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Eco Friendly Pipe Hose Cleaning System

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Abstract: ***It is inevitable that the oil in a hydraulic system will contain contamination in particle form. The sources and types of oil-borne contaminants are well known and will include particles of silica's, metals flakes, elastomers and fibers of hydraulic hose material. Sizes and concentration of particulate contaminants are indicated. There is considerable interest among manufacturers and users of hydraulic systems in establishing acceptable limits of contaminations in which particular systems will operate satisfactorily. Such information would be used to***

1) ***Specify the degree of filtration required in the system***
2) ***Specify the contamination sensitivity of the system***
3) ***Define the contamination tolerance level of the system***

To this end, it is necessary to gather reliable data on the performance of system components under controlled contaminated oil conditions. Thus, we designed a new Eco-friendly portable setup which does not use hazardous liquids to clean hose. Instead the setup uses a fresh, clean pressurized atmospheric air; hence there is no harmful effect on human health and contamination of environment.

Keywords : CAE, Solidmechanics, Pipe cleaning system, Contamination, Pressure vessel, Eco-friendly, Mechanical engineering.

I. INTRODUCTION

Up to all hydraulic system failures can be concluded to particles and debris generated due to processes involved in manufacturing from a study for all wear. Filtration systems help to reduce the failure percentage, but what actually causes the failure of hydraulic systems and its solution is more important. In fluid power systems, power is transmitted and controlled through a fluid under pressure within an enclosed circuit. The initial cleanliness level of a hydraulic system can affect its performance. Unless removed, particulate contamination present after assembly of a system may circulate through the system and can damage the components. To reduce the probability of such cases, the fluid and the internal surfaces of the system need to be flushed. Flushing of lines in a hydraulic system needs to be viewed as one means of removing in-built and residual contamination.

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II. EASE OF USE

This hydraulic hose cleaning system works with same efficiency and improves the utilization of available resources that are used for cleaning. This cleaning system will overcome the problems of existing flushing machine system. In future, automated bullet loading can be introduced for ease of operation by means of use pressurized or compressed air from pressure vessel.

III. REVIEW

Currently used machines are Flushing machine can be used only after assembly of final product. It is difficult to operate the machine because it involves liquid agent which in heated during operation, also it contains harmful contents to operator if leakage takes place. [1] Mega clean device which is used by some manufacturers consists of nozzle needs to change for different types of hydraulic hoses. [2] The stated rectification methods for identifying causes of contamination and how to eliminate them. Also, the concept of cleanliness in hydraulic system and their standards are proposed by Merritt. H.E. [3]

A theory and relative equations regarding influence of residual stresses induced in the cylinder pressure vessel. The other documents from various manufacturers like Gates Hoses, Parker Hoses, etc., states how the various (Hydraulic and Pneumatic hoses) hoses are manufactured and their assembly on the actual site or location, at the same time cleanliness standards need to be followed with manufacturing proposed by M. Jayakumar. [4]

IV. PROBLEM STATEMENT

The failure modes of hydraulic system are identified. The existing machines cannot be used after assembly of product or it is difficult & costly.

V. PROPOSED MODEL

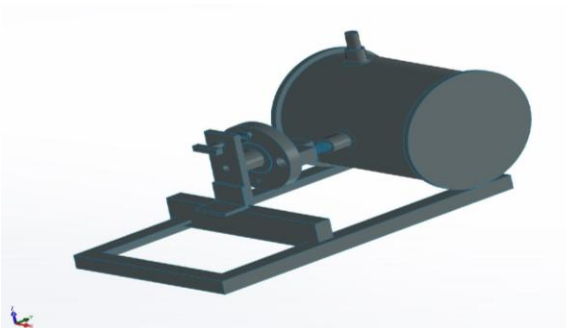


Fig. 1: Assembly setup

This cleaning machine functions effectively during the operation which had more sophisticated nozzle design which accommodates various diameters of hoses and simultaneously provides clamping to them.

The pallet indexer introduced contains the bullets of thermosetting plastic which we have to put all the time whenever we perform the cleaning operation. It comprises of construction materials which are available in market, works efficiently and simple to build.

A. Pressure Vessel

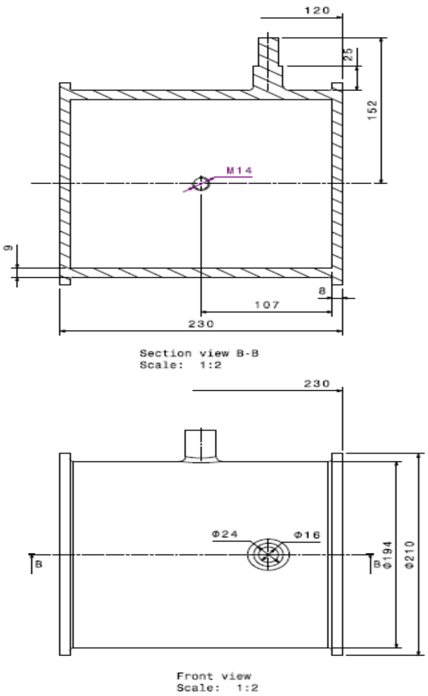


Fig. 2: Pressure Vessel

Table- I: Specification of Pressure Vessel.

