Design and Dynamic Analysis of Existing Container Lifting Device used for Solid Waste Management

Himanshu D. Raiyani[1] Kaushik A Devmurari[2] Prof. G. H. Upadhyay[3] Prof. U. V. Shah[4] Vijay Mistry[5]

[1,2,3,4,5]Department of Mechanical

[1,2,3,4,5]L D College of Engineering, Ahmedabad

Abstract— For transport of solid waste the concerned authority need to decide the type of vehicles to be procured and the system of transportation to be adopted. In all mega cities and municipal corporations' HCV chassis are used for loading and unloading the containers having size more than 5.5 cubic meters. But for all towns and Nagarpalikas these may not be preferred due to space limitations and narrow size roads. So here tractor driven lifting device may be used which will lift up to 4.5 cubic meter containers. The objective of this dissertation is to design various component of CLD model like hydraulic cylinder, leaf spring, hoisting chain, mechanical jack, cross-rod etc. it's necessary to find out the performance of device in dynamic software environment like ansys workbench and based on obtained result find out whether design is safe or not.

Key words: MSWM, container lifting device, rigid and transient dynamic analysis

I. INTRODUCTION

Human activities create waste, and the ways that waste is handled, stored, collected, and disposed of can pose risks to the environment and to public health. In urban areas, especially in the rapidly urbanizing cities of the developing world, problems and issues of municipal solid waste management (MSWM) are of immediate importance. Most governments have acknowledged the importance of MSWM; however, rapid population growth overwhelms the capacity of most municipal authorities to provide even the most basic services.

Typically one- to two-thirds of the solid waste that is generated is not collected. The uncollected waste is dumped indiscriminately in the streets and in drains, contributing to flooding, breeding of insect and rodent vectors, and spreading of diseases. Even waste that is collected is often disposed of in uncontrolled dumpsites or burned, polluting water resources and the air. The implementation of MSWM practices benefits both public health and environmental quality directly and substantially.

Fig. 1: Tractor trailer container lifting device

II. DESIGN OF CONTAINER LIFTING DEVICE

Hydraulic cylinders are actuation devices that convert the hydraulic energy of a pressurized fluids into the mechanical energy needed to control the movement of machine linkages and attachments. Cylinder tubes are divided in to two categories.

1) Thin Cylinder Tube
2) Thick Cylinder Tube

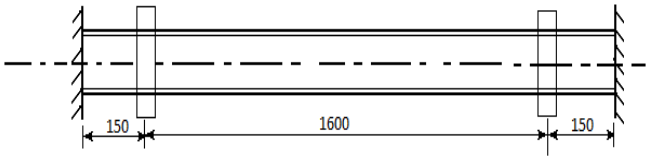
Hydraulic cylinder is consider as thick cylinder and there are several types of theory and equation used for design of hydraulic cylinder like Lame's equation for designing cylinder of brittle material, Brinies' equation is generally used for open-end cylinder made of ductile material, Clavarino's equation applies to closed-end cylinder made of ductile material etc. here cylinder is close ended that's why Clavarino's equation for finding cylinder thickness.

$$t = \frac{d_i}{2}\left[\sqrt{\frac{\sigma t + (1-2\mu)\,P}{\sigma t - (1+\mu)\,P}} - 1\right]$$

Design of piston is based on the simple consideration like required piston area which can lift design load at normal operating hydraulic pressure and in design of piston rod is simply consider as circular rod comes under normal load. But it is also necessary to consider piston road as long column and design according to Euler's design criteria.

A. Design of Cross-Rod

In container lifting device (CLD) cross-rod is used to support the load by container loading and transmit motion from the cylinder to container for loading and unloading. In design of cross-rod, it is consider as a fixed beam supported at two ends with two point load at a same distance from ends. Here beam is consider as a hollow pipe section.



ALL DIMENSIONS ARE IN mm

Now, due to applied load W at distance 'a' from both end general stress generated is given like below…

Flexure bending stress $\sigma = \dfrac{32M}{\pi D^3\left(1-C^4\right)}$

Shear stress $\tau = \dfrac{4W}{\pi D^2\left(1-C^2\right)}$

All rights reserved by www.ijsrd.com

Maximum principal stress $\sigma_1 = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$

B. Design of rear mechanical jack of CLD model

We know that jack is a device which can support and also raise the load at some height. In tractor driven container lifting device rear jack is used to support the load. Generally loading and unloading of container is not done with proper ground level like at storage depot station and dumping site. So, at that time mechanical jack is used not only support the load but also stabilize the vehicle.

