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Design & Development of Viscous Fluid Tank of Dispensing Machine for Automotive Applications

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Abstract

Viscous Fluid like Adhesive and Additives has widespread applications in many industries including automotive, aerospace, ship building manufacturing. The goal of Cylindrical Tank analysis is to first study static and modal analysis of viscous fluid empty and full filled Cylindrical tank to improve the tank design to reduce noise levels, stresses on the structure and optimize the arrangements of Dispensing Machine. Dispensing Machine used in a Viscous Fluid mixing to provide accurate blend ratios in producing the desired end-use product for automotive applications.
The focus of the present paper is on the design & development of viscous fluid tank. Finite element analysis method is used to investigate the Natural Frequency and Total Deformation of viscous fluid in empty & full filled Cylindrical tanks undergoing base excitation. Study & compare the Results of Finite Element Analysis with the material properties. A finite element analysis method has been used to analyze this complex event. The study is done with the help of finite element model of tank-fluid system using ANSYS software.
Keywords: *Finite Element Analysis, ANSYS, Viscous Fluid, Cylindrical Tank, Dispensing Machine*

Introduction

Increasingly, high-performance adhesives are being used in the automotive industry to join disparate parts. Adhesive products are used to create a bond between two different or similar materials. Adhesives are made from precise blends of resins, synthetic rubber elastomers, and agents or additives used to enhance certain characteristics, depending on the end use. Adhesives find several applications in an automobile. Adhesives are used to assemble metal, glass, plastics, rubber, and a variety of other materials during the manufacture of automobiles. Adhesive bonding is increasingly replacing conventional joining techniques such as welding, riveting or bolting. Adhesive bonding renders the vehicles lighter, quieter, more durable and safer. This not only increases safety but also simplifies many production operations, thus enhancing cost efficiency. Another important advantage of adhesives is the relatively high speed with which they can be applied on the production line. As a result, savings can be realised in set-up and processing time and volume of material processed.

Innovative adhesive technologies that address a multitude of issues ranging from cost saving to durability to efficiency to environmental compliance. Compared to traditional manufacturing methods, adhesives offer greater flexibility to the production process of automobiles and automotive sub-components. This is a very important factor driving adhesive consumption in the automotive industry. So to achieve the above requirement a dispensing machine is required. Dispensing system used to provide accurate blend ratios in producing the desired end-use product for automotive applications. Control of fluid, mixing ratio, the size and volume of the shot are main advantages of dispensing machine where it is applied. Adhesive dispensing equipment is easily adapted to changes in the sub-component design, making the use of the technology very attractive to the car industry, as vehicle manufacturers continue to accelerate the pace of change in automotive design.

Design Criteria for Dispensing Machine:

Following fig. shows setup of Dispensing Machine for Various Automotive Applications.

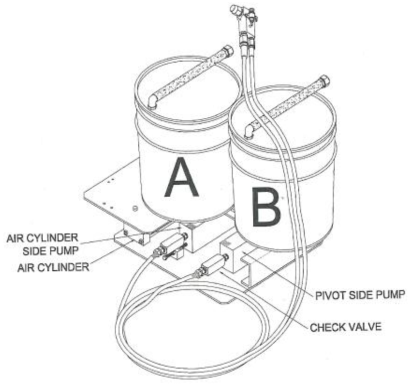


Fig. Set of Dispensing Machine

Filling Criteria for designing the Reservoirs/Tanks:

1. Place the material A in the reservoir A located on the left side of the machine. The left Tank should be designed in such a way that it can withstand the Weight of Viscous Fluid inside the tank, Pouring Pressure and working pressure inside the tank. Finite Element Stress analysis will predict the safe stress limit of the tank designed.

2. Place Material B in reservoir B located on the right side of the machine. The right Tank Should be designed in such a way that it can withstand the Weight of Viscous Fluid inside the tank, Pouring Pressure and working pressure inside the tank. Finite Element Stress analysis will predict the safe stress limit of the tank designed.

3. Sloshing Phenomenon should be evaluated for both the tank to find out the Resonance Characteristic of completely filled and partially filled tank. This can be predicted using the CFD ANSYS-FLUENT Software. All above three analysis will decide the Size of the Tank (Height, Weight, Volume and Thickness).

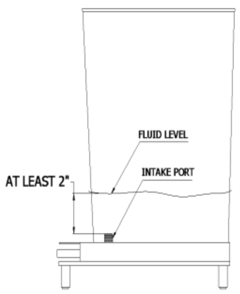


Fig. 4.2 Tank

NOTE: - The fluid level in each reservoir must be two inches or more above the intake port to prevent air from being sucked into the pump. A higher fluid level may be required for viscous fluids.