Description	Dimensions
Cylinder outside Diameter	194 mm
Cylinder inside Diameter	176 mm
Cylinder Length	214 mm
Cylinder volume (actual)	5.20 liter
Cylinder volume (useful)	2.60 liter
No. of Test	6

The Planned dimensions of the cylinder are such that the pressurized volume of the cylinder is to be close to 5.6 ltrs, hence the dimensions of the cylinder assumed are 194 mm OD, 176 mm ID and 214 mm Length - Volume close to 5.20 ltr. The minimum operating pressure required is 6 bar and we are going to pressurize the cylinder up to 12 bar such that pressure being inversely proportional to volume the 50% volume of cylinder is useful, thus the useful volume is close to 2.8 liters. Thus, minimum number of test possible for the cylinder for 1 "hose will be $\frac{2600}{507} = 6$ test.

B. Nozzle and Clamp

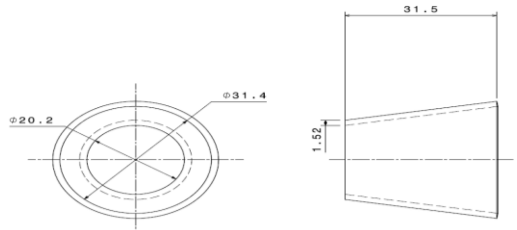


Fig. 3: Nozzle and Clamp

Table- II: Specification of Nozzle and Clamp.

Sr. No.	Description	Hose OD	
		Inch	mm
1	6 EFG6K	3/8	20.2
2	8 EFG6K	1/2	24.0
3	10 EFG6K	5/8	27.8
4	12 EFG6K	3/4	31.4

Nozzle is a combination of projectile shooter and first end of clamp which serves the two purposes. As per the available specimen's ranges between starting from 20.2 mm to 31.4 mm. While accommodating this range of diameter there is one concern arises that is as the length increases the volume of air consumption increases. To avoid this problem, we have tried various lengths like 40 mm, 38 mm, 35 mm. But the results were non acceptable. After number of trial and error method we have achieved a length of 33.0 mm, which makes the angle of 9.63º with horizontal. But considering the machining processes it is impossible to manufacture. So, we have taken the value of angle as 10º that makes the length of nozzle 31.5 mm.

C. Pallet Indexer

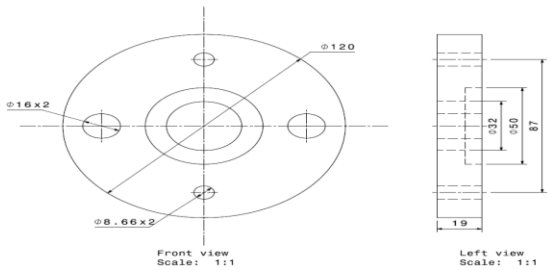


Fig. 4: Pallet Indexer

Indexer is a loader used for loading projectiles (Sponge Bullets), which are going to be injected into the hydraulic hose with the help of compressed air. It can be modified for multiple loading capacities to facilitate faster production rate and to reduce the loading time of Sponge projectiles during operation.

D. Base Frame

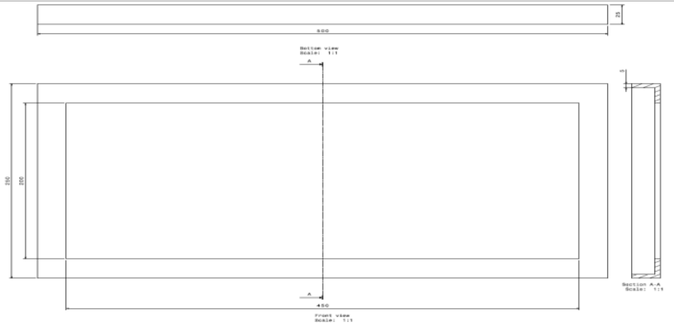


Fig. 5: Base Frame

A rigid frame in structural engineering is the load-resisting skeleton constructed with straight or curved members interconnected by mostly rigid connections which resist movements induced at the joints of members. Its members can take bending moment, shear and axial loads.

The two common assumptions as to the behavior of a building frame are:

1. That its beams are free to rotate at their connections
2. That its members are so connected that the angles they make with each other do not change under load.

Frameworks with connections of intermediate stiffness will be intermediate between these two extremes. Frameworks with connections of intermediate stiffness are commonly called semi rigid frames. The AISC specifications recognize three basic frame types: Rigid Frame, Simple Frame, and Partially Restrained Frame.

E. Pneumatic Valve

Table- III: Specification of Pneumatic Valve.

Electrical data			
Operating voltage	24 V DC	110 V AC	230 V AC
Electrical connection	Plug to EN 175301-803 type A, square design		
CE marking	-	73/23/EEC	73/23/EEC
Insulation class	H	F	F
Duty cycle [%]	100		
Permissible voltage fluctuations [%]	10		
Switching time on [ms]	25		
Switching time off [ms]	10		
Coil characteristics			
Direct current DC [V]	24	-	-
Alternating current AC [V]	-	110	230
Power consumption [W]	6.8	-	-
Switching power [VA]	-	10.5	10.5
Holding power [VA]	-	8	7.6
[Hz]	-	50,60	50,60
Materials			
Solenoid valves		Material number	
Housing	High-alloy stainless steel	1.4305	
	Brass	CW614N	
Seals	FPM		
Note on materials	Contains PWIS (paint-wetting impairment substances)		
	RoHS-compliant		

VI. METHODOLOGY

In today's fast-growing world, it is mandatory to clean, recycle; reuse the materials, equipment's, machine components to improve its performance and efficiency. In most of the industries, hydraulic machines are extensively used for different purpose. These machines make use of hydraulic hoses which are continuously subjected to oil.

