ADAMA SCIENCE AND TECHNOLOGY UNVERSITY

School of Mechanical, Chemical and Materials Engineering

Design and development of Automotive Automatic Air Filter Cleaner

A thesis submitted to Adama Science and Technology University in partial fulfillment of the requirements for the award of the degree of

Master of Science

in

Automotive Engineering

by

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled "**Design and development of Automotive Automatic Air Filter Cleaner** " in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Engineering is an authentic record of my own work carried out from November 2017 to June 2018 under the supervision of N. RAMESH BABU, Department Mechanical systems and Vehicle Engineering department, Adama Science and Technology University, Ethiopia.

The matter embodied in this thesis has not been submitted by me for the award of any other degree or diploma. All relevant resources of information used in this thesis have been duly acknowledged.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

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ACRONYMS AND ABBREVIATIONS

2D	Two dimensional
3D	Three dimensional
A	Area
AISI	American Iron and steel Institute
ANSYS	Analysis system
ASTU	Adama science and technology university
d	Diameter
F	Force
FE	Finite element
g	Gravitational acceleration
HP	Horse power
l	Length
m	Mass
p	Power, pressure
T	Torque
W	Weight
μ	Coefficients friction
σ	Stress
τ	Shear stress
ω	Angular velocity
ρ	Density

ABSTRACT

For any engine there a necessity to prevent the impurities from air so that engine should run smoothly so for that we are using air filter. ***.*** *The air filters in an air intake system permanently remove foreign particles such as dust, dirt and soot from the intake air, thereby maintaining the performance of the engine and protecting it from damage. Proper maintenance can help vehicles perform as designed, thereby positively affecting fuel economy, emissions, and overall drivability. Because this air filter has to be cleaned for every 1500 kM. In Ethiopia it is observed that the air filter cleaning causing air pollution, affecting human health, consuming more human power and leading to the wastage of time. So in this context it is aimed to design air filter cleaning system which helps in minimizing the problems mentioned. The activities performed in this work are like designing, modeling, analyzing and producing prototype of the new system. The new air filter cleaner bench had been designed. The designed parts are modeled in CATIA V5 by using tube of 25*25mm and 2 or 3mm thickness and 2mm sheet metal. The other parts of cleaner bench are selected from standards. There for AC motor; bolts, round head screws bearing and hose are selected from standards. After the parts designed and modeled the finite element analysis was done using ANSYS 18.1 workbench in order to find out how the cleaner bench parts react for operation loads. From the results of FEA, it is apparent that the stresses induced in the components are less and the factor of safety is also well above the limit. Also the Von Mises stresses are less than ultimate strength for the material. Thus the design of cleaner bench components is durable. The use of ANSYS software makes the process of calculation fast and several iterations are permissible to arrive at the best possible results. The results are relevant provided the assumptions and boundary conditions are perfect. After analysis and 3D and 2D drawing developed, the prototype of air filter was fabricated and tested. From testing it is observed only 4minutes of time it takes to clean (or remove all dirty particles) for TOYOTA –Hilux air filter.*

Key words: Air filter, air filler cleaner, filter element, dust particles.

CHAPTER ONE

INTRODUCTION

1.1 Background

An air filter cleaner is a device which removes solid particulates such as dust, pollen, mold and bacteria which is collected from the air. Air filters are used in application where air qualities are important, notably in building ventilation system and in engines such as internal combustion engines, gas compressor gas turbine and other [1]. An air filter is an important part of intake system of an automobile because it is through the air filter that the engine “Breaths”. An engine needs an exact mixture of fuel and air in order to run, all of the air enters the system first through the air filter. The air filter purpose is to filter out the dust and other foreign particles in the air, preventing them from entering the system and possibly damaging the engine. An air filter is generally made up of fibrous material, pleated accordion-style. An air filter can also be made of cotton or fabric like materials which is then oiled in order to increase air flow to the filters. The effects of air filter performance were studied carried out with the different diesel engine of cleaned air filter [2 - 4].

This process was very time consuming and costly in terms of amount paid by the contractor to a mechanic for other person to have a filter clean. This manual cleaning of filter also often resulted in a pin holes or other damage to the pleated material of the filter. If the pleated material of the filter gets damaged, the filter would be useless and time invested in the cleaning of air filter would be a complete loss. Therefore, in the view of this hazards and the high cost of labor. There is a need to design a new system to clean air filter which eliminates encounter at present. The present project is directed to design an air filter cleaner which may be used on a job site to clean the air filter of construction equipment and vehicle during normally scheduled downtime. In the past, this air filter element was either cleaned by the process of spraying the compressed air from the hoses [5,6].

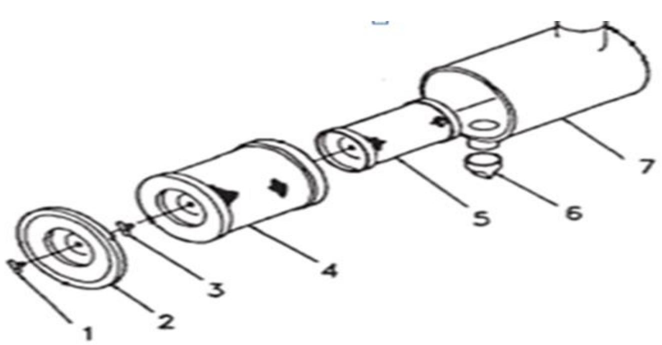
1.2 Air filter cleaning system

Most automotive engines use air filter because of for the combustion process cleaned air from intake system is coming in order to mix with fuel in case of gasoline and in case of diesel first cleaned air is coming in to cylinder and compressed lonely in combustion chamber so both case cleaned air is important [7]. In local garage like in Ethiopia most of the vehicle cleaned their air filter with 1500 km and the local technician cleaned air filter by manual way which seriously affecting their health life or breathing system as well as the system pollute air, in addition to this it takes more time to clean and more human effort.

1.2.1 Air filter cleaning procedure followed

To clean air filter, the following steps are commonly followed

1. Loosen the wing bolt, and remove the band securing the dust pan.
2. Loosen the wing nut.
3. Remove the dust shield from the dust pan. Clean the dustpan and shield.
4. Remove the wing nut and secure the air cleaner primary element in the air cleaner housing. Inspect the rubber-sealing washer on the wing nut.
5. Clean the element from the clean air side with compressed air not exceeding 207 KPa. Inspect the after cleaning. Install the cleaned primary element or a new element.
6. Make sure the gasket washer is in place under the wing nut before tightening.
7. Assemble the dust shield and dustpan again. Position them to the air cleaner housing and secure with the band [5].



1. Wing nut
2. Cover
3. Wing nut
4. Primary filer element
5. Safety filter element
6. Evacuator
7. Body

Figure 1.1 Disassembled air filter parts [7]

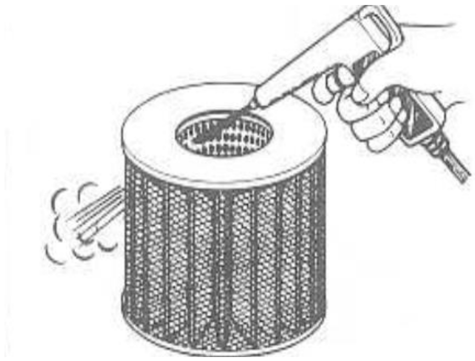


Figure1.2 Manual cleaning method of Air filter [7]

1.3 Statement of the problem

Air filter of the engine is to be cleaned in scheduled interval for better performance of the engine. In Ethiopia air filters are being cleaned manually causing air pollution which has great effect on the health of the people. So there is a need of developing system to clean air filter which solves these problems.

1.4 Objectives of the study

1.4.1 General objective

The general objective of this work is to develop automotive automatic air filter cleaner.

1.4.2 Specific objectives

The specific objectives are as given below

- To study the present process of filter cleaning
- To design and model the filter cleaner
- To analyse the filter cleaner using ANSYS
- To prepare the prototype of the cleaner

1.5 Significance of the study

- It helps in reducing the air pollution,
- It saves the time of technician
- It improves the health of the people.
- It helps in better cleaning of the filter

1.6 Beneficiaries

Automotive garages, technicians, society, Researcher in the field, and country as a whole get benefitted.

1.7 Scope of the study

This study is focusing on a device which is used to clean air filter. It includes the designing of various parts of air filter cleaner. Also, included in this work construction of prototype of air filter cleaner.

1.8 Limitations

Unavailability of journals and periodicals in the library, dependence on only materials from internet, frequent interruption of power which affected the survey of literature time is the first hand constraint.

Difficulties encountered in obtaining proper materials for the study such as Ac motor and a proper shaft is the second constraint.

CHAPTER TWO

LITERATURE REVIEW

2.1 Automobile air filter

Air filters serve the primary needs of removing airborne particulate contaminants from outdoor air prior to introducing the cooling resource into the data hall. Additionally, they serve to increase reliability of mechanical equipment such as fans and spray cooling systems. However, the process of removing dust and particulates presents impedance to airflow that must be accounted for as it may significantly increase the power required to operate supply fans. Darcy's Law, the first law of filtration, states that pressure drop across a filter is proportional to the flow rate of the fluid moving through it [1].

Gaurav Balpande, et.al; Studied Fabrication of Automatic Air Filter Cleaning System ,the system which makes use of compressed air to obtain the mechanical motion & mechanical work. Because of rotating motion of an air filter and reciprocating motion of the nozzle, the incoming compress air from the external compressor helps to remove maximum amount of particulate collected on the air filter from the environment within short interval of time and hence the air filter will be clean.

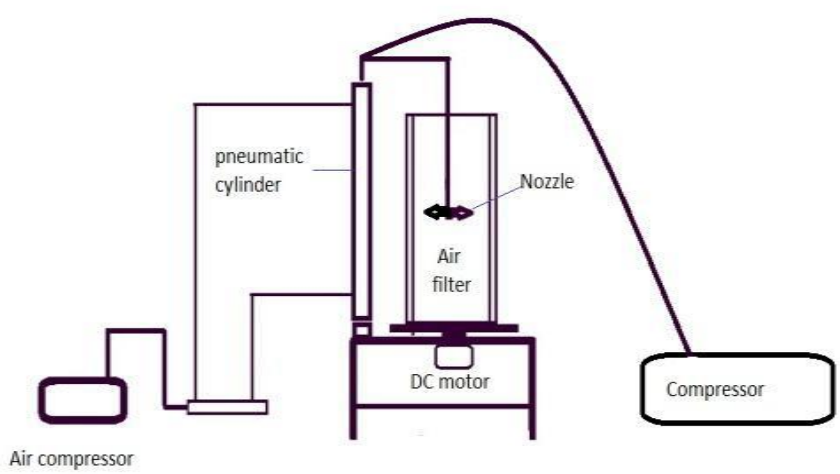


Fig 2.1 Automatic Air Filter Cleaner

Benjamin woodward, studied and developed diesel engine air filter cleaner with the pateneted 360 clane diesel air filter cleaner (U.s.patent No.9,605,628)

The 360 clean does all the work, inside an enclose self-contained module. The operator is never in contact with moving parts. A green light on control panel indicates when the cleaning cycle is complete.