Load applied to jack is eccentric so that the eccentricity causes bending stresses by a moment of value P x e. Within the elastic range (Linear stresses) we can superposition or add up the normal and bending stresses:

$$f_x = f_a + f_b = \frac{P}{A} + \frac{My}{I}$$

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq \frac{1}{F.O.S}$$

C. Design of Leaf spring

A leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential energy is stored in spring as strain energy and then released slowly.

In design of leaf spring it is simply consider as a cantilever beam. By using this theory the stress and deflection equations for a laminated spring is,

$\sigma_{bg} = \frac{12FL}{bt^2(3n_f + 2n_g)}$ (stress induce in n_g graduated leaf)

$\sigma_{bf} = \frac{18FL}{bt^2(3n_f + 2n_g)}$ (stress induce in n_f master leaf)

Length of (n-1) leaf = $\frac{\text{effective length}}{n-1} \times (n-1)$+ Ineffective Length

III. 3-D SOLID MODEL OF CLD

Design of container lifting device which can handle container of capacity around 4 to 4.5 m^3 capacity and design according to maximum load carrying capacity about 5000 Kg. Design calculation for different components for maximum load carrying capacity is done by above design calculation. And according to derive dimension 3-D model of CLD is built in solidworks 14.0.

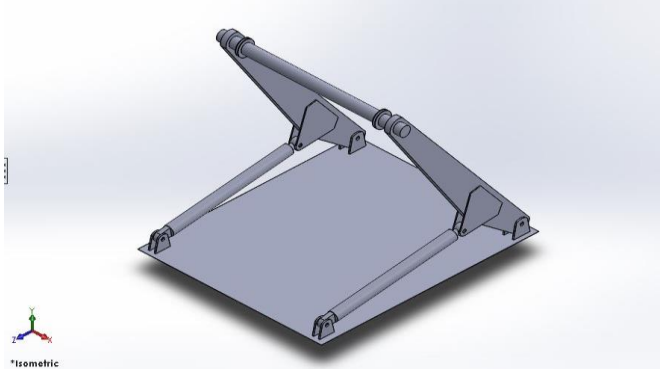


Fig. 2: SolidWorks 3-D model of container lifting device

IV. DYNAMIC ANALYSIS OF CONTAINER LIFTING DEVICE

Transient structural analysis provides users with the ability to determine the dynamic response of the system under any type of time-varying loads. Unlike rigid dynamic analyses, bodies can be either rigid or flexible. For flexible bodies, nonlinear materials can be included, and stresses and strains can be output. Transient structural analysis is also known as time-history analysis or transient structural analysis. Transient structural analysis encompasses static structural analysis and rigid dynamic analysis, and it allows for all types of Connections, Loads, and Supports.

Transient structural analysis can be either linear or nonlinear. All types of nonlinearities are allowed - large deformations, plasticity, contact, hyper elasticity and so on. The transient structural analysis that specifically uses the ANSYS Mechanical APDL solver also ANSYS Workbench offers an additional solution method of Mode Superposition to perform linear transient structural analysis.

In a transient structural analysis, rigid parts are often used to model mechanisms that have gross motion and transfer loads between parts, but detailed stress distribution is not of interest. The output from a rigid part is the overall motion of the part plus any force transferred via that part to the rest of the structure. So by using rigid dynamic analysis in ansys of CLD model total or directional force, moments at every joints and probe can measure. For performing dynamic analysis material specification for each component are given below.

Material and it's property	Component of CLD model				
	Hydraulic cylinder	Piston rod	Cross-rod	Big link	Base
Material	ST 52	SAE 1045	S 355		
Density	7800	7872	7800		
Tensile Yield stress	520	310	355		
Compressive yield stress	520	310	355		
Ultimate stress	900	565	470 - 630		
Young's Modulus	200	200	210		
Poisson's Ratio	0.3	0.29	0.3		
Shear Modulus	77	77.5	80.7		

Table 1: Material Property for Individual Component Of CLD

Contact, joints and springs are all valid in a transient structural analysis. In CLD model connection applied between piston- cylinders is translation and between base to cylinder, piston rod to big link, big link to base are all revolute joints.