In order to avoid inconvenience in machine operation, it is must to clean hydraulic hoses after regular intervals instead of replacing with new ones. The Flushing machine uses flushing oil which is toxic, harmful, and difficult to dispose. Hence the proposed ultraclean projectile machine developed to avoid use of flushing liquid.

This ultra clean machine uses principle of pressurized compressed air and projectiles to clean the hose. But it requires number of nozzles for different hose diameter. To overcome this problem, here we developed a machine working on same principle but use a common nozzle for different hose diameters. The setup is also portable and common; it does not use hazardous liquids to clean hose. It uses a fresh, clean atmospheric air; hence there is no dangerous effect on humans and environment.

VII. MATERIAL PROPERTIES

Table- IV: Material- Structural Steel.

Property	Value
Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m
Compressive Yield Strength Pa	2.5e+008
Tensile Yield Strength Pa	2.5e+008
Tensile Ultimate Strength Pa	4.6e+008
Reference Temperature C	22

Strength Coefficient Pa	9.2e+008
Ductility Coefficient	0.213
Cyclic Strength Coefficient Pa	1.e+009
Cyclic Strain Hardening Exponent	0.2
Young's Modulus Pa	2.e+011
Poisson's Ratio	0.3
Bulk Modulus Pa	1.6667e+011
Shear Modulus Pa	7.6923e+010
Relative Permeability	10000

VIII. CALCULATIONS

A. Maximum operating condition of Pressure vessel

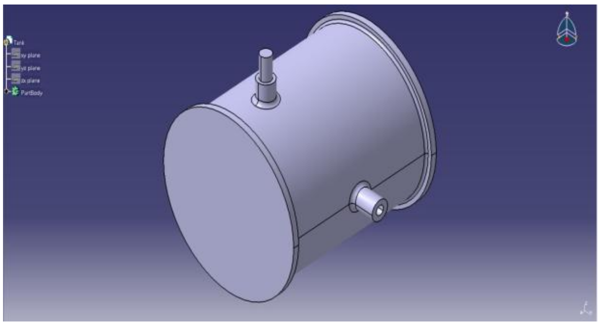


Fig. 6: Model of pressure vessel

Material of Cylinder = Mild Steel

Ultimate Tensile Strength = 500 MPa

- **Hoop's stress due to Air Pressure is-**

$$f_{ch} = (P * d)/2t = \mathbf{13.2\ N/mm^2}$$

Where,

f_{ch} = Hoop's stress due to Air Pressure.

P = Maximum pressure induced in system due to Air = 12 bar.

D = Inner diameter of Pressure Vessel.

t = Thickness of Pressure Vessel.

If $f_{ch} < f_{c\ all}$; Cylinder is safe.

The Allowable Stress = Ultimate Tensile Strength/4

= **125 MPa**

- **Longitudinal stress due to Air Pressure is-**

$$f_{cl} = (P * d)/ 4t = \mathbf{6.6\ N/mm^2}$$

Where,

f_{cl} = Longitudinal stress due to Air Pressure

P = Maximum pressure induced in system due to Air = 30 bar.

D = Inner diameter of Pressure Vessel.

t = Thickness of Pressure Vessel.

As $f_{cl} < f_{c\ all}$; Cylinder is safe.

- **Cylinder Failure Pressure:**

Considering Clavarino's Equation,

$$t = \frac{d_i}{2}\left[\sqrt{\frac{s_{ut}+p_{max}(1-2\mu)}{s_{ut}-p_{max}(1+\mu)}} - 1\right]$$

$$p_{max} = \mathbf{54.306\ N/mm^2}$$

Where,

p_{max} = Maximum pressure of cylinder.

t = Wall thickness of Cylinder.

μ = Poisson's ratio of material.

d_i = Inner diameter of pressure vessel.

S_{ut} = Tensile yield strength of material.

Therefore; maximum pressure of Pressure Vessel is obtained.

IX. ANALYSIS AND RESULTS

A. Meshing Results

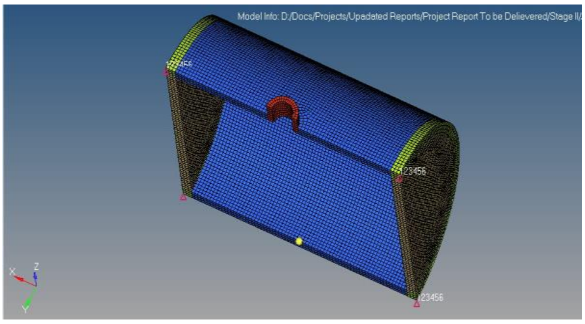


Fig. 7: Meshed model of pressure vessel

Above representation of fully meshed FE model of Pressure Vessel on Hyper mesh with following color representations-

Blue hexahedral elements for Hoop's stress and Yellow hexahedral elements for weldments. Batch meshing done with focus on wields edges of pressure vessel.

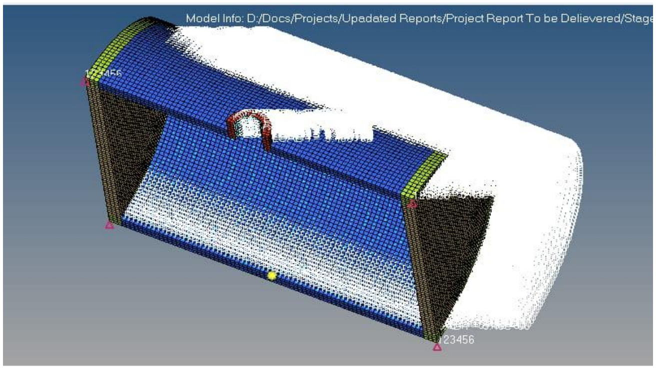


Fig. 8: Pressure vessel Tet-collapse check

Analyzed results confirm FE model doesn't have Tet collapse and 87 percent satisfactory results obtained. Following meshed model imported at ANSA for post-processing. Final results complied with both Hyper mesh and calculated results with 3 times normal working condition for excess safety.