Fig 2.2 360 air filter cleaner

Pavan kumar goud, and chakradhara goud [8], studied on Experimental and Numerical Study on Performance of Air Filters for Diesel Engine, and found that. The air filters in an air intake system permanently removes foreign particles such as dust, dirt and soot from the intake air, thereby maintaining the performance of the engine and protecting it from damage. Proper maintenance can help vehicles perform as designed, thereby positively affecting fuel economy, emissions, and overall drivability.

Chandrasekaran et al. [9] studied on Interfacing of Automation in Air Filter Cleaner, and found that the air filters in an air intake system permanently removes foreign particles such as dust, dirt and soot from the intake air, thereby maintaining the performance of the engine and protecting it from damage. Proper maintenance can help vehicles perform as designed, thereby positively affecting fuel economy, emissions, and overall drivability. This paper addresses the issues of air filters proper cleaning. In contrast, a recent study showed that the fuel economy of modern gasoline vehicles is virtually unaffected by filter clogging due to the closed loop control and throttled operation of these engines. Because modern engines operate without throttling, a different result could be anticipated. This paper describes the measured results with focus on changes in vehicle fuel economy but also includes performance. The effects of air filters performance were studied and the analysis is carried out with the different diesel engine of cleaned air filters.

2.2 Overall Discussion on literature review

It can be concluded that, air filter cleaner designed and developed by different researcher from literature review, show that the system is automatic and the time taken to clean is depending on the model. Also, cleaning method also show that it is safe; dust and pollution free to create healthy and pleasant working environments for both workers and civilians around. But the following table show that the difference between previse and new design of air filter cleaner.

Table 2.1 Comparison of new and previse design

Previs design						New design		
No	Author	Title	Finding		material	Finding		mater
			Time to clean in minute	Model	Material	Time to clean in minute	Model	material
1.	Gaurav Balpande	Fabrication of Automatic Air Filter Cleaning System	5	Light vehicle	DC motor	4	Both light and heavy duty vehicle	AC motor
2.	Benjami Woodward	Developed diesel engine air filter cleaner	3	For Diesel engine air filter	solar energy			

2.3 AC motor

An AC motor is an electric motor driven by an alternating current (AC). The AC motor commonly consists of two basic parts, an outside stator having coils supplied with alternating current to produce a rotating magnetic field, and an inside rotor attached to the output shaft producing a second rotating magnetic field. The rotor magnetic field may be produced by permanent magnets, reluctance saliency, or AC electrical windings [13,14].

2.3.1 Operating principles

The two main types of AC motors are induction motors and synchronous motors. The induction motor (or asynchronous motor) always relies on a small difference in speed between the stator rotating magnetic field and the rotor shaft speed called slip to induce rotor current in the rotor AC winding. As a result, the induction motor cannot produce torque near synchronous speed where induction (or slip) is irrelevant or ceases to exist. In contrast, the synchronous motor does not rely on slip-induction for operation and uses either permanent magnets, salient poles (having projecting magnetic poles), or an independently excited rotor winding. The synchronous motor produces its rated torque at exactly synchronous speed. The brushless wound-rotor doubly fed synchronous motor system has an independently excited rotor winding that does not rely on the principles of slip-induction of current. The brushless wound-rotor doubly fed motor is a synchronous motor that can function exactly at the supply frequency or sub to super multiple of the supply frequency [13,14].

2.6 Finite element software (ANSYS)

American Dr. John Swanson founded ANSYS. Inc. in 1970 with a vision to commercialize the concept of computer simulated engineering, establishing himself as one of the pioneers of Finite Element Analysis (FEA). ANSYS publishes engineering analysis software across a range of disciplines including finite element analysis, structural analysis, computational fluid dynamics, explicit and implicit methods, and heat transfer. It enables us to solve complex structural engineering problems and make better, faster design decisions. With the finite element analysis (FEA) tools available in the suite, we can customize and automate solutions for our structural mechanic’s problems and parameterize them to analyze multiple design scenarios. We can connect easily to other physics analysis tools for even greater fidelity. ANSYS structural analysis software is used throughout the industry to enable engineers to optimize their product designs and reduce the costs of physical testing.

ANSYS provides a cost-effective way to explore the performance of products or processes in virtual environment. This type of product development is virtual prototyping. With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. The enables a reduction in the level of the risk, and in the cost of infective design.

ANSYS also can work by integration with other CAD software Connections are referred to as Geometry Interfaces. With direct interfaces to all major computer-aided design (CAD) systems, support of additional readers and translators, and an integrated geometry modeler exclusively focused on analysis, ANSYS offers the most comprehensive geometry-handling solutions for engineering simulation in an integrated environment. The currently supported CAD Connections are: Autodesk, CATIA V4, V5 and V6, Creo Elements/Direct Modeling, Creo Parametric, Solid Edge, SolidWorks.

2.6.1 Static structural analysis

A static strength analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. This analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects.

2.6.1.1 Equivalent Stress (Von-Mises Stress)

While the Equivalent Stress at a point does not uniquely define the state of stress at that point, it provides adequate information to assess the safety of the design for many ductile materials. It states that inelastic action at any point in a body, under any combination of stress begins, when the strain energy of distortion per unit volume absorbed at the point is equal to the strain energy of distortion absorbed per unit volume at any points in a body stressed to the elastic limit under the state of uniaxial stress as occurs in a simple tension/compression test. Equivalent stress is related to the

Principal stresses by the equation:

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2{S_e}^2 \quad \ldots\ldots 2.1$$

Distortion energy theory is used in design work because it allows any arbitrary three-dimensional stress state to be represented as a single positive stress value. It cannot be applied for material under hydrostatic pressure. Equivalent stress is part of the maximum shear stress energy theory used to predict yielding in a ductile material.

2.6.1.2 Total Deformation

The applied external loads on a body are transmitted to the support through the material of the body. This phenomenon tends to deform the body. The deformation of a part under a load is proportional to its length. Deformation is calculated relative to the part or assembly in coordinate system.

$$U^2 = {U_X}^2 + {U_Y}^2 + {U_Z}^2 \quad \ldots\ldots 2$$

Where, U_X, U_Y and U_Z are the three components of deformation.

2.6.1.3 Stress tool (Factor of safety)

In simple systems only one kind of stress is easy to anticipate the failure, but in complex stress systems in which direct as well as shear stresses act, it is not easy to do so. The following factor of safety tools is available to design the safe strength of the object:

I. Maximum Equivalent Stress Safety Tool
II. Maximum Shear Stress Safety Tool
III. Mohr-Coulomb Stress Safety Tool
IV. Maximum Tensile Stress Safety Tool

In the present analysis Maximum Equivalent Stress Safety Tool has been used. The Maximum Equivalent Stress Safety tool is based on the maximum shear strain energy theory for ductile materials, also referred to as the Mises' and Hencky's theory, or maximum distortion energy theory (or shear strain). Out of the four failure theories supported by Simulation, this theory gives most appropriate result when applied to ductile materials such as aluminum, brass and steel. As shear stress and shear strain energy theories depend upon the stress differences, a material has no chance of failure if the principal stresses are the same nature (tensile or compressive) and the magnitude since the difference will be negligible. Thus these theories should not be applying when the material under hydrostatic pressure. The theory states that the failure takes place when the shear strain energy in a complex system becomes equal or exceeds to that in simple tension.

$S_e \geq S_{limit}$

Expressing the theory as a design goal:

$S_e / S_{limit} < 1$

If failure is defined by material yielding, it follows that the design goal is to limit the maximum equivalent stress to be less than the yield strength of the material:

$S_e / S_y < 1$

The fracture occurs when the maximum equivalent stress of the material reaches or exceeds the ultimate strength of the material:

$S_e / S_u < 1$

Safety Factor $FS = S_{limit} / S_e$

Using the Equivalent Stress (Von Mises Stress), the Total Deformation and the Stress Tools; it was determined whether the parts would yield under loading conditions or not.

CHAPTER THREE

MATERIALS AND METHODS

The step followed in the execution of this work is as given below

- Literature review
- Data collection
- CAD modeling
- FE analysis
- Construction of prototype

3.1 Literature review

Literature review is the first and foremost activity to be performed in any research work. Various sources like journal, books, article, others and previous research works on an air filter cleaner were referred in order to have comprehensive understanding of the subject under research.

3.2 Data collection

After related research review was done, different motor vehicle (light to heavy duty), air filter data was collect by direct measurement from garages and Ambesa city bus company. Overall dimension of the air filter cleaner bench was determined from air filter size, AC motor mount size and ergonomic principle.

3.3 CAD modeling

The rewired dimensions are obtained, 3D CAD modeling of the air filter cleaner bench and other its parts generated in CATIA V5R20 and Solid work and saved in IGES format.

3.4 FE analysis

In IGES format saved model imported to ANSYS 18.1 to perform finite element analysis.

3.4.1 General steps to solve problem in ANSYS

a) Build geometry

Construct a two or three dimensional representation of the object to be modeled and tested using the work plane coordinates system within ANSYS.

b) Define material properties

Now that the part exists, define a library of the necessary materials that composed the object (or project) being modeled. This includes thermal and mechanical properties.

c) Generate mesh

At this point ANSYS understands the makeup of the part. Now define how the modeled system should be broken down into finite pieces.

d) Applying loads

Once the system is fully designed, the last task is to burden the system with constraints, such as physical loading or boundary conditions.

e) Obtain solution

f) This is actual a step, because ANSYS need to understand within what state (steady, state, transient …. etc.) the problem must be solved [18].

3.5. Prototype construction

After the analysis was done and assured that all parts are safe for operational loads, the 2D detail drawing had been papered. All the parts were constructed as per the drawing. The cleaner bench was prepared by joining the parts by using welding, bolt joints and screw joints.

3.6 Material

Material selection for motor vehicle air filter cleaner bench applications plays very important role in providing the desired strength, endurance, safety, and reliability to the cleaner bench. The cleaner bench incorporates major decisions for both materials and design. Some basic requirements for the material selection of the cleaner bench are: light weight, high strength, availability, manufacturability and cost. With these design constraints in mind, material properties of common materials utilized in air filter cleaner bench, includes Carbon Steel and Aluminum.

The common carbon steel material used are AISI 1018, 1020, 4130 and 4340, these steel alloys are a low-cost, strong, easy to manufacture and available materials. If weight is the optimizing parameter aluminum is better. Aluminum is lightweight, expensive and is relatively easy to machine but is difficult to weld [19].

The selection of material for vehicle air filter cleaner bench is done by detailed study of properties of material regarding strength, weight, manufacturability, cost and availability results found that steel alloy AISI 4340. As the load expected is less in this application AISI 1018 preferred to be used because it is, cheaper, available everywhere.

Table 3. 1 Frame Materials property

Mechanical property	AISI 1018	AISI 1020	AISI 4130	AISI 4340.
Density $(kg/m^3) \times 10^3$	7.8	7.7	7.85	7.85
Young's Modulus (GPa)	210	210	205	200
σ_{ut} (MPa)	400	394	670	1255
σ_y (MPa)	220	294	435	1165
Cost	Very cheap	Cheap	Expensive	Very expensive

3.7 Bench frame section

Generally, frame of a bench table made from the following section such as box and tubular section as shown in fig. 3.1.

