFTS

In this section, it is shown the CAD model designing and drafting-

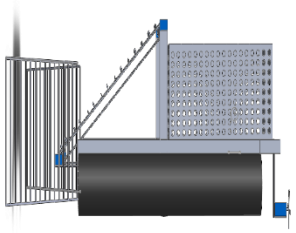

Fig 1.Left Side View of Model

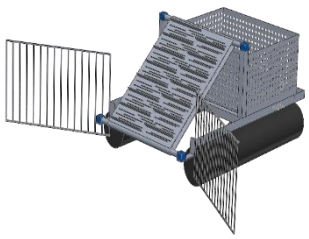

Fig 2.Isometric View of Model

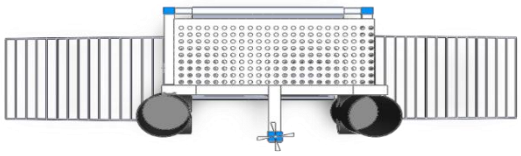

Fig 3. Front View of Model

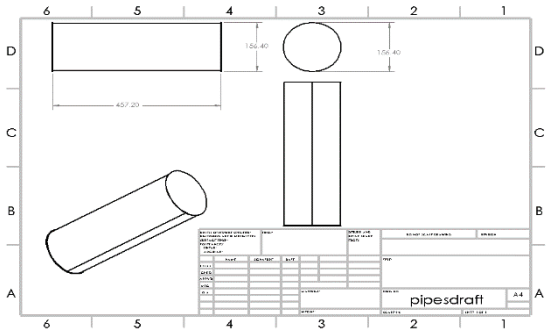

Fig 4.Draft of Hull of Model

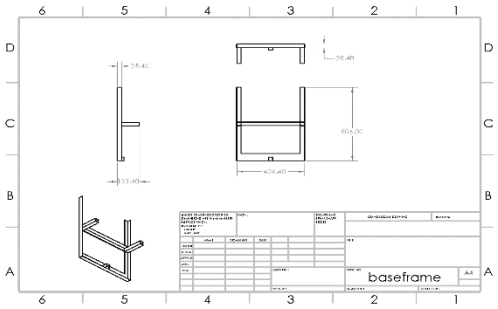

Fig 5. Draft of Base Frame of Model

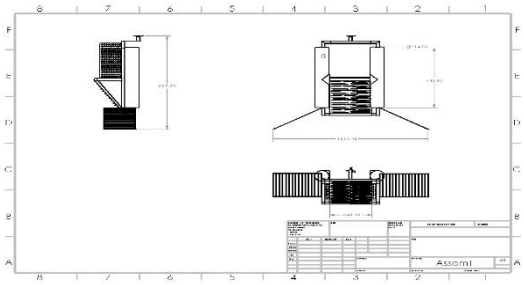

Fig 6. Draft of Overall Assembly of Model

VI ANALYSIS AND RESULTS

In the designing of our prototype robot it was necessary that we build it with atmost rigidity and robustness not compromising on its weight factor also. We had to conceptualize the design of our model and select the proper material so that they may fulfil the basic

Requirements of the purpose they are serving also an analysis of the critical components of the model was then done prior to the fabrication. To ensure that the model we wish to fabricate is safe and will function as desired a virtual analysis is a must. We did our analysis on ANSYS software. Where theoretically calculated force values are fed into the program and the program runs an analysis on the model computing the possible failure junctions (if present).

Table 2. Mechanical Properties of Materials

Properties	Aluminum	PVC
Density (kg/m^3)	2770	1180
Young's Modulus (GPa)	71	3.3
Poisson's ratio	0.33	0.35
Tensile Yield Strength (MPa)	240	69
Ultimate strength (MPa)	310	82

Mesh size -Mesh size is calculated by checking the mesh independency. As per earlier studies static analysis of front impact with force value 26,698 N is carried out for various mesh sizes from 1 mm to 5 mm and then a graph is plotted between Von-Misses stress and mesh size.

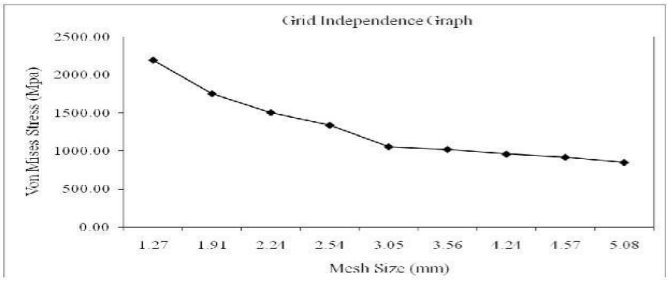

Fig 7.Von-misses stress vs Mesh size

Hence a mesh size of 5 mm is selected, as the Von-misses stress becomes constant and also it was suitable for system availability. The meshing method was tetrahedron and element order quadratic.