B. Analysis & Results Finding:

1. **Pallet Indexer Results-**

i. Equivalent (von-Mises) Stress

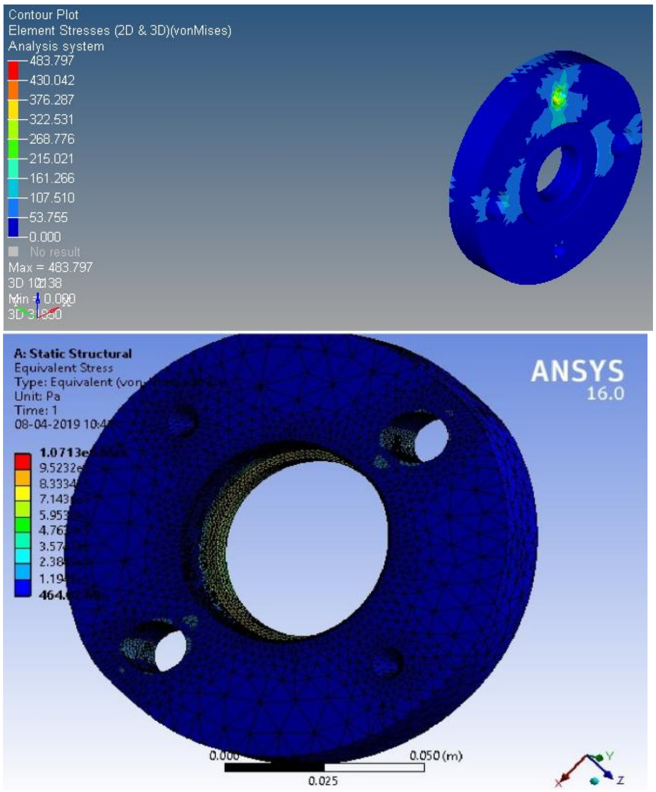


Fig. 9: Equivalent stress of Pallet indexer

Time [s]	Minimum [Pa]	Maximum [Pa]
0.125	1.0606e-005	2.8453e+006
0.25	2.1208e-005	5.6907e+006
0.375	3.1788e-005	8.536e+006
0.5	4.2325e-005	1.1381e+007
0.625	5.2936e-005	1.4227e+007
0.75	6.3585e-005	1.7072e+007
0.875	7.4124e-005	1.9917e+007
1.	8.48e-005	2.2763e+007

ii. Max Shear & Equivalent Total Strain

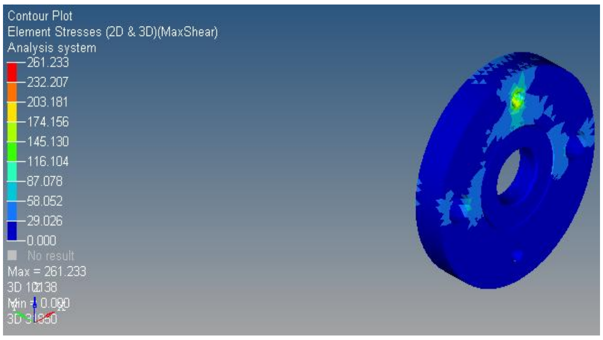


Fig. 10: Maximum shear strain of pallet indexer

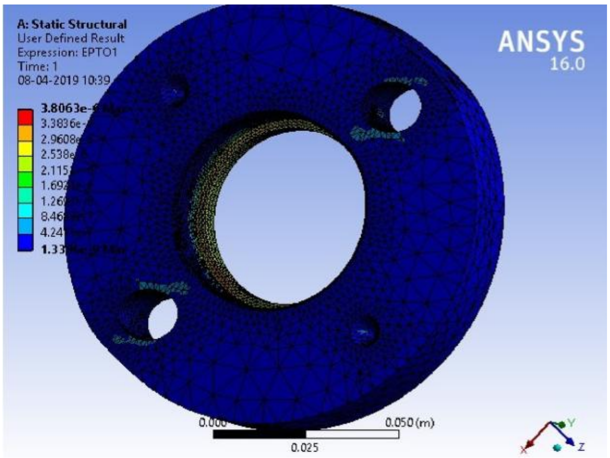


Fig. 11: Equivalent total strain of pallet indexer

Time [s]	Minimum [m/m]	Maximum [m/m]
0.125	1.0931e-016	2.6023e-005
0.25	2.187e-016	5.2045e-005
0.375	3.2876e-016	7.8068e-005
0.5	4.4011e-016	1.0409e-004
0.625	5.4925e-016	1.3011e-004
0.75	6.5726e-016	1.5614e-004
0.875	7.6855e-016	1.8216e-004
1.	8.7579e-016	2.0818e-004