Viscous Fluid Filling Timing for designing the Tank:

Suction pressure and out flow from the respective tank depends on the suction pressure and timing of the pump. The fluid suction mechanism is as explained below. CFD simulation will predict the out flow from individual tank. The Velocity profile, Mass flow output are the key parameters for deciding the timing as explained below. This can be predicted from the CFD will decide the proper mixing of both the Viscous Fluid.

Correct machine timing is achieved when both materials begin dispensing at the same time. When you first start your new dispenser, or after installing a new pump at the timing must be verified. If the timing is not correct "off ratio" material will be dispensed.

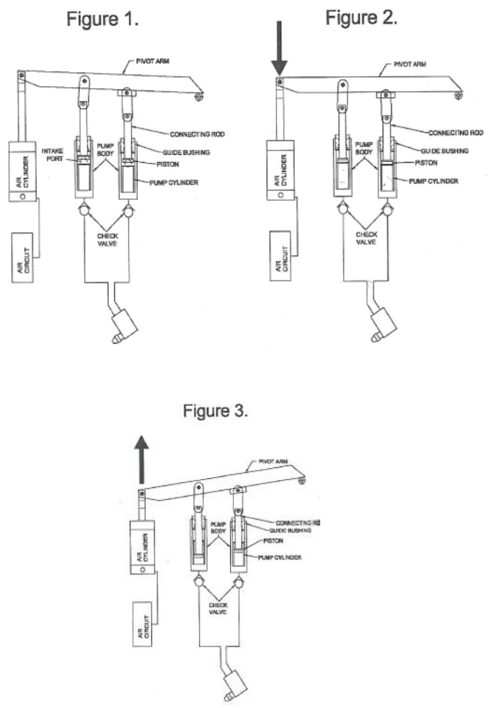


Fig.Working of Dispensing Machine

Before we begin the timing process it is often helpful to understand how the machine functions. When arm is in the position of Fig 1, material will fill the pump through the intake port. As the air cylinder pulls the pivot arm forward, the pistons are being pushed towards their pump cylinders.

When the piston enters its pump cylinder, material from that pump begins dispensing. In order to achieve a good mix and proper ratio, both pistons must enter their pump cylinders at the same time (Figure 2). If the pistons do not enter at the same time, one material will be dispensing before the other, resulting in an incorrect ratio.

After dispensing begins the air cylinder will continue to pull the pivot arm until a full shot is delivered. The air cylinder will then push the pivot arm back, pulling the pistons back towards their intake position (Figure 3).

As the pivot arm begins moving forward the out position the check valves prevent material in the hoses from being drawn back into the pump. The air cylinder continues to push the pivot arm until it reaches it's out positions (Figure 1) at which point the pumps intake material and the process is repeated.

Ratio:-

It is important to check the ratio of each tank of the machine. Material mixed with the wrong ratio may never develop its full strength. The ratio of the Viscous Fluid depends on the Velocity and Mass outflow from the tank, which was predicted using CFD. Most machines are set to the correct ratio before they are shipped and will never need to be changed. Checking the ratio ensures that everything is set and performing correctly. Make sure to check the ration on regular basis.

Ratio Testing:-

It is important to check the ration of your machine. Material mixed at the wrong ratio may never develop its full strength. The machine is set to the right ratio before it is shipped/function and will probably not need to be changed. The ration check is the responsibility of the user, you may want to check that it is right to order to verify the factory settings.

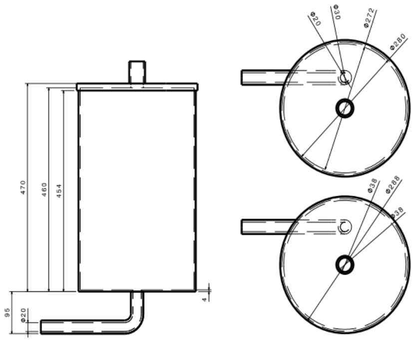
Material Used for Tank & Support:

For giving above requirements I design the Tank such that it satisfied all requirement of end user for Automotive Applications. Material taken for tank used for Viscous Fluid storage which is used after mixing for various automotive applications is given in following table.

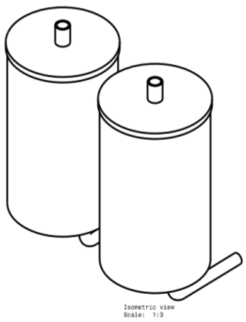
Material: SS304

Material properties	Unit	Value
Young's Modulus	GPa	193
Density	Kg/m^3	8000
Poisson's Ratio	---	0.3
Tensile Strength	MPa	515
Yield Strength	MPa	205

Following figure shows Design of Tank in 2 Dimensional View & Isometric View.



Front/Top View of Tank



Isometric View of Tank

Fig. Design of Tank

Following fig Shows 3 Dimensional View of Viscous Fluid Tank with Support drawn in CATIA V5 which is used after mixing of Viscous Fluid for various Automotive Applications.