Table 3. Ansys Inputs

Sr.no.	Element	Description
1	Meshing Method	Tetrahedron
2	Element order	Quadratic
3	Mesh Size	5 mm

Base frame Analysis-The base frame is constructed with L-angles of dimensions 1" inch on both sides. The material chosen is Aluminium as it is light in weight and offers sufficient rigidity and support to the system. Static analysis was performed on the static loading that was due to the weight on the frame.

Constraints Applied-

In ANSYS basically two types of constraints are needed.

1) Fixed components,

2) Components on which force is applied.

For Base Frame,

As the lower part of the frame will be rigidly fixed with the hull using clamp fixture, it can be considered to be a fixed part.

So the lower members in the Base frame are treated as Fixed.

And due to the conveyor mechanism and the other systems on the frame the forces will be acting on it

from the upper part. So force vectors are applied on the upper members of it.

Calculations-Force estimated to be 80 N on the base frame considering FOS of 2.

As the total weight of the subsystems obtained is about 4 Kg.

Force = m*g

= 4 * 9.81

= 39.24 N

With FOS of 2,

F = 39.24*2

= 78.8 N ≈ 80 N

Calculated forces resulted in 80 N of force that was applied on the base frame and the following results were obtained as shown in the figures below-

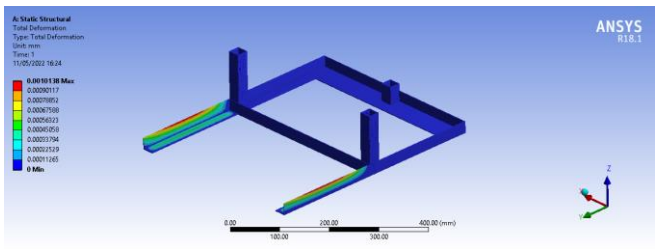

Fig 8. Von-misses stress analysis of base frame

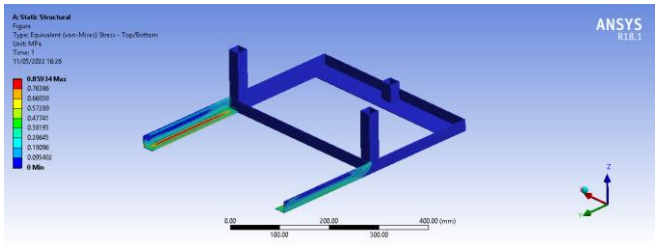

Fig 9. Total deformation of base frame

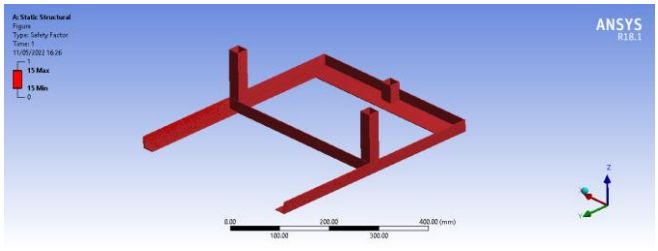

Fig 10. F.O.S of base frame

From the analysis, deformation obtained is 0.001mm and stress-induced is 0.8Mpa. For the aluminium extrusion, the yield strength is 240MPa. Therefore, the design is safe with a high factor of safety.

Hull Analysis-PVC is selected as a material for the hulls. PVC is light in weight and provides very low overall density when used in the form of a circular tube. Which is helpful for the floating of the overall structure? The dimensions of the hulls used are-

Table 4. Dimension of hull

Sr.no	Mechanical specification	Dimension
1	Length	432 mm
2	Outer diameter	101.6 mm
3	thickness	3 mm

Plastic things are susceptible to the hydrostatic stress component; hence the Von-Mises criterion is not applicable in the plastic component design, Therefore, the conic or parabolic criterion is employed. Equation 1 and 2 represents equivalent conic and parabolic stress. The advantage of using parabolic or conic criteria is that the knowledge of material behaviour is not required.

Constraints Applied-Here, the portion of the hull which is in contact with the base frame is considered as Fixed and the forces (being hydrostatic) are applied all over the surface.