All rights reserved by *www.ijsrd.com*

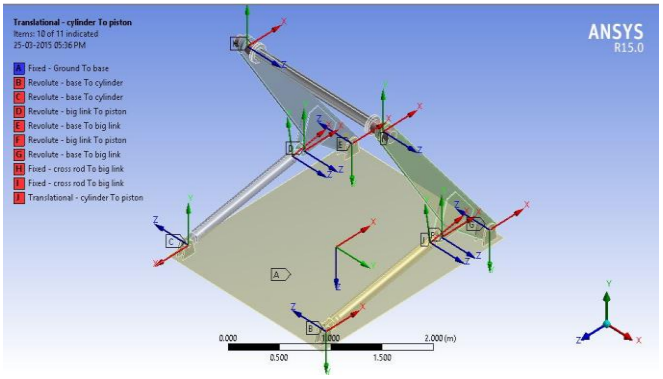


Fig. 3 : joints between individual components of CLD model

In Rigid dynamic analysis setup like load, velocity, displacement, slandered earth gravity etc. are given to CLD model. Like on cross-rod point load of 25000 N is applied near to two ends and hydraulic cylinder piston velocity 20 mm/s.

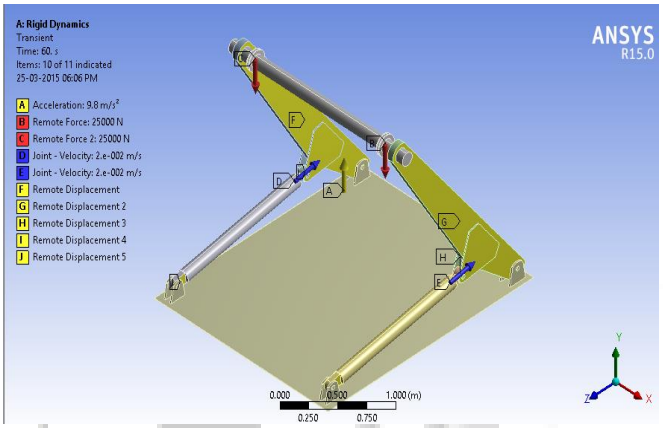


Fig. 4: Remote force, constrain, joint velocity, acceleration shown in CLD model

Aim to perform rigid dynamic analysis is to find out force generate at different joint probe and working behaviour of model in 3-D space. It's also help full to find out translational join force generated on piston during operation at maximum load. Which is also consider as hydraulic oil force on piston. After completion of solution result are found are as follows.

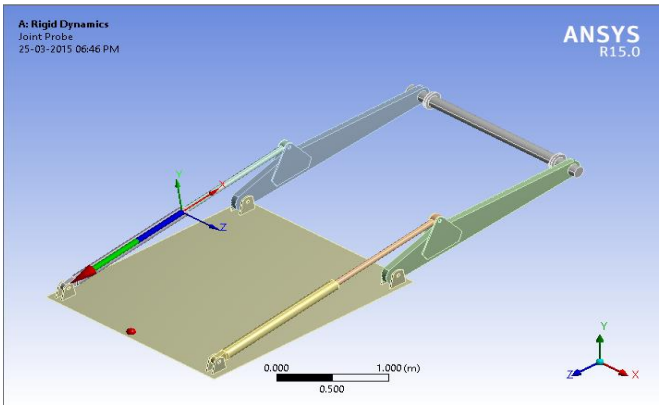


Fig. 5: Force shown on translation joint probe

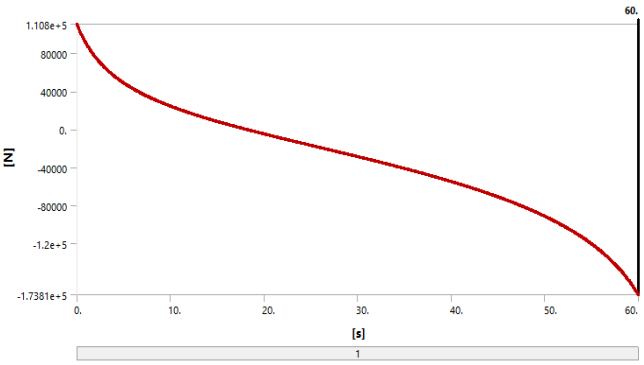


Fig. 6: Translation joint force change with time

This translational joint force on piston rod is used as a input parameter in transient dynamic analysis. Also by considering this force as a hydrostatics force which can produce opposite reaction force in cylinder tube.