iii. Maximum Displacement & Complied Results

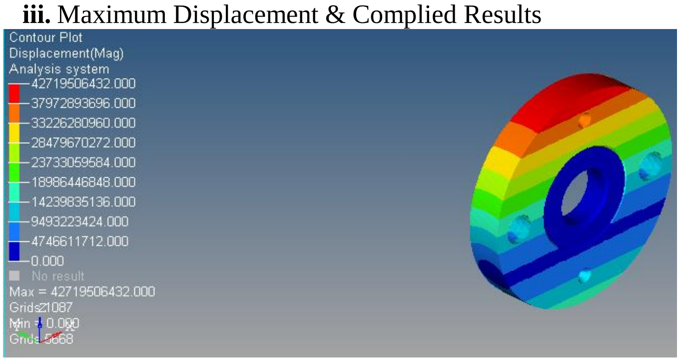


Fig. 12: Maximum displacement of pallet indexer

From above fig.4 the magnitude of Maximum displacement is within calculated limits and there is no failure in pallet indexer when 3X working load is applied. The three times excess load input was done in order for safety measures and to maintain green working environment.

Table V: Analysis results of Pallet indexer

Type	Equivalent (von-Mises) Stress	Equivalen t Elastic Strain	Strain Energ y	Equivalent Total Strain
Results				
Min	8.48e-5 Pa	8.7579e-0 16 m/m	6.1848 e-029 J	8.7579e-01 6 m/m
Max	2.2763e+7 Pa	2.0818e-0 04 m/m	2.0419 e-007 J	2.0818e-00 4 m/m
Minimum Value Over Time				
Min	1.0606e-5 Pa	1.0931e-0 16 m/m	9.7046 e-031 J	1.0931e-01 6 m/m
Max	8.48e-5 Pa	8.7579e-0 16 m/m	6.1848 e-029 J	8.7579e-01 6 m/m
Maximum Value Over Time				

Min	2.8453e+6 Pa	2.6023e-005 m/m	3.1905 e-009 J	2.6023e-005 m/m
Max	2.2763e+7 Pa	2.0818e-004 m/m	2.0419 e-007 J	2.0818e-004 m/m

iv. Maximum Equivalent Stress vs Strain

Steps	Time [s]	Equivalent Stress (Max) [Pa]	[C] Equivalent Elastic Strain (Max) [m/m]
1	0.125	2.8453e+006	2.6023e-005
	0.25	5.6907e+006	5.2045e-005
	0.375	8.536e+006	7.8068e-005
	0.5	1.1381e+007	1.0409e-004
	0.625	1.4227e+007	1.3011e-004
	0.75	1.7072e+007	1.5614e-004
	0.875	1.9917e+007	1.8216e-004
	1.	2.2763e+007	2.0818e-004

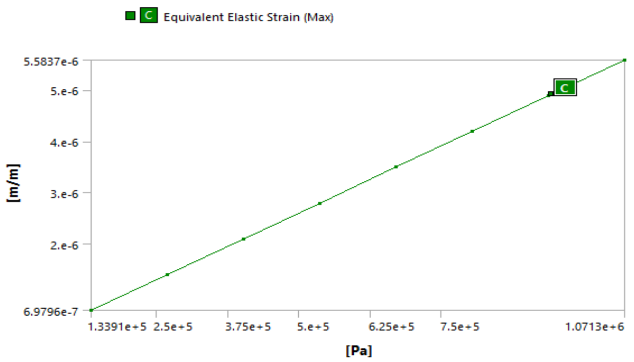
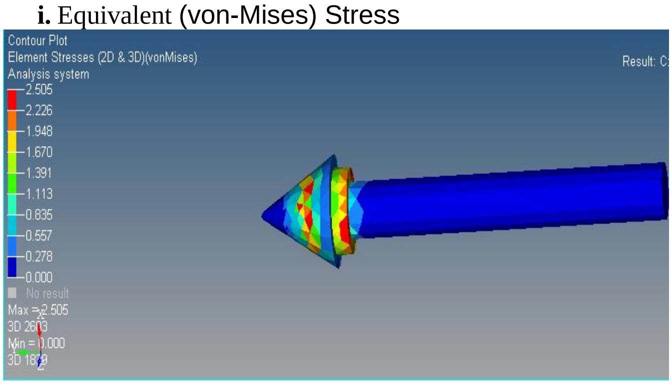


Chart 1: Max Equivalent stress vs Strain of Pallet Indexer

The above Chart.1 indicates three times maximum operating values of Pallet indexer. The original operating conditions are 36 percent of the displayed data. The tubular above indicates the substeps with which graph was plotted and studied for working safety of system. The breaking point C which is displayed in graph is still within the maximum operating calculated values & the system can be recommended safe to use at 300 percent operating conditions.

2. Indexer Pin Results-

i. Equivalent (von-Mises) Stress



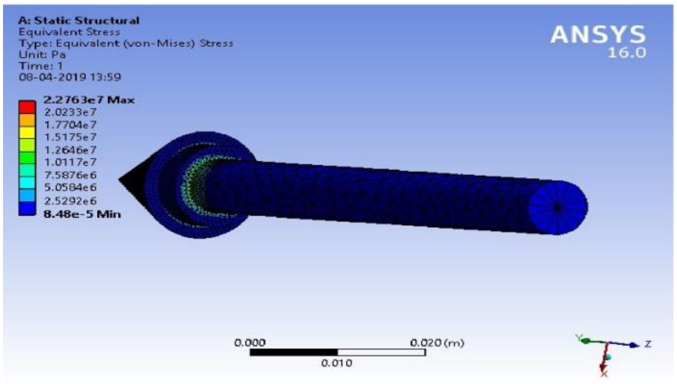


Fig. 13: Equivalent stress of Indexer Pin

Time [s]	Minimum [Pa]	Maximum [Pa]
0.125	1.0606e-005	2.8453e+006
0.25	2.1208e-005	5.6907e+006
0.375	3.1788e-005	8.536e+006
0.5	4.2325e-005	1.1381e+007
0.625	5.2936e-005	1.4227e+007
0.75	6.3585e-005	1.7072e+007
0.875	7.4124e-005	1.9917e+007
1.	8.48e-005	2.2763e+007