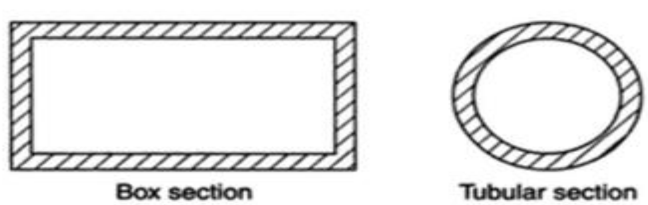


Figure 3.1 Type frame Sections

Box section used in short members of the frame and it has good resistance to bending and torsion. While tubular section is used in the frame which subjected to torsion. Therefore, box section is selected for this study [20].

3.8 Sheet materials

Materials used for cylinder, dust collector, and bench table top face cover have less structural requirements. Plastic material, it is a cheap material and easy to manufacture, but cannot be welded to the structure and do not provide any strength to the assembly. Fiberglass, it is a light material, but harder than plastic. It cannot be welded to the structure and it is more expensive than plastic or sheet metal. Sheet metal, it is cheap materials, provides desired strength and can be welded. However, it is heavier than plastic [19].

3.9 AC electric motor selection

An electric motor converts electrical energy into mechanical energy. A 0.5 HP AC motor is used in motor vehicle air filter cleaner bench. AC motor is an internally commutated electric motor designed to be run from a direct current power source. The base to select this motor are

1. The diameter of the Ac motor
2. The length of shaft
3. Accessibility
4. Much the motor with the environment(humidity, corrosion, temperature)

The AC motor and its installation detail are in table 3.2 and tabel 3.3 [31]

Figure 3.2 AC electric motor

Table 3.2 Overall installation data of AC motor [31]

Frame size	Mounting Dimensions(mm)											Over all dimension (mm)		
	A	B	C	D	E	F	H	K	R	S	T	AD	HD	L
2	160	112	63	19	40	6	100	12	0	M8	3	128	246	330
1	140	100	56	16	40	5	90	10	0	M8	3	121	220	286
09	125	100	50	14	30	4	80	10	0	M8	3	108	190	256

Table 3.3 Technical data of AC motor

Frame size	Model	Out put		Speed	Power factor	η Efficiency(%)	Max torque related torque	Starting torque rated torque
		(W)	(HP)	(r/min)				
2	JY2A-2	1100	1.5	2850	0.77	71	1.8-2	2-3.5
	JY2B-2	750	1	2850	0.75	70	1.8-2	2-3.5
	JY2A-4	750	1	1400	0.68	69	1.8-2	2-3.5
	JY2B-4	550	3/4	1400	0.68	67	1.8-2	2-3.5
1	JY1A-2	550	3/4	2800	0.72	66	1.8-2	2-3.5
	JY1B-2	370	1/2	2800	0.72	66	1.8-2	2-3.5
	JY1A-4	3370	1/2	1400	0.62	64	1.8-2	2-3.5
	JY1B-4	250	1/3	1400	0.62	60	1.8-2	2-3.5

3.10 Flow chart for design

The flow diagram shown below Figure 3.4, describes the method followed in the overall design and analysis motor vehicle air filter cleaner bench.

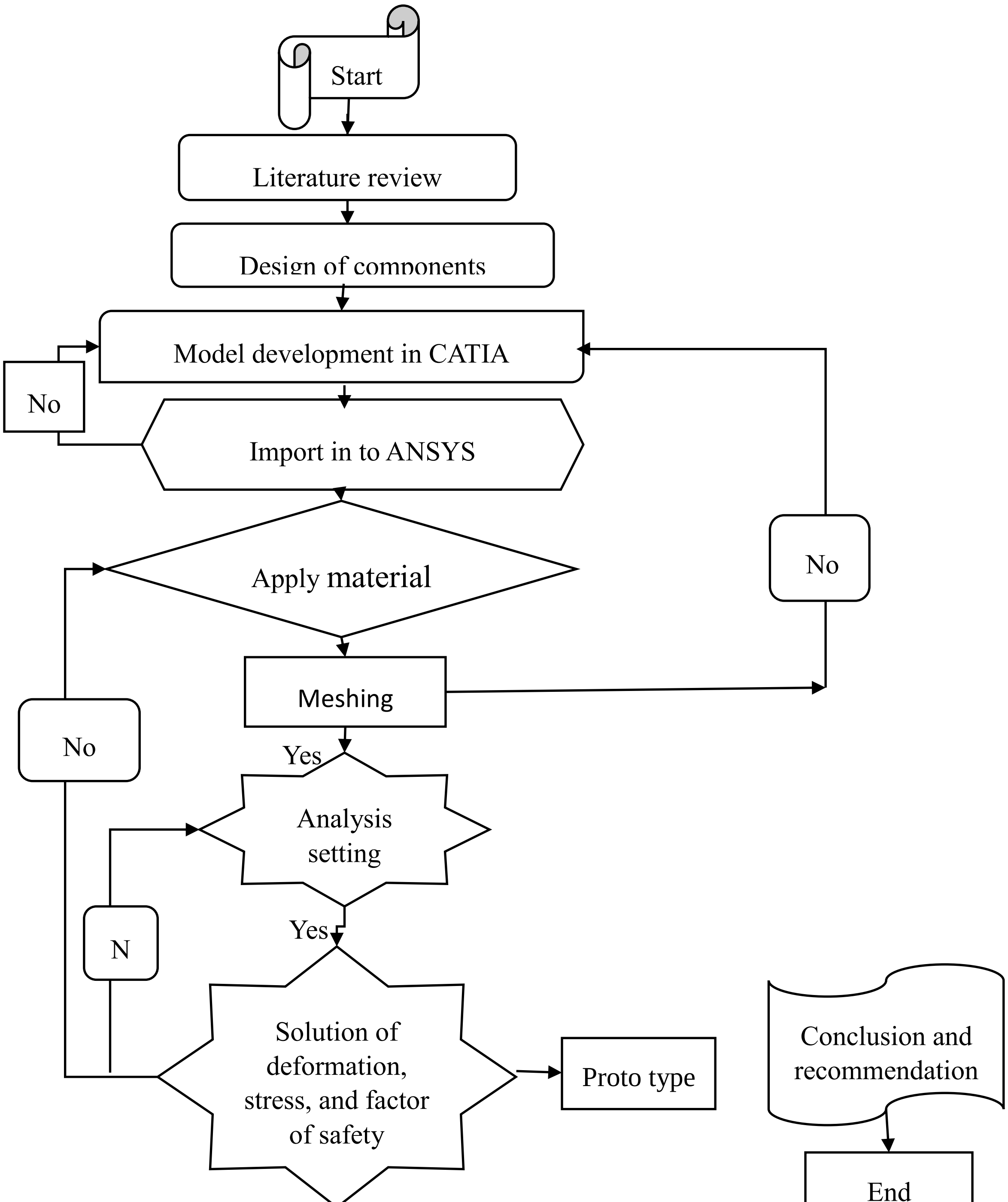


Figure 3.4 Flow chart

3.11 Air filter specification

Table 3.4 Truck air filter specification (Addis Ababa Anbessa Bus)

Parameter	Unit (mm)
Outer diameter	240
Inner diameter	130
Height	465
Small hole	20

Table 3.5 Light motor vehicle air filter specification (TOYOTA –Hilux air filter)

Parameter	Unit (mm)
Outer diameter	160
Inner diameter	110
Height	320
Small hole	20

CHAPTER FOUR: Design and Analysis

4.1 Cleaner bench frame

Cleaner bench frame is the main supporting structure to which all other components are attached. The components which attached are cylinder, AC motor, air filter etc. Therefore, the frame should be strong enough to withstand the force that will act on it but at the same time it should be as light in weight for easy access.

4.2. Bench frame design and geometry analysis

Motor vehicle air filter cleaner bench used by human being and major of its dimensions are conditioned by the morphology of the human body. So it is important to see what the standard dimensions of the human beings are, in order to design comfortable bench frame to any size of user. The other dimension determined from direct measurement of the motor vehicle air filter [21]. The figure 4.1 given below shows the human body dimensions considered in the designing of air filter cleaner bench.

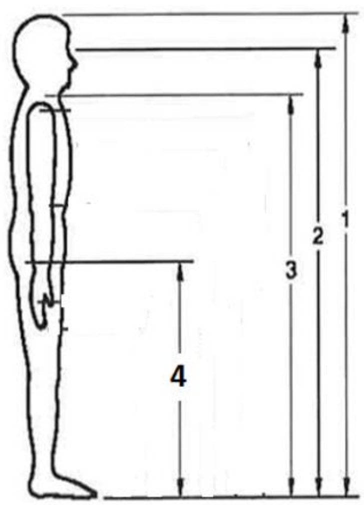


Figure 4.1 Human body parts dimension considered for cleaner bench design [21]

4.2.1 CAD Modeling of the bench table.

The CAD model of the air filter cleaner bench was developed based on anthropometrics and truck air filter sizes. The bench CAD models concepts was developed on CATIA V5 as shown in figure 4.2 and detail drawing of each parts is enclosed in appendix C. The box section of (25x25 mm with thickness 2 and 3mm) and 2 mm thick sheet metal has been used to develop following CAD models. The detail drawing is Appendix drawing number 1.

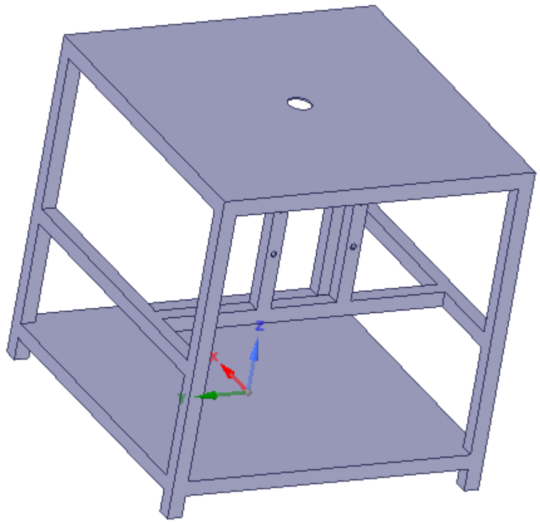


Figure 4.2 Air filter cleaner bench model

4.2.2 Cylinder geometry and CAD model

The cylinder main function in cleaner bench is to prevent dust diffusion in to working environment and safe guarding the technician from injury by any chance if air filter gets loosened during cleaning process.