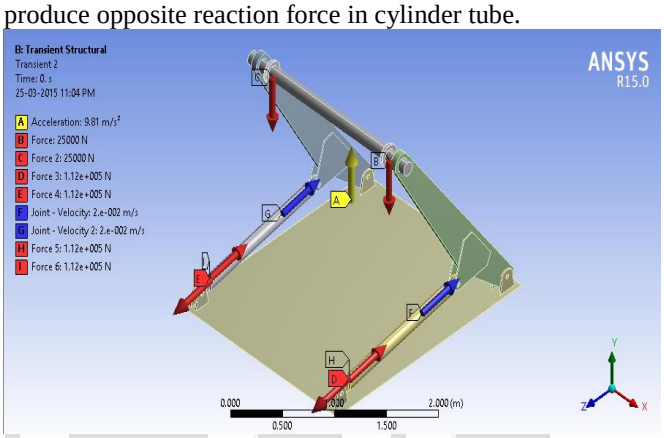


Fig. 7: Remote force, constrain, joint velocity, acceleration shown in CLD model for transient analysis

Aim to perform transient dynamic analysis is to find out time-history charts to understand the transient response of the system. Like time varying stress, strain, acceleration, joint force and moment etc.

V. RESULT AND DISCUSSION

From the above setup of CLD model transient analysis is to be done andafter completion of solution result are found are as follows.

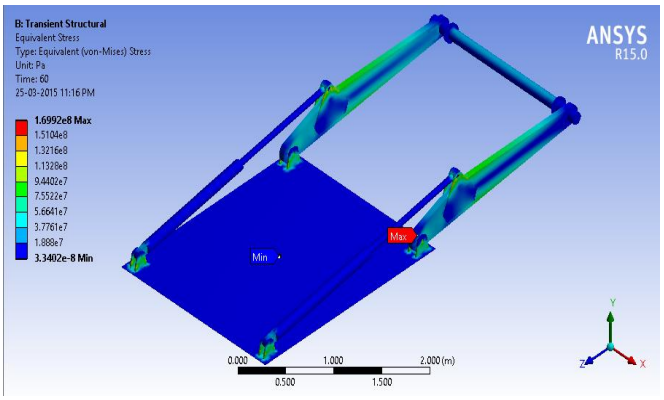


Fig. 8: Von-Mises stress contour generated in CLD model

All rights reserved by *www.ijsrd.com*

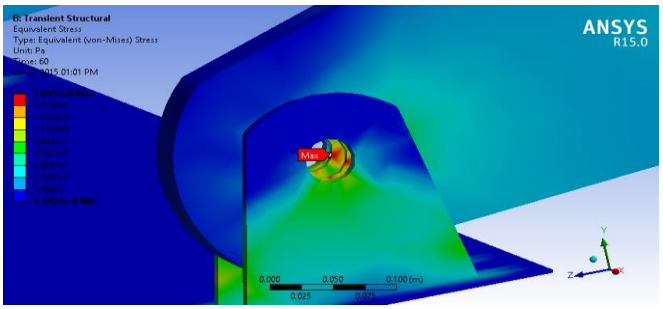


Fig. 9: maximum von-mises stress generate in CLD model

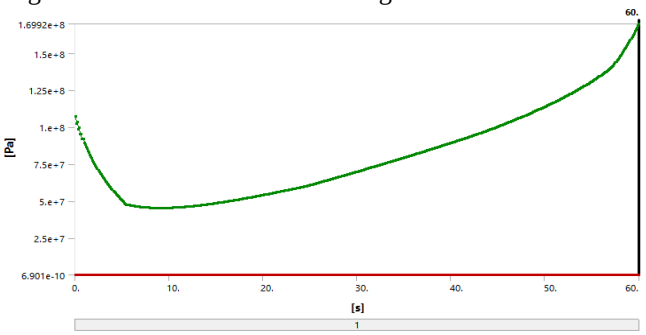


Fig. 10: Maximum and Minimum Value of Von-Mises Stress Change with Time

Result derive from ansys transient structure analysis of CLD model in form of deformation, von-mises stress, von-mises strain, joint probe force and total safety factor of CLD model as output from analysis.

Form the obtained result we can show from that maximum von-mises stress is generated at revolute joint between big links to base is around 166 MPa, which is much below to yield stress. But this stress is because of rigid behavior of joint. Otherwise normal generated stress is much below around 95-110 MPa, which we can show in fig. (8), (9), (10).