ii. Max Shear & Equivalent Total Strain

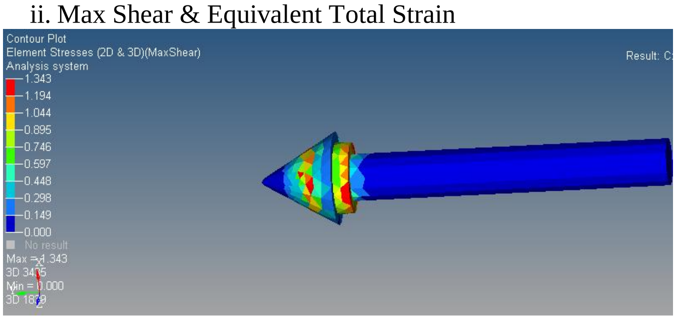


Fig. 14: Maximum Shear strain of Indexer Pin

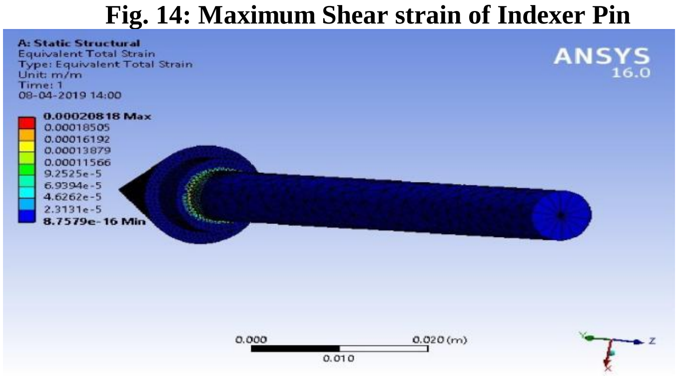


Fig. 15: Equivalent Total strain of Indexer Pin

Time [s]	Minimum [m/m]	Maximum [m/m]
0.125	1.0931e-016	2.6023e-005
0.25	2.187e-016	5.2045e-005
0.375	3.2876e-016	7.8068e-005
0.5	4.4011e-016	1.0409e-004
0.625	5.4925e-016	1.3011e-004
0.75	6.5726e-016	1.5614e-004
0.875	7.6855e-016	1.8216e-004
1.	8.7579e-016	2.0818e-004

iii. Maximum displacement & Compiled results

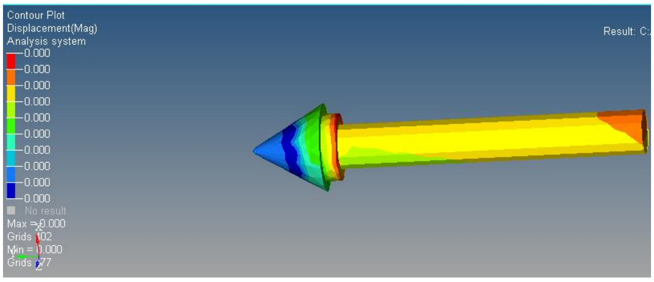


Fig. 16: Maximum displacement of Indexer Pin

From above fig.16 the magnitude of Maximum displacement is within calculated limits and there is no bending twist, crack or failure with 3X working load conditions. The three times excess load input was done in order for safety measures and to maintain green working environment.

Table VI: Analysis results of Indexer Pin

Type	Equivalent (von-Mises) Stress	Equivalent Elastic Strain	Strain Energy	Equivalent Total Strain
Results				
Min	8.48e-005 Pa	8.7579e-016 m/m	6.1848e-029 J	8.7579e-016 m/m
Max	2.2763e+7 Pa	2.0818e-004 m/m	2.0419e-007 J	2.0818e-004 m/m
Minimum Value Over Time				
Min	1.0606e-5 Pa	1.0931e-016 m/m	9.7046e-031 J	1.0931e-016 m/m
Max	8.48e-005 Pa	8.7579e-016 m/m	6.1848e-029 J	8.7579e-016 m/m
Maximum Value Over Time				
Min	2.8453e+6 Pa	2.6023e-005 m/m	3.1905e-009 J	2.6023e-005 m/m
Max	2.2763e+7 Pa	2.0818e-004 m/m	2.0419e-007 J	2.0818e-004 m/m

iv. Maximum Equivalent stress vs Elastic strain

Steps	Time [s]	Equivalent Stress (Max) [Pa]	[C] Equivalent Elastic Strain (Max) [m/m]
1	0.125	2.8453e+006	2.6023e-005
	0.25	5.6907e+006	5.2045e-005
	0.375	8.536e+006	7.8068e-005
	0.5	1.1381e+007	1.0409e-004
	0.625	1.4227e+007	1.3011e-004
	0.75	1.7072e+007	1.5614e-004
	0.875	1.9917e+007	1.8216e-004
	1.	2.2763e+007	2.0818e-004