The geometric major dimension of the cylinder was considered based on truck air filter size and considering certain space for displacing dust from around of air filter. The direct measured city bus or truck filter is 240mm diameter and 465 mm length. Keeping those parameter magnitudes and constraint in mind, 428mm diameter, 2mm thick and 528mm length cylinder were modeled in CATIA V5 as shown below in figure 4.3

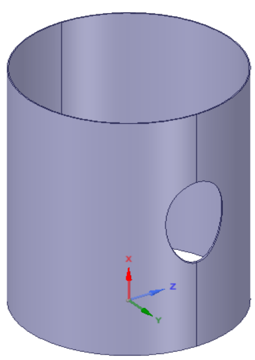


Figure 4.3 Cylinder model

4.2.3 Dust collector geometry and CAD model

The dust collector used to collect dust during cleaning air filter. In the collector there is oil which dissolves the dust into it.

The basic dimension of the dust collector considered on the basis of easy access and cleaning purpose.

The following CATIA model of dust collector was developed using 2mm thick, 465mm long, 165mm height, 226mm width and 25x25mm box section with 2 mm thick. For detail dimension of each parts see appendix C.

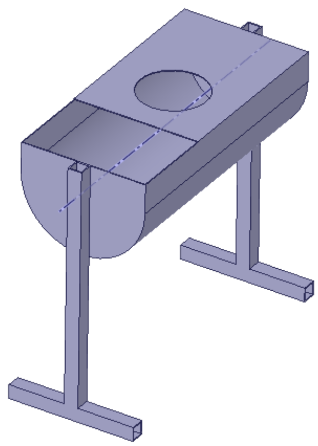


Figure 4.4 Dust collector model

4.2.4 Shaft geometry and CAD model

A shaft is a rotating member, usually of circular cross section, used to transmit power or motion [22]. But the main function of this project shaft is to secure air filter with AC motor shaft through flange and stud. This shaft also has hole on round to displace the air in the longitudinal direction of the air filter during cleaning.

The main geometrically dimension determined from large or truck air filter size, i.e. 428mm length, 35mm and 25mm outer and inner diameter respectively. The no of holes are 4 with the difference of 50mm and the diameter of each hole is 6mm and the total no of holes are 32.

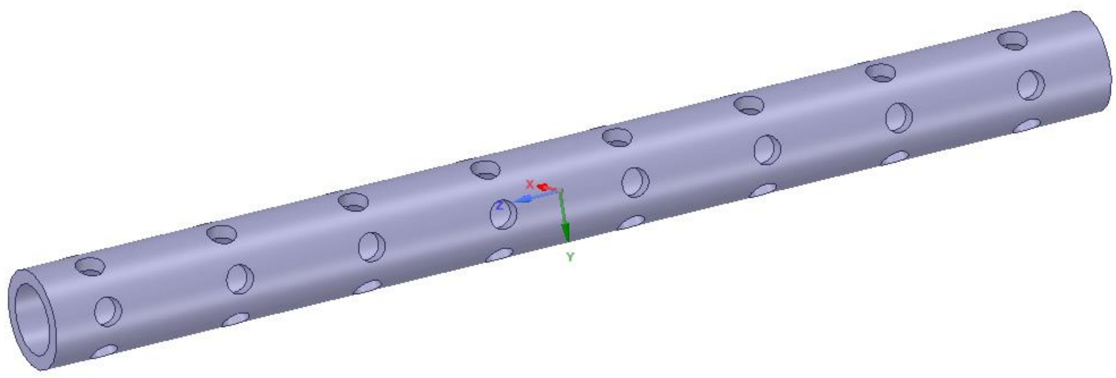


Figure 4.5 Cleaner bench Shaft

4.2.5 Intermediate coupling shaft design

The intermediate coupling shaft is hollow at AC motor shaft assembly side and solid at bench shaft assembly side which is used to connect and transmit power from electric motor shaft to air clean bench shaft. This shaft has concave face at solid side, to direct air into outer direction. Intermediate coupling shaft connects both shafts by using four round head screw. This intermediate coupling shaft made from mild steel because this metal is cheaper, available and has sufficient strength.

The geometrical size of the intermediate coupling shaft determined from inner diameter of cleaner shaft and outer diameter and extension length of AC motor shaft.

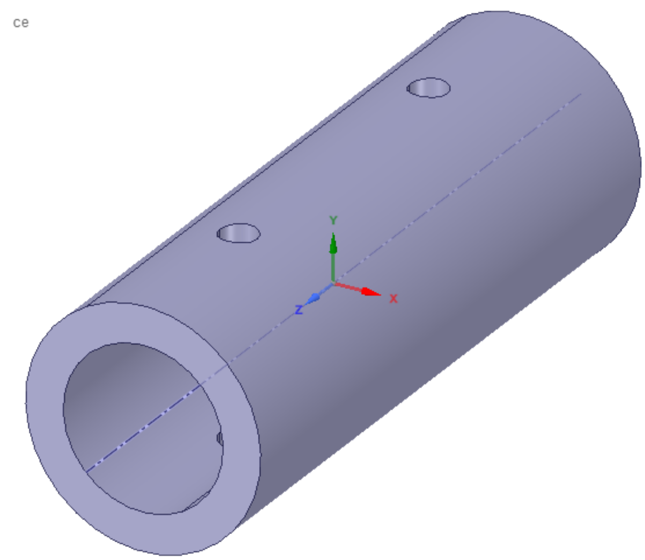


Figure 4.6 Intermediate coupling shaft

4.2.6 Cylinder cover design

The cylinder door is made from steel sheet. Its major geometric dimension considered from cylinder size. The cylinder door assembled to cylinder by two 6 mm diameter pin. The main purpose of the cylinder door to prevent dust diffusion from working environment.

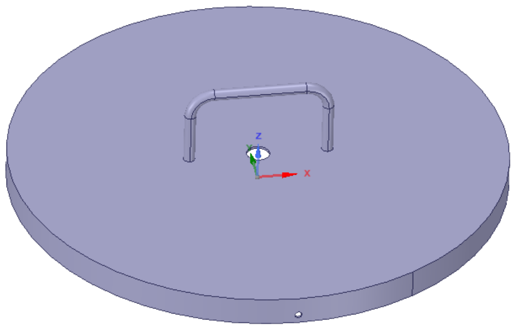
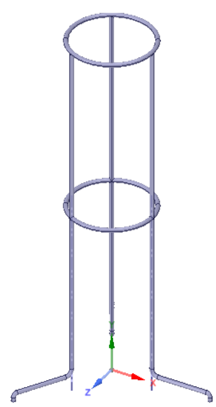


Figure 4.7 Cylinder cover

4.2.7 Support rail

Support rail which made from 6mm diameter steel wire based on basic air filters sizes. The prurpose of support rail is to hold air filter statetionary inside of the cylinder during cleaning process. That means if we put air filter inside the cylinder without support rail when the pressized air blow in to it air filter may not be stable, it can collide with shaft may cause possibly damege on the air filter and cealing bench shaft and aslo can make noise which not pleasant for working enviroment. So, support rail can eliminate those side effects and helps to clean air filter effictively and pleasant manner.



Figures, 4.8 Support rail CATIA model

4.2.8 Ball bearing selection

A bearing is a machine element which supports another moving machine element. It permits a relative motion between the contact surfaces of the members, while carrying the load. A little consideration will show that due to the relative motion between the contact surfaces, a certain amount of power is wasted in overcoming frictional resistance and if the rubbing surfaces are in direct contact, there will be rapid wear. In order to reduce frictional resistance and wear and in some cases to carry away the heat generated, a layer of fluid (known as lubricant) may be provided [23, 24].

This project bearing does not carry any loads, it used to support the shaft in order to prevent vibration. The vibration cased in proto type test due to length of shaft. To eliminate the shaft vibration, the bearing installed on the top table cover sheet from bottom side. For this project work per lubricated and sailed radial ball bearing had been selected.

Table 4.1 Radial ball bearing specifactions [25]

Bore (d) mm	Bearing no.	OD (D) (mm)	Width W (mm)	Basic load rating (N)	
				Dynamic	Static
25	6005	47	12	2260	1320

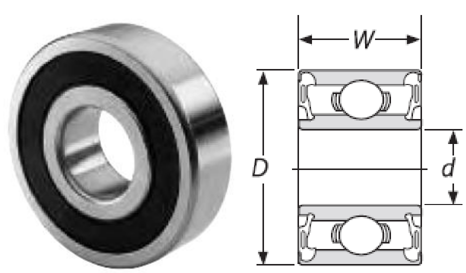


Figure 4. 9 Radial ball bearings [25]

4.2.9 Round head screw selection

A screw thread is formed by cutting a continuous helical groove on a cylindrical surface. A screwed joint is mainly composed of two elements *i.e.* a bolt and nut. The screwed joints are widely used where the machine parts are required to be readily connected or disconnected without damage to the machine or the fastening. This may be for the purpose of holding or adjustment in assembly or service inspection, repair, or replacement or it may be for the manufacturing or assembly reasons. For this project 6 mm round head screw had been selected for assembling of bench shaft, intermediate coupling shaft and AC motor together.

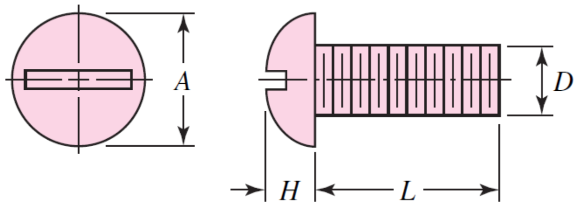


Figure 4.10 Round head screw

4.3 Assembly of air filter cleaner bench

Air filter cleaner bench has many parts. The parts are assembled using different joint methods, like welding and bolting for easier assemble disassembly and cleaning bench itself.

The bench table frame tubes, top and bottom sheets metal, cylinder and dust collector joined by weld. While AC motor, AC motor shaft, cleaner shaft and intermediate hollow shaft assembled with bench table by threaded joint or blot and screw.

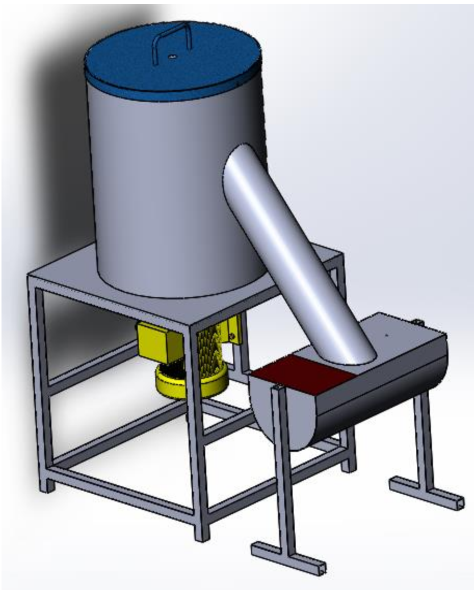


Figure 4.11 Assembled model of air filter cleaner model

4.4 Working principle

Before start up AC motor put air filter on support rail then close cylinder door and lock it by two small pins. Next connect compressed air hose with cylinder door hose and turn on compressed air valve to allow pressurized air to enter into hollow holed shaft and then start up AC motor to rotate radially holed shaft. The radial holes on the shaft help to displace pressurized air over internal face of the air filter in order to push out dust and any unnecessary dirty particles.