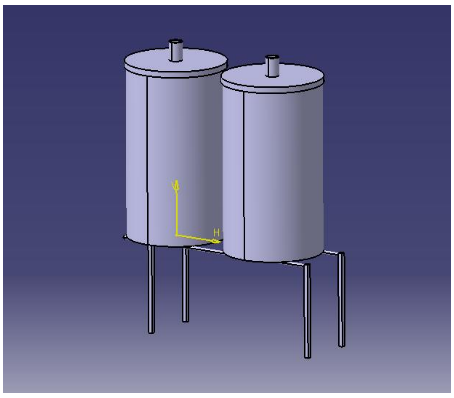


Fig. 3D View of Tank with Support

After calculations get following Values-

1. Weight of One Tank – 21. 27 Kg
2. Weight of other Tank – 21.27 Kg
3. Weight of Support – 1.65 Kg
4. Total Weight of Tank & Support – 44.19 Kg = 45 Kg

Viscous Fluids Used for Adhesive Automotive Applications is below

Fluid 1 - Ethyl Cyanoacrylate		
Material properties	Unit	Value
Density	Kg/m^3	1060
Viscosity	Cps	90

Fluid 2 - Polyurethane		
Material properties	Unit	Value
Density	Kg/m^3	1410
Viscosity	Cps	120

After calculations we get the following values -

Weight of First Fluid in Full Filled Tank – 27.96Kg

Weight of Second Fluid in Full Filled Tank – 37.20 Kg

Total Weight of Empty Tank – 42.54 Kg

Total Weight of Full Filled Tank – 107.7 Kg

FINITE ELEMENT ANALYSIS APPROACH

Finite Element Model: Geometry and Finite Element Model of Cylindrical Tank is given below.

Fig. FEA Model

Meshing:

To find out number of nodes meshing of tank is done. Mesh details are shown in following Figure.

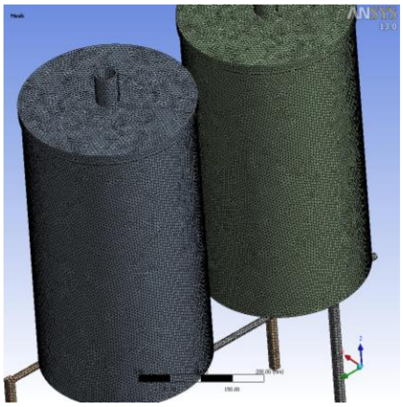


Fig. Meshing Details of Tank

No. Of nodes: 685851

Static Stress Analysis of Support Frame during Empty Tank & Full Filled Tank Condition:

To find out Stress and Deformation on support frame two types of Static Stress Analysis were done on the tank assembly.

1. Self Weight of tank is consider for Stress Analysis
2. Full filled tank is consider for Stress Analysis

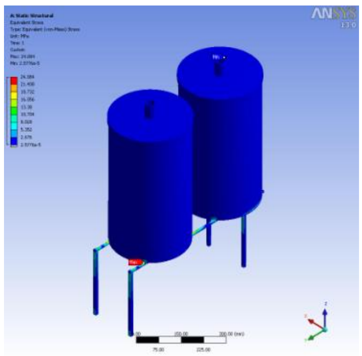


Fig. Stress Analysis of Empty Tank

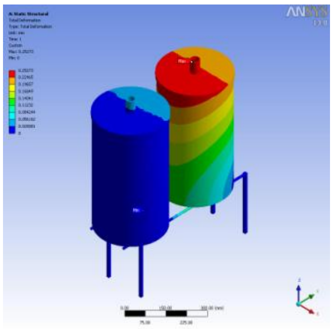


Fig. Total Deformation of Empty Tank

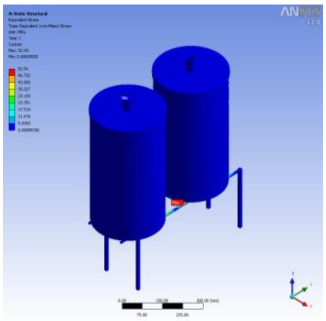


Fig. Stress Analysis of Full Filled Tank

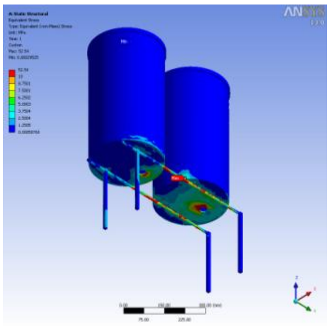


Fig. Stress Analysis of Full Filled Tank

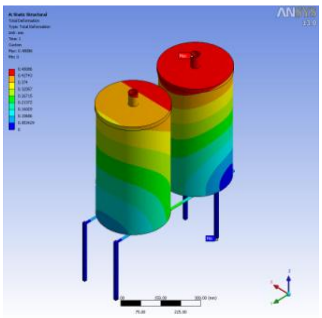
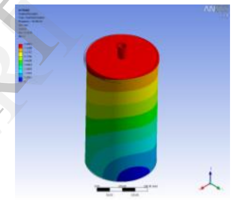