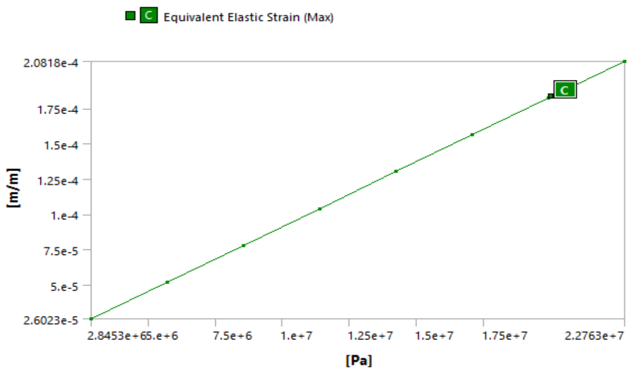
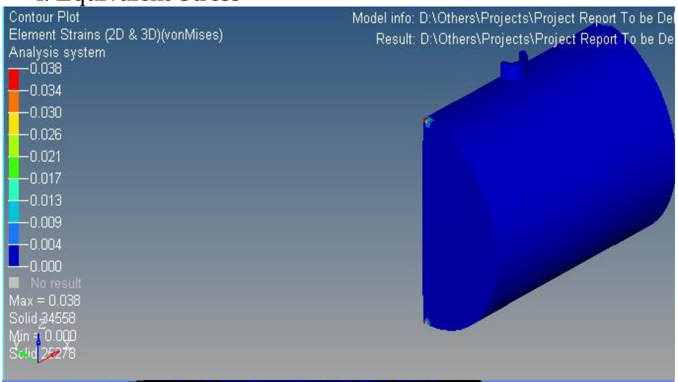


Chart 2: Max Equivalent stress vs Elastic Strain of Indexer Pin

The above Chart.2 indicates three times maximum operating values of Indexer Pin. The original operating conditions are 37 percent of the displayed data. The tubular above indicates the substeps with which graph was plotted and studied for working safety of system. The breaking point C which is displayed in graph is still within the maximum operating calculated values & the system can be recommended safe to use at 300 percent operating conditions.

3. Pressure Vessel Results-

i. Equivalent Stress



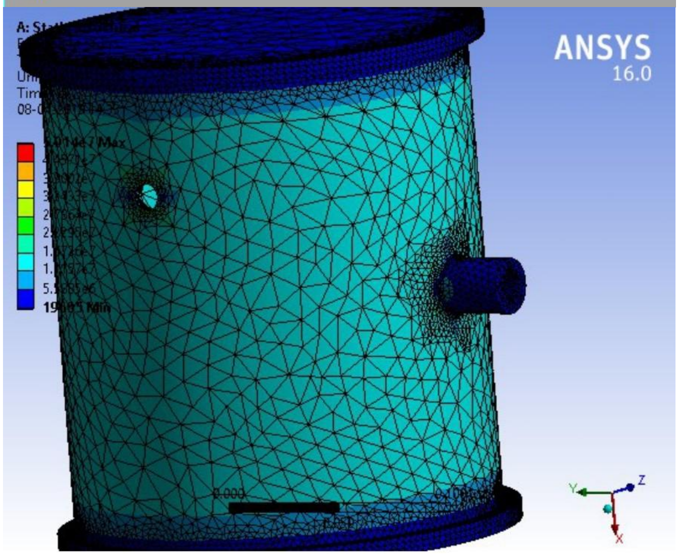


Fig 17: Equivalent stress of Pressure vessel

Time [s]	Minimum [Pa]	Maximum [Pa]
0.125	2450.6	6.2675e+006
0.25	4899.3	1.2535e+007
0.375	7350.9	1.8803e+007
0.5	9814.9	2.507e+007
0.625	12246	3.1337e+007
0.75	14708	3.7605e+007
0.875	17156	4.3872e+007
1.	19605	5.014e+007

ii. Max Shear & Equivalent Elastic Strain

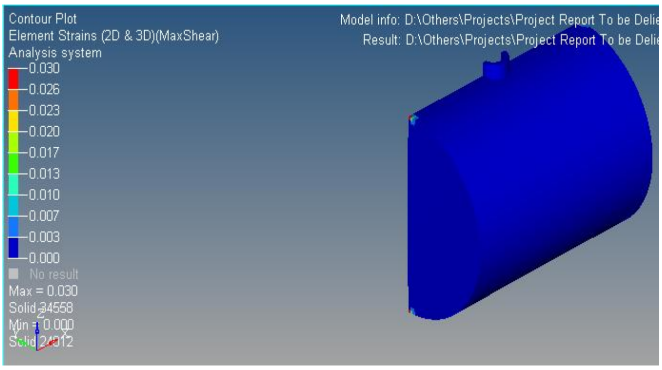


Fig 18: Equivalent Elastic Strain of Pressure Vessel

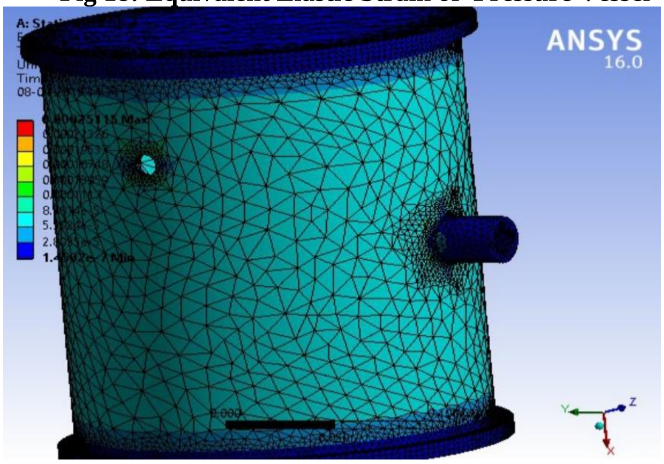


Fig 19: Equivalent Elastic Strain of Pressure Vessel

Time [s]	Minimum [m/m]	Maximum [m/m]
0.125	1.8102e-008	3.1394e-005
0.25	3.6202e-008	6.2788e-005
0.375	5.433e-008	9.4182e-005
0.5	7.2424e-008	1.2558e-004
0.625	9.0552e-008	1.5697e-004
0.75	1.0868e-007	1.8836e-004
0.875	1.2668e-007	2.1976e-004
1.	1.4502e-007	2.5115e-004