When the operator switch ON the AC motor, the shaft starts rotating and also hollow shaft rotates because the shaft is assembled to motor shaft by intermediate coupling hollow shaft. After compressed air is blown against internal face of air filter, this compressed air pass through from air passage by removing dust from air filter cell. Then, the dust come out from air filter cell and goes to the dust collector through the passage provided. Inside the dust collector there is the oil used to absorb the dust into it.

4.5 Finite element analysis of cleaner bench

Finite element analysis is important to do a numerical simulation in order to find out how cleaner bench frame and its components react to application of the load. In order to perform finite element analysis, FEA modeling process requires three types of input data such as geometry, material properties, and loading. After modeling the analysis of frame is done in ANSYS 18.1 workbench, for that purpose frame model preparing the in CATIA then it is imported to ANSYS workbench, the file is imported from CATIA by file>import>IGS. To carry out the analysis static structural finite element had been utilized based on application of load.

4.5.1 Finite element analysis of cleaner bench

A. Frame model

CAD model of air filter cleaner bench has been prepared in CATIA V5 as shown below in figure 4.10.

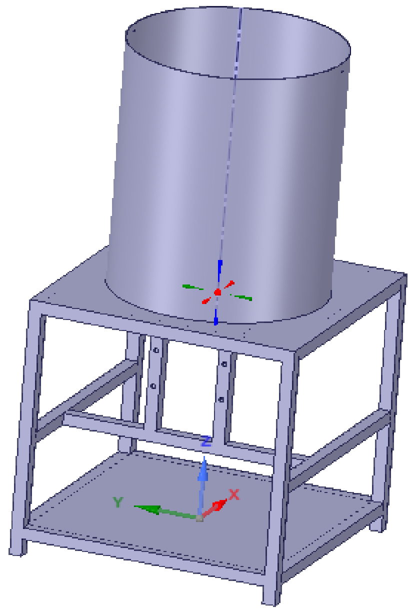


Figure 4.12 Air filter cleaner bench table model

B. Material

Material for the bench already had been selected in section 3.3 that is AISI 1018 carbon steel and its mechanical properties are given in table 3.1

C. Mesh

Meshing is one of the most important step of the finite element analysis (FEA). The model of cleaner bench meshed to coarse mesh which is 36309 nodes and 20038 elements. However, from coarse mesh we cannot get better stress results. To get better or more accurate result we can use either check error plot or check result convergence method. Because as mesh density increases the stress also increase that means result accuracy is increased. Therefore, as we increase the mesh, the result should converge to a single value.

For this work convergence method had been applied, because it is easier to control on ANSYS design modular by setting error percentage close to zero, which means we can obtain error zero result. In this method, ANSYS software automatically identify critical stress area on the model, then it refines the mesh density in to high number, in order to get more accurate results.

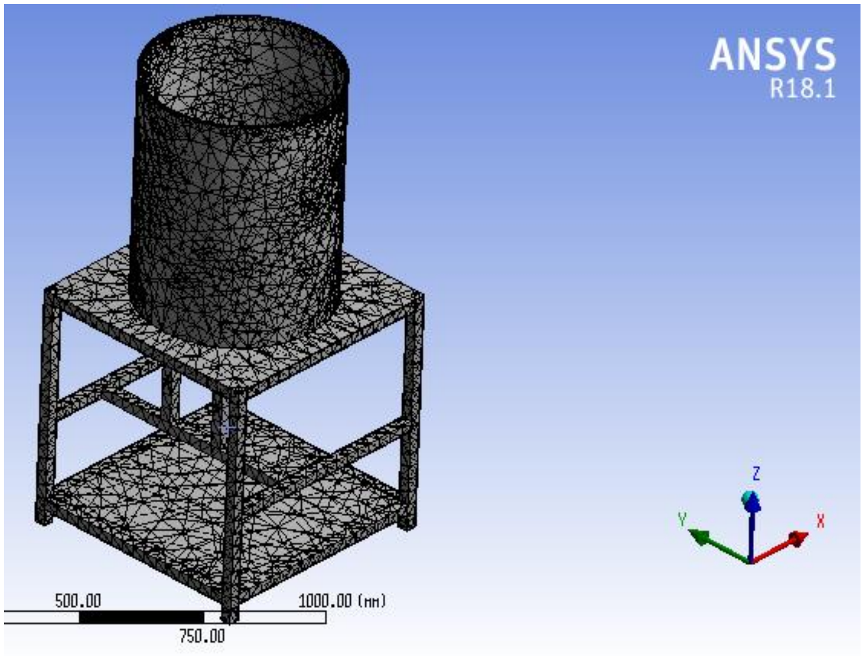


Figure 4.13 Meshed model of the cleaner bench table

D. Boundary and loading conditions

Finally, the externally acting loads must be specified in terms of magnitude, direction, and point of application on the cleaner bench table. Loading information is derived from analytical. This information is then used to specify forces acting at endpoints (nodes) of key elements the cylinder inner face subjected to 0.3MPa pressure, AC motor support middle tube assembly subjected to10kg mass of AC motor and 147.2 N force also applied to the AC mount tube due to pressure and the legs of the table are fixed at bottom . It is shown in figure 4.12

$$F = \frac{\pi}{4} {d_{inner}}^{2} \times P \text{ or } \frac{\pi}{4} \times 0.025m^2 \times 0.3 \times 10^6 = 147.2N$$

For design purpose the maximum loading scenario was considered in order to justify the designed parts are safe or not. For this project the maximum loading scenario was considered that is 0.3Mpa pressure applied to the bench cylinder just in case. And the AC motors mount also subject to load of AC motor weight and load due cleaning air pressure through shaft which is calculated above.

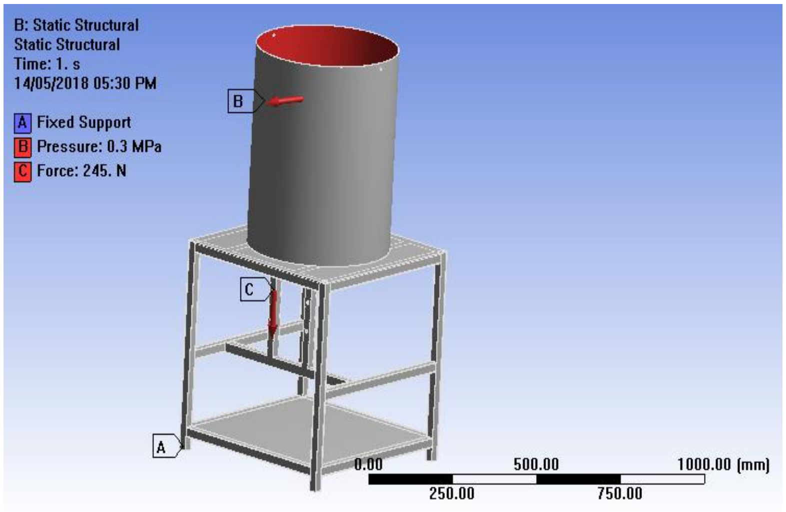


Figure 4.14 Cleaner table boundary and loading condition.

E. Result

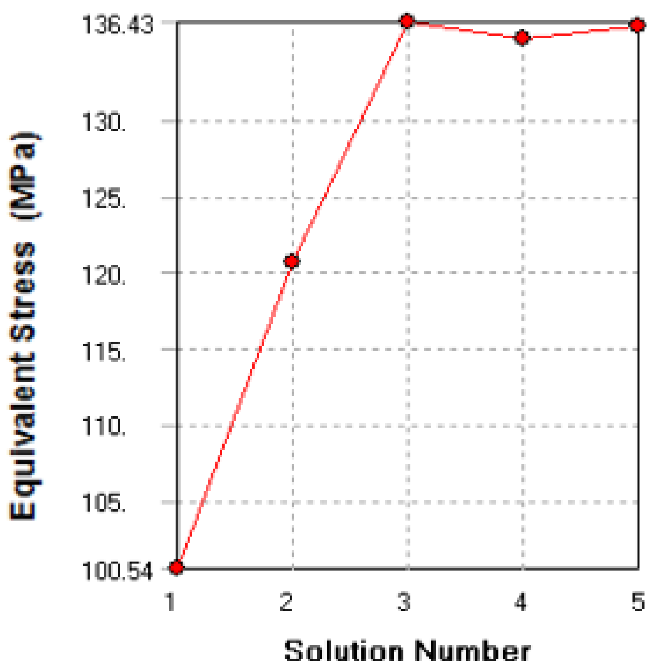


Figure 4.15 Convergence graph of Air filter cleaner bench table model

Table 4.1 Stress variation as density of cleaner bench table mesh increase

	Equivalent Stress (MPa)	Change (%)	Nodes	Elements
1	100.54		39822	20047
2	120.72	18.241	120893	68644
3	136.43	12.215	161754	89954
4	135.37	-0.77658	322728	197816
5	136.14	0.56609	892264	595833

The above table 4.1 shows the convergence result from 20% error to 0% error, the 100.54 Mpa obtained for 20% error. The rest of the value of 5%, 3%, 1% and 0% error. As we can see from above plot figure 4.15 and table 4.1 the stress value is converged to maximum stress of 136MPa.

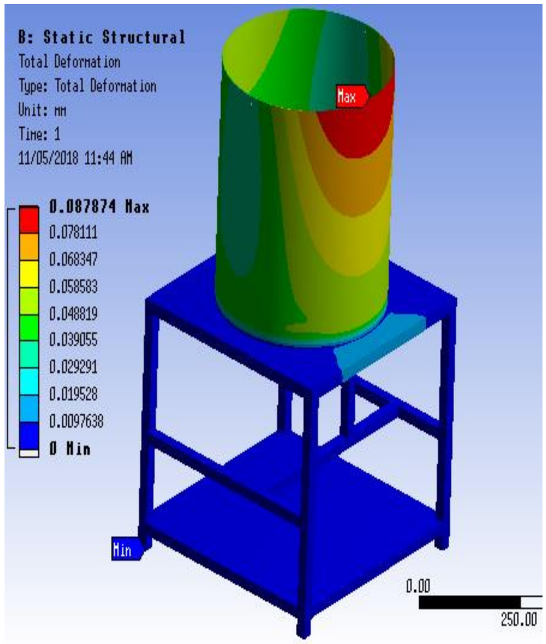
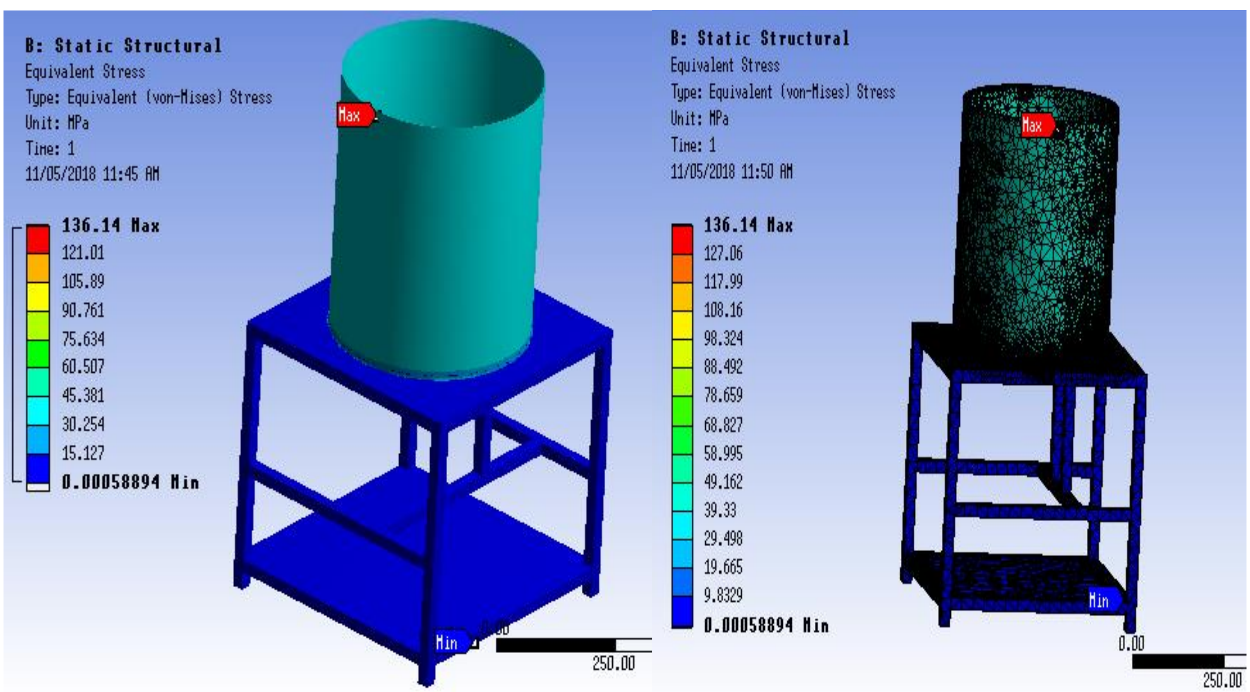