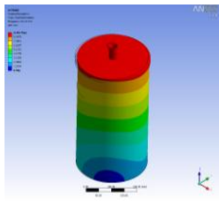
Fig. Total Deformation of Full Filled Tank

Conclusion from Static Stress Analysis: I observe maximum stress and total deformation of both cases. In first case maximum Stress is 24.08 MPa and Total Deformation is 0.25 mm. In second case maximum Stress is 52.54 MPa and Total Deformation is 0.48 mm. From the material properties Yield Strength of Tank Support Material is 205 MPa. Maximum stress in both cases is compared with Yield Strength of material, which is very less so Support Frame of Tank Design is Safe. So we further goes for Modal Analysis of Tank.6.4 Modal Analysis of Tank: Due to dispensing of fluid into the mixing nozzle, time flow is there. Due to that cyclic stress condition is occurring for tank. So I have done modal analysis of tank. To understand failure due to vibrations of tank we go for Modal Analysis. Modal Analysis of Full Filled Tank by Viscous Fluid is used to determine the natural frequencies and mode shapes of a continuous structure. Following Figures shows the natural frequency & total deformation of viscous fluid full filled tank.

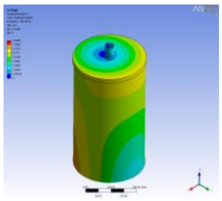
Modal analysis of Full Filled Tank-



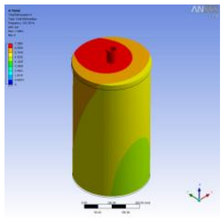
Mode 1



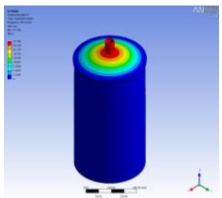
Mode 2



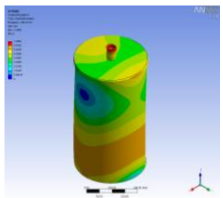
Mode 3



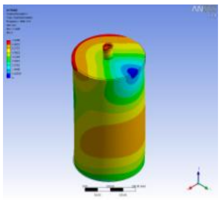
Mode 4



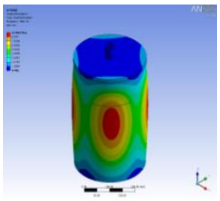
Mode 5



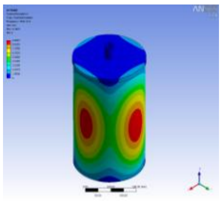
Mode 6



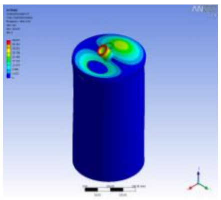
Mode 7



Mode 8



Mode 9



Mode 10

Results from Modal Analysis of Tank: Full Filled Tank

Following table shows Natural frequencies of Full Filled Tank for 10 Modes.

Mode	ANSYS – Frequency (Hz)	Total Deformation (mm)
1	19.65	8.06
2	23.11	9.32
3	183.39	8.66
4	333.75	8.35
5	910.13	27.15
6	996.47	7.25
7	1088.1	7.42
8	1504	9.79
9	1544.4	9.48
10	1841.9	38.63

Conclusion from Modal Analysis:

To understand Viscous Fluid and Tanks Dynamic behaviour during different conditions we have done Modal Analysis of Viscous Fluid Tank for 100% filled Conditions.

I done modal analysis for 10 different Mode Shapes because 3 Translational Mode Shapes (along X, Y, Z axis),3 Rotational Mode Shapes (about X, Y, Z axis), 3 Combination (axis XY,YZ, ZX) and one take extra for better understanding of result.

Modal Analysis predicts the Natural Frequency along corresponding Deformation. During Different filling conditions mass of fluid is changing so frequency keeps in changing with deformations. No stress can be predicted because there are no external forces.

I have taken reciprocating pumps natural frequency is 5 Hz. None of the frequency from modal analysis is matching with the external pumps natural frequency which avoids resonance. Also total deformation of tank is within permissible limit of deformation related to yield strength of material. So Tank design is safe for these conditions.

Conclusion

In design of tank it was found that tank design for viscous fluid is safe. By analytical method tank design is done by with ANSYS software for static stress and modal analysis. In both conditions the tank design was safe for viscous fluid. Fluid passing through mixing nozzle gives proper blend ratio in dispensing machine used for various automotive applications.

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