iii. Max Displacement and Compiled results

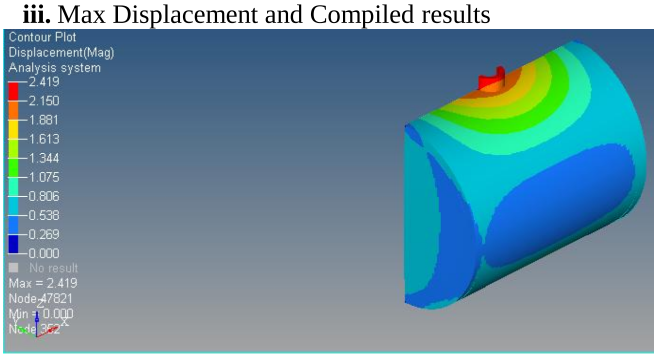


Fig. 20: Maximum displacement of Pressure Vessel

From above fig.20 the magnitude of Maximum displacement for Pressure vessel, pipes and welds joints is within calculated limits and there is no pressure or air leaks, crack or failure with 3X working load conditions. The three times excess load input was done in order for safety measures as top priority and to maintain green working environment. With multiple iterations for different load conditions, the results were carefully studied & calculated which are displayed below.

Table VII: Analysis results of Pressure Vessel

Results					
Min	19605 Pa	1.4502e-007 m/m	4.6629e-011 J	22.191 m	1.4502e-007 m/m
Max	5.014e+7 Pa	2.5115e-004 m/m	1.3167e-004 J	23.432 m	2.5115e-004 m/m
Minimum Value Over Time					
Min	2450.6 Pa	1.8102e-008 m/m	7.2843e-013 J	2.7739 m	1.8102e-008 m/m
Max	19605 Pa	1.4502e-007 m/m	4.6629e-011 J	22.191 m	1.4502e-007 m/m
Maximum Value Over Time					
Min	6.2675e+6 Pa	3.1394e-005 m/m	2.0573e-006 J	2.929 m	3.1394e-005 m/m
Max	5.014e+7 Pa	2.5115e-004 m/m	1.3167e-004 J	23.432 m	2.5115e-004 m/m

iv. Maximum Equivalent stress vs Elastic strain

Steps	Time [s]	Equivalent Stress (Max) [Pa]	[C] Equivalent Elastic Strain (Max) [m/m]
1	0.125	6.2675e+006	3.1394e-005
	0.25	1.2535e+007	6.2788e-005
	0.375	1.8803e+007	9.4182e-005
	0.5	2.507e+007	1.2558e-004
	0.625	3.1337e+007	1.5697e-004
	0.75	3.7605e+007	1.8836e-004
	0.875	4.3872e+007	2.1976e-004
	1.	5.014e+007	2.5115e-004

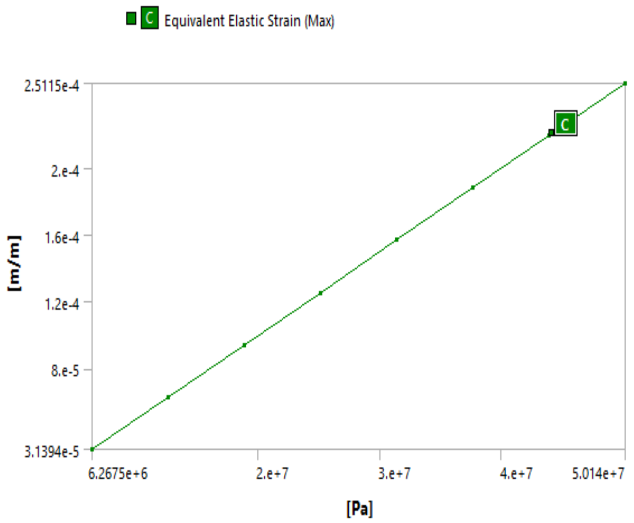


Chart 3: Max Equivalent stress vs Elastic Strain of Pressure Vessel.

The above Chart.3 indicates three times maximum operating values of Pressure Vessel. The original operating conditions are 36 percent of the displayed data. The tubular above indicates the substeps with which graph was plotted and studied for working safety of system.

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The breaking point C which is displayed in graph is still within the maximum operating pressure of Vessel & the system can be recommended safe to use at 300 percent operating conditions.

X. CONCLUSION

This New Green system is Eco-friendly than previously used highly contaminated models. It is ideal for portable small & also large volume production applications; it has broad variety of projectile and nozzle types & sizes to match application needs. As it has simple and robust construction compared to other cleaning machines used in the industry, it can be used in both ways as a hand-held and bench-mount configuration. Furthermore, it requires minimal setup, works off shop air (80-110 psi) with capability 1/8 to 4-1/2 ID hose, tube or pipe and only one system can be flexibly used for multiple purposes.

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