Calculations-Hydrostatic pressure under 4" of water level was applied.

Pressure = ƍ*g*h

= 1000*9.81*0.1016

= 996.696 N/m^2

With FOS of 2,

F = 1993.392≈ 2000 N/m^2

The hydrostatic pressure of water below 4" was applied and the results obtained are as shown in the figure-

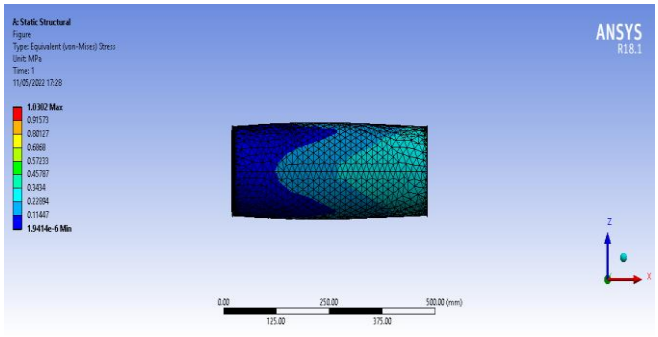

Fig 11. Hydrostatic stress of shaft

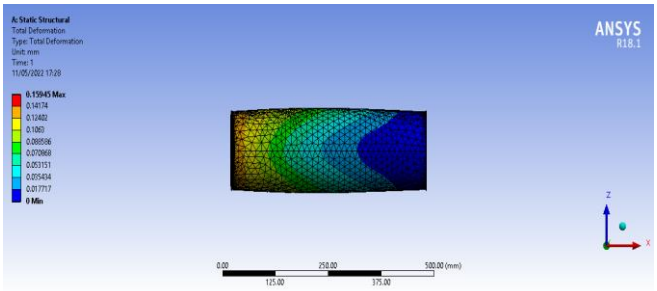

Fig 12. Total deformation of shaft

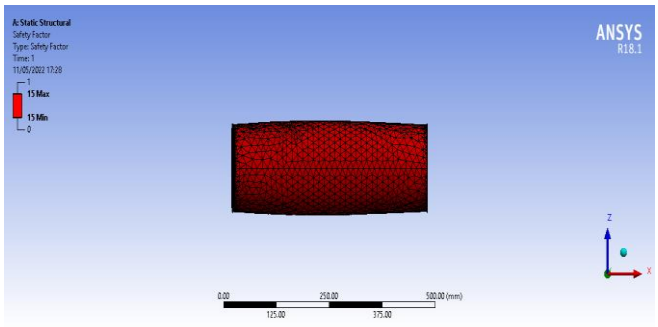

Fig 13. F.O.S of shaft

Table 5. Analysis result of base frame

Sr.no	Analysis	Result
1	Von-misses stress	0.85 MPa
2	Deformation	0.001 mm
3	F.O.S	15

Table 6. Analysis result of hull

Sr.no	Analysis	Result
1	Von-misses stress	0.85 MPa
2	Deformation	0.001 mm
3	F.O.S	15

VI. CONCLUSION

This work shows the study of Analysis results obtained by analysing the various components of a LAKE CLEANING ROBOT. The whole purpose of the research was to bring about some positive change to our mother nature. The negatives we know. The way we humans are hampering the nature, misusing it, misbehaving with it. There is a limit to everything and if that limit of patience is crossed by our nature it will ultimately be disastrous to us. The way people are treating water bodies as there dustbin is pitiful to see. Being the young generation of this developing nation India we are supposed to become an aware citizen who knows and understands such problems that are arising in our surroundings and act accordingly to at least try to limit them.

Apart from it, the Static analysis of the robot was conducted and the results obtained using ANSYS 18.1 software. Proper mesh size was decided by referring from previous studies on analysis. Meshing order selected was Tetrahedrons. There are various more methods provided by ANSYS 18.1 for various complex designs. Meshing method implied was Quadratic. Results showed that the components are safe to design. Proper factor of safety was considered to ensure safety. These results may not be similar for a larger dimensional model. As the analysis was done on the prototype design of the robot.

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Cite this article as :

Prof. Sunil R. Kewate, Mr. Kaushik Gautam, Shailaja Parkor, Lokesh Bhuyar, "Study and Analysis of Various forces acting on developed Automated Lake Cleaning Robot Model - A Review ", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 9 Issue 3, pp. 306-313, May-June 2022. Available at doi : https://doi.org/10.32628/IJSRST229366

Journal URL : https://ijsrst.com/IJSRST229366