Figure 4.16 Total deformation of the cleaner bench table



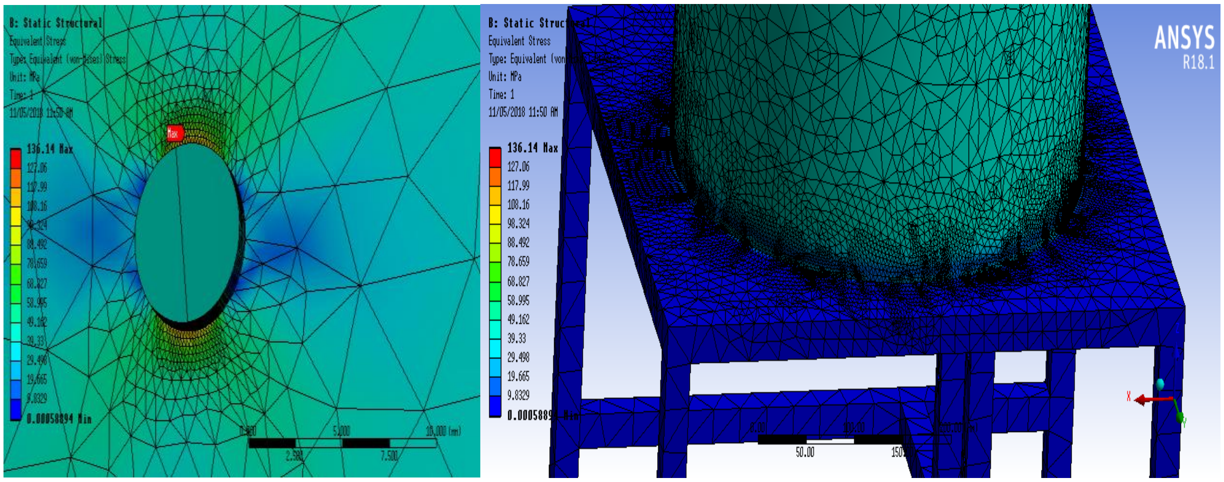


Figure 4.17 Von-mises stress result of the cleaner bench

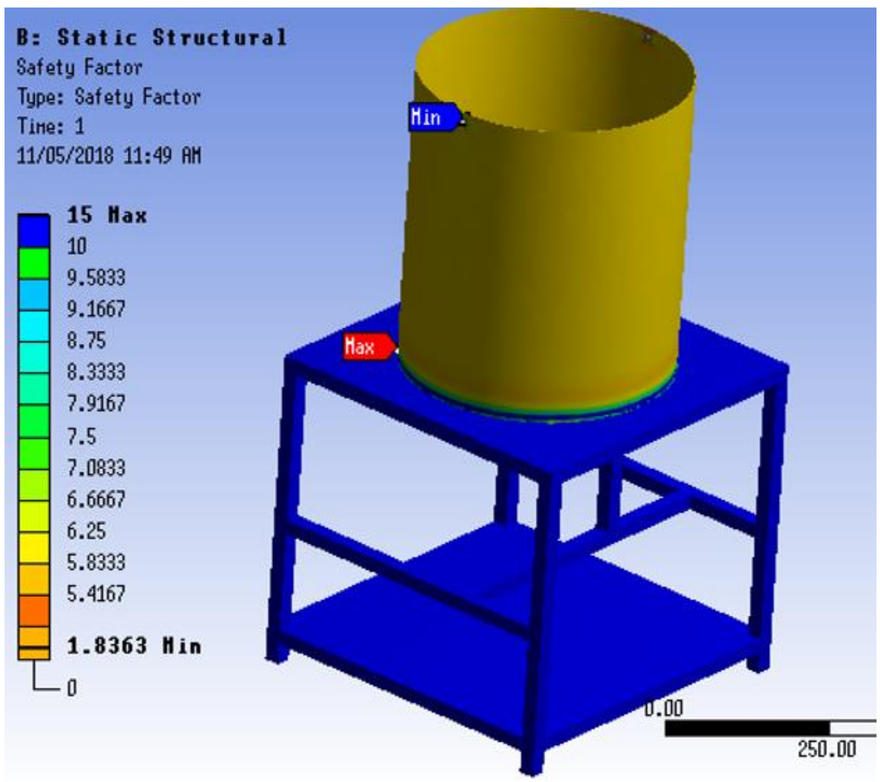


Figure 4.18 Factor of safety result of the cleaner bench table

4.5.2 Cleaner bench table result and discussion

As seen in figure 4.12-14 in section 4.5.1 Static structural analysis of FE for cleaner bench table was done using ANSYS workbench 18.1 for down ward load condition. From this analysis the result of total deformation, von-mises stress and factor of safety obtained and tabulated in table 4.2 given below.

The colored contour of each parameter indicates intensity of simulation parameter magnitude, red color for maximum value.

Table 4.2 Simulation result of the air filter cleaner bench table

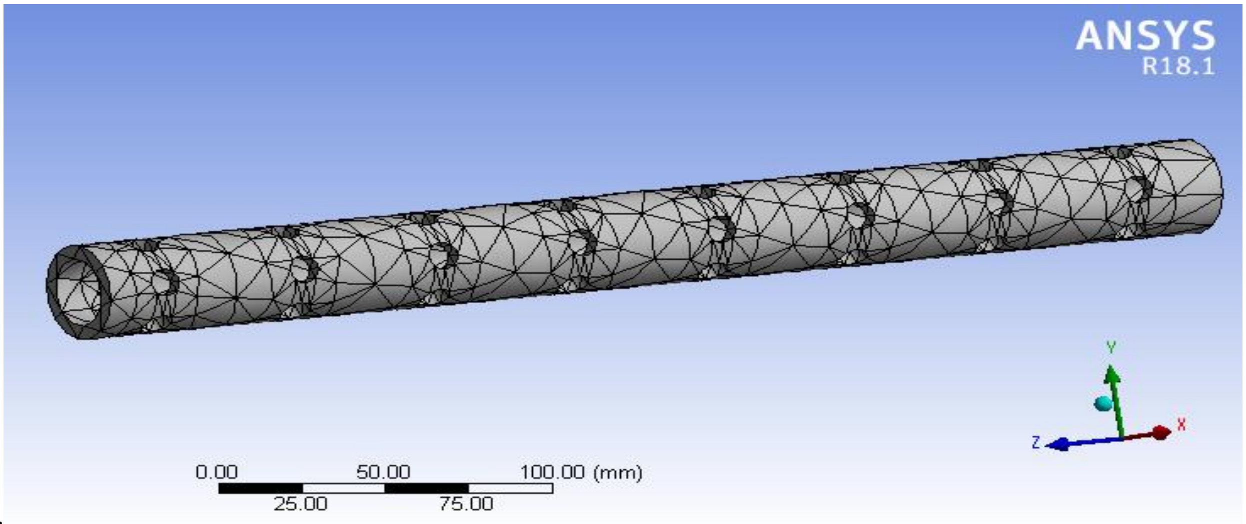
Result	Maximum	Minimum
Total deformation (mm)	0.087	0
von mesis stress (MPa)	136.14	0
Factor of safety	15	1.836

The total deformation obtained from FEA for cleaner bench table with the application of load is 0.087mm on cylinder cover free end. This value indicates the cylinder is stiff to applied load. This maximum deformation occurred at the free end of the cover because the other side is fixed to bench table top sheet metal through welding this give extra strength, this means that side is stiffer than free end. Also, von mesis stress of magnitude of 136.14 MPa obtained on cylinder cover lock hole that due to pressurized air which is less than yield strength of cylinder material. And the minimum factor of safety is 1.836 which means the cylinder is safe. This factor of safety value should not make us concerned because the pressure not directly applied and the cylinder is not closed, that value is practically feasible.

4.5.3 Finite element analysis of the shaft

A. Mesh

The shaft model divided into finite pieces that is 6987 nodes and 3188 elements using default global mesh control. But the accuracy of result increase with refinement of an adjacent mesh. That means as mesh density increases, the result should be more accurate. Therefore, as increase the mesh, the result should converge to a single value.



.

Figure 4.19 Meshed model of the shaft.

B. Material for shaft

The same material used to shaft also that is AISI 1018.

C. Boundary and loading conditions

The load that applied to shaft are AC motor torque (50Nm) and compressed air of pressure 0.2 to 0.3MPa applied to internal face of the shaft. Other face of the shaft is fixed.

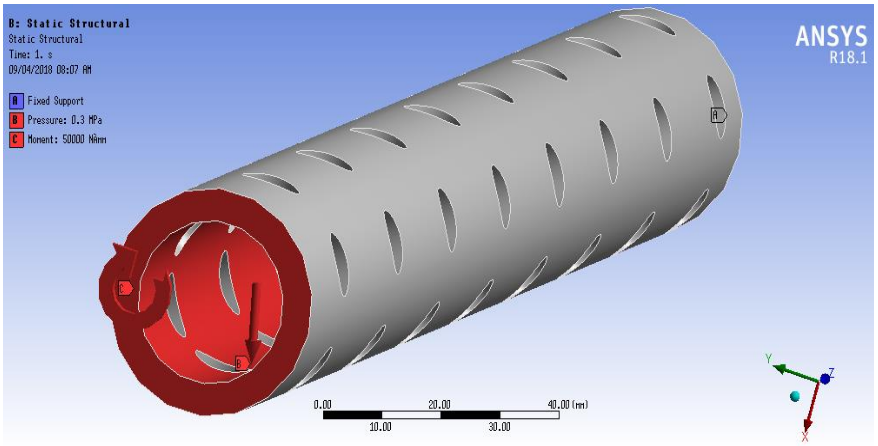


Figure 4.20 Boundary and loading conditions of the shaft

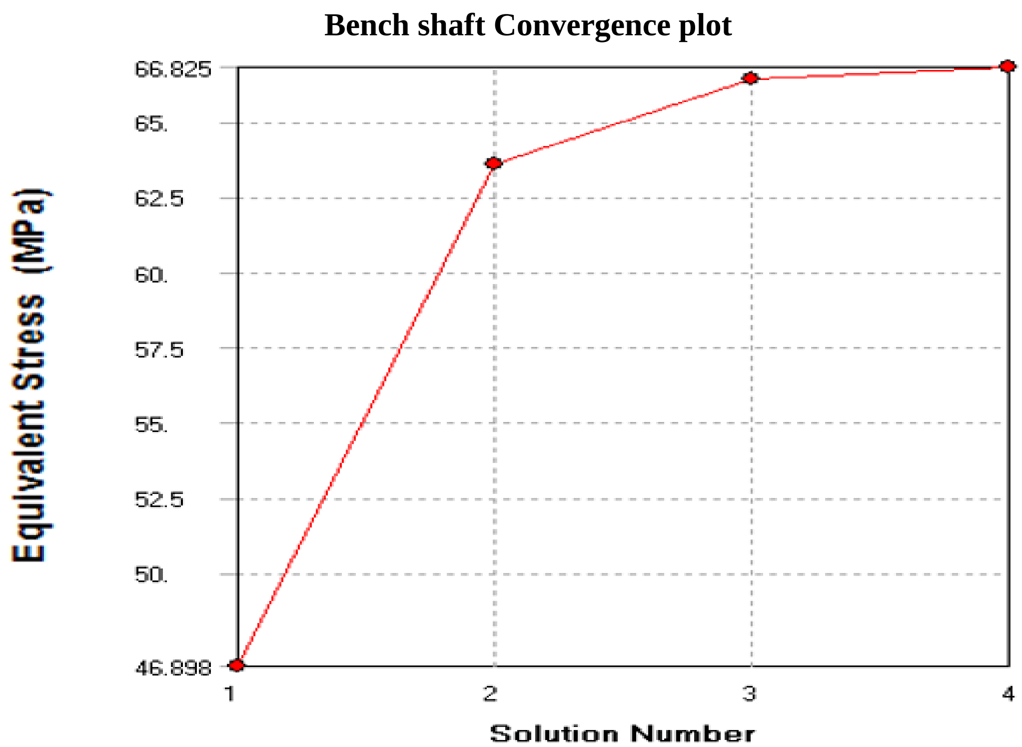


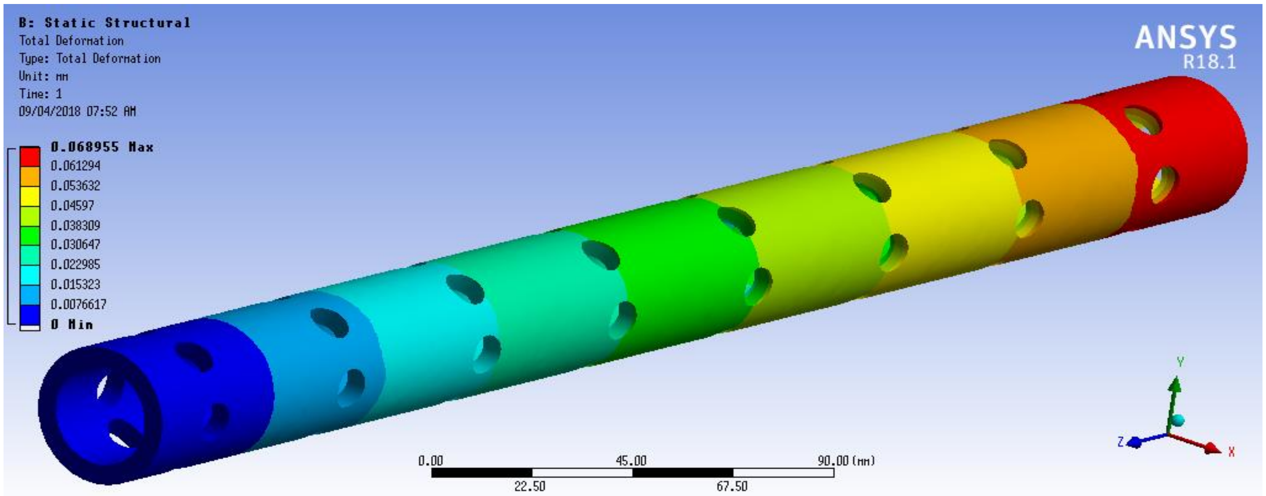
Figure 4.21 Stress change as adjacent mesh increases

Table 4.3 Stress variation as density of shaft mesh increase

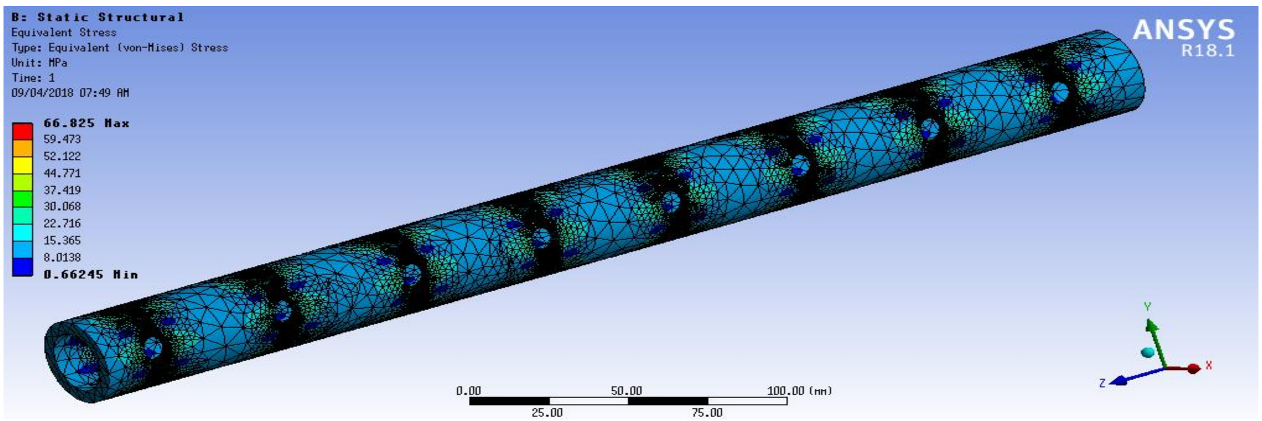
	Equivalent Stress (MPa)	Change (%)	Nodes	Elements
1	46.898		6987	3188
2	63.583	30.204	47209	27212
3	66.441	4.3964	269617	175430
4	66.825	0.57532	854860	580648

As we can see in the graph and table 4.3 the stress value increases linearly until 63.583 Mpa with more mesh refinement, after this value stress change is not more with further mesh changes which means the stress result converges to single value. The maximum stress that is 66.825 MPa obtained at 854860 nodes and 580648 elements. Refining beyond this mesh, the result change is not that much.

D. Deformation and factor safety

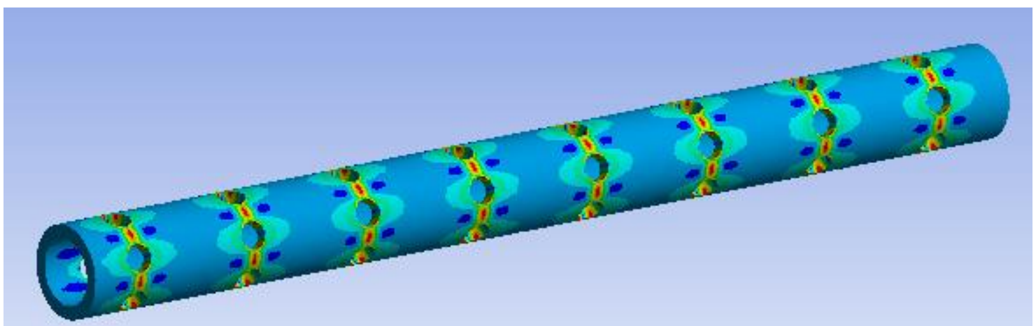


(a) Figure 4.23 Total deformation of the shaft

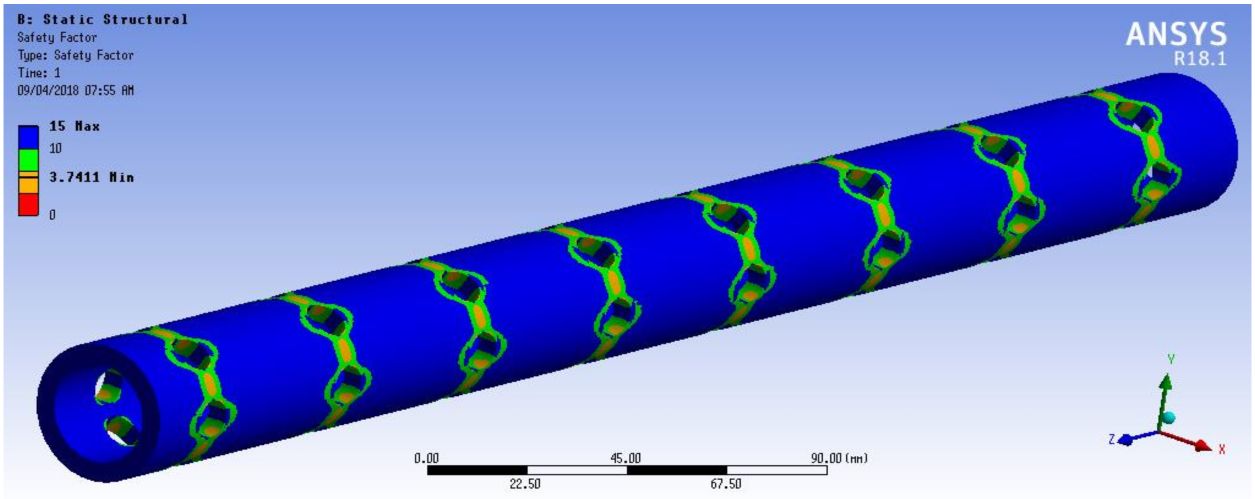


(b0

(b) Figure 4.24 Von-mises stress with high mesh refinement of the shaft



c) Figure 4.23 Von-mises stress with high mesh refinement of the shaft



(C)Figure 4.24 Factor of safety of the shaft

4.5.4 Discussion

As seen in figure 4.18-20 in section 4.5.3 static structural analysis of FE for cleaner bench shaft done on ANSYS workbench 18.1 for heavy operational condition. From this analysis the result of total deformation, equivalent (von-mises) stress and factor of safety obtained and tabulated below in table 4.5.

Table 4. 5 Clear bench shaft simulation result

Result	Maximum	Minimum
Total deformation (mm)	0.0689	0
Equivalent Stress(Von-Mises Stress) (MPa)	66.825	0.66
Factor of safety	15	3.76

After applying boundary condition, the file is imported to the solver. ANSYS is used as solver here for the analysis. Finally, the post-process is done. The location of maximum Von Mises stress and minimum factor of safety are on the air blowing hole. The maximum Von-mises stress is about 66.825 MPa and the maximum deflection is about 0.0689 mm. The obtained total deformation value is minimum which indicates, it is stiff to applied load and minimum factor of safety is 3.74 which is safe and practically feasible.

CHAPTER FIVE

PROTOTYPE FABRICATION AND TEST

5.1 Fabrication of prototype

The prepared CATIA models of various parts of the air filter cleaner are used for fabrication of the prototype.

. The square tube that is 25 X 25 mm of AISI 1018 steel was used for frame and 2 mm thick sheet metal was used for cylinder, covers and dust collector. To cut those parts to design dimension, grinder, hacksaw, shear cuter were used. To join these parts, basic Arc welding process was used. After completing the fabrication of the bench frame and cover sheet the AC motor and bench shaft are assembled to it by threaded joint.
For the purpose of the assembling of AC motor and bench shaft, M10 bolt and M6 round head screw were used. Figure 5.1 shows complete fabricated model of prototype cleaner bench.

Figure 5.1 Fabrication of prototype of air filter cleaner bench.

5.2 Testing the prototype

To perform the test TOYOTA –Hilux air filter model number 178101 and analytical balance was used. Analytical balance was used to determine the weight of dirty particles in gram. The test was conducted in steps of 1 minute each. The procedure followed during the test is as follows.

1. Measure dirty air filter
2. Open cylinder covers by removing two pins.
3. Put air filter on support rail
4. Close cylinder cover and secure by two pins
5. Connect compressed air hose with compressor hose
6. Open the air valve.
7. Connect AC motor with electric line and turn ON motor start switch.


a,


Figure 5.2 (a) Measuring dirty TOYOTA –Hilux air filter, (b) Testing

5.3 Result and discussion

a) Test

The cleaning test done five times, each test long for one minute. The test frequency used to determine dirty particle removal rate and to justify complete cleaning time. The test data shown in table 5.1

Table 5.1 Measured data

No	Time in second	Mass of the filter in gram	Remark
1.	0	985.8	Before cleaning
2.	60	985.5	
3.	120	985.3	
4.	180	985.0	
5.	240	985.0	After cleaned

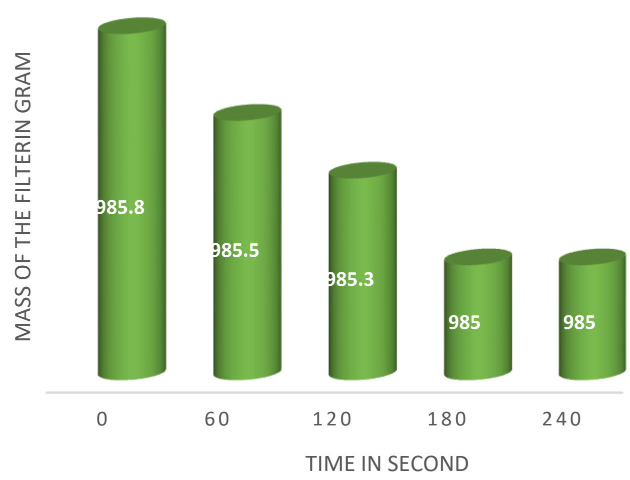


Figure 5.3 Cleaning test plot

The above plot shows the difference in mass of air filter on each minute (or 60 second) that difference on mass indicates the dirty particles removal. As we can see on the plot the difference in mass continued until 180 second, testing beyond this there is no difference in mass, the result merges to single. Which means, that the final value is the mass of air filter cleaned completely. So the time required for cleaning air filter using newly developed air filter cleaner system is only four minutes.

b) Manual cleaning

The manual air filter cleaning procedure starts with the technician holding air filter with one hand and blow compressed air into it with other hand. In this way manual air filter cleaning was performed. For cleaning all parts of air filter it required certain time. Therefore, for manual test five-minutes interval was used. Table 5.2 shows manual test result lasting for twenty minutes.

Figure 5.4 Manual cleaning method how stress full

Table 5.2 Manual test result

Test no.	Time in second	Mass of the filter in gram	Remark
1.	0	985.8	Before cleaning
2.	300	985.5	
3.	600	985.3	
4.	900	985.1	
5.	1200	985.0	After cleaned

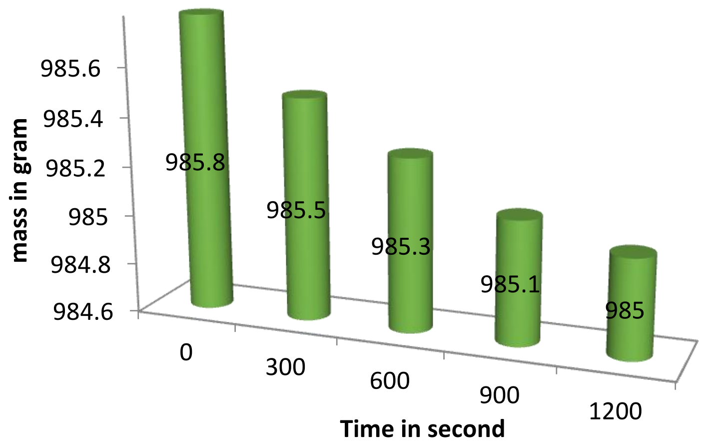


Figure 5.5 Manual test result plot

The above plot figure 5.5 shows the manual air filter cleaning test, which indicates the change in the mass of air filter with test time interval. The mass change or mass reduction of the air filter is due to the removal of dirty particles. The total time required to remove all dirty particles was 20 minute.

5.4 Comparison of new bench and manual test results

Table 5.3 Comparison of new clear bench and manual test results

R. no.	Manual	New clear bench
1	Took 20 minutes to clean	Only took four minutes
2	The weight of the filter stressed the hand of the technician	Technician doesn’t carry air filter
3	Open cleaning method, can cause pollution	Closed cleaning mothed no pollution
4	Not Comfortable and pleasant to technician	Comfortable and pleasant to cleaner

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Summary

The purpose of this thesis is to design automotive air filter cleaner. The automotive air filter cleaner was designed to remove dust, other unnecessary particles from automobile air filter in most efficient manner. That means cleaning process proceed inside the cylinder to prevent the dust from displacing to work environment and for safety manner. This new automobile air filter cleaner cleaning method is different from manual cleaning method with above stated advantage. In new air filter cleaning process carried out inside the cylinder. The cleaning procedure is, first place support rail in the cylinder, next put air filter on it, then cover the cylinder and place compressed air hose on the provided hole on the cylinder cover. Finally, be sure cover and cylinder as secured by two small pin, next turn on air valve and the AC motor. AC motor rotate radial holed shaft to distribute air over inside face of air filter. This cleaning method completely closed which is safe and maintain clean working environment. While in manual cleaning method the technician holds air filter by one hand and blow compressed air over air filter. This cleaning method is open which allow dust to displaced to working environment.

The design of the cleaner bench carried on the principle of the ergonomics in order to design comfortable efficient product. The cleaner bench table frame, cylinder, dust collector, shaft and support rail were designed on the basis of anthropometrics and analysis. Those design parts are modeled in CATIA V5 by using tube of 25x25mm and 2 or 3mm thickness, 2mm sheet metal. The other parts of this project cleaner bench are selected from standards. That is AC motor, bolts, round head screws, bearing and hose were selected from standards.

After the parts designed and modeled the finite element analysis was done using ANSYS workbench in order to find out how the cleaner bench parts react for operation loads.

From the results of FEA, it is apparent that the stresses induced in the components least and the factor of safety is also well above the limit. Also the Von Mises stresses are less than ultimate strength for the material. Thus the design of cleaner bench components is durable. The use of ANSYS software makes the process of calculation fast and several iterations are permissible to arrive at the best possible results.

After analysis and 3D and 2D drawing developed, the prototype of air filter was fabricated and tested. The test result shows it takes only four minutes to clean (or remove all dirty particles) TOYOTA –Hilux air filter.

6.2. Recommendation

It is recommended that, garages, researcher to invest their money and knowledge on the sector of automobile air filter cleaner, in order to reduce cleaning delay time, make working environment clean, dust and pollution free.

6.3. Future works

- ✓ This thesis covered only designing of air filter cleaner for cleaning circular air filters. But there are some models of light duty vehicle fitted with non-circular air filter. So there is a need to design air filter cleaner bench for cleaning non circular air filters as well.
- ✓ If automatic clamping mechanism is used, it can improve safety and cleaning time.
- ✓ Air filter cleaner bench which holds more than one filter at a time, is to be developed to increase the productivity.

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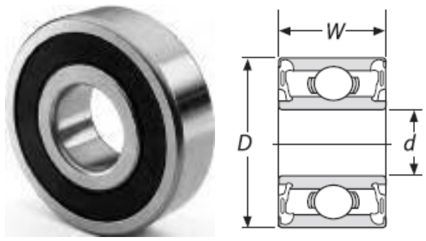
Appendix A: Radial ball bearing specification

RADIAL BALL BEARINGS

6000 SERIES EXTRA LIGHT DUTY – METRIC



Bore mm d	OD mm D	Width mm W	Bearing Number	Basic Load Rating Pounds Dynamic	Static	Speed Rating Grease RPM	Oil RPM	Weight (lb)
10	26	8	**6000**	1030	440	29000	34000	0.042
12	28	8	**6001**	1150	540	26000	30000	0.050
15	32	9	**6002**	1260	640	15000	28000	0.070
17	35	10	**6003**	1350	730	13000	26000	0.090
20	42	12	**6004**	2110	1140	18000	21000	0.150
25	47	12	**6005**	2260	1320	15000	18000	0.180
30	55	13	**6006**	2970	1860	13000	15000	0.260
35	62	14	**6007**	3600	2310	12000	14000	0.340
40	68	15	**6008**	3750	2590	10000	12000	0.420
45	75	16	**6009**	4720	3400	9000	11000	0.520
50	80	16	**6010**	4900	3700	8400	9800	0.570
55	90	18	**6011**	6350	4850	7700	9000	0.850
60	95	18	**6012**	6600	5200	7000	8300	0.915
65	100	18	**6013**	6850	5850	6500	7700	0.930
70	110	20	**6014**	8550	6950	6100	7100	1.330
75	115	20	**6015**	8890	7550	5700	6700	1.430
80	125	22	**6016**	10700	8950	5300	6200	1.880
85	130	22	**6017**	11100	9700	5000	5900	1.960
90	140	24	**6018**	13100	11200	4750	5600	2.560

Appendix B: Detail and assembly drawing of air filter cleaner bench