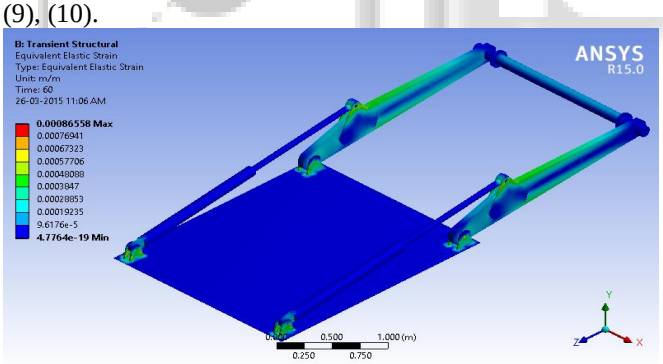


Fig. 11: Equivalent elastic strain contour generated in CLD model

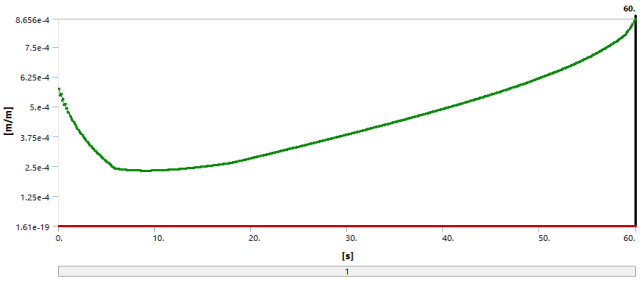


Fig. 12: maximum and minimum value of Equivalent elastic strain change with time

From the fig. (11), (12) it is show that initial maximum initial strain is 0.000575 at beginning which is reduce to minimum at vertical position of big link and again increase to maximum strain 0.00086.

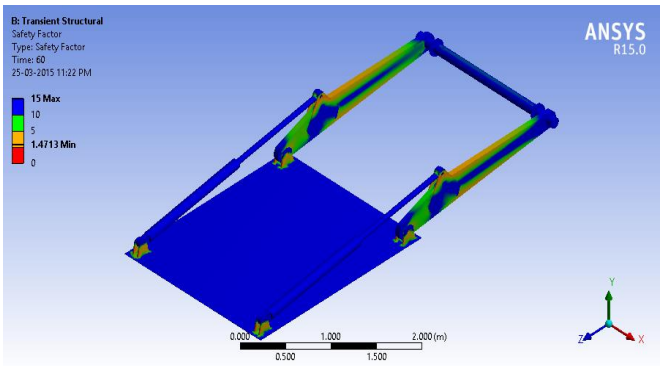


Fig. 13: Safety factor contour generate in CLD model

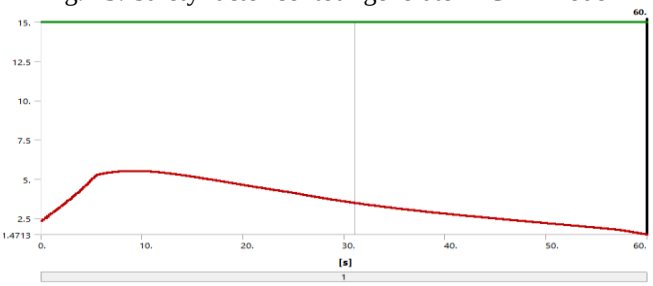


Fig. 14: Maximum and Minimum time varying safety factor

Safety factor shows overall result like stress, strain generated at different time with respect to permissible stress. Graph shows that minimum safety factor in some area is 15 at all time. And maximum safety factor at begging is 2.5 which subsequently increase to 5 at time of 18s and again decrease to 1.4. Which shows that at all time CLD model is safe under maximum load.

VI. CONCLUSION

Proper solid waste management is a primary criterial for any municipality in cities and nagarpalicas. It is also beneficial to human health and good aesthetic to cities.

But for small nagarpalica it is not possible to fully implement MSWM skim due to cost limitation, narrow size road and space limitation. So for that it is necessary to design and develop waste handling tool which can handle 4 to 4.5 m^3 container with effective used of tractor and its hydraulic system.

So, after design of CLD model for maximum load capacity and performing rigid and transient analysis in ansys 15.0, results foundand discuss in previous section. Based on the result found comparison is given below.

Component	Result	Maximum value generated	Allowable value
Piston	Stress	64.5 MPa	310 MPa
Cross- rod	Stress	35 MPa	355 MPa
Big link	Stress	169 MPa	355 MPa
Base	Stress	129 MPa	355 MPa
All body	Strain	0.00086	0.002
All body	Safety factor	Max. – 15 Min. – 1.49	1.5

Table 2: comparison of result found with allowable value

So, from that we can conclude that new design of container lifting device is safe under maximum load condition.

All rights reserved by *www.ijsrd.com*

VII. NOMENCLATURE

CLD = container lifting device
MSWM = municipal solid waste management
d_i = inside diameter of cylinder/ outside diameter of piston
σ_t = tensile yield stress
P = hydraulic oil pressure
C = ratio of inner to outer diameter
D = outer diameter of cross-rod
f_a , f_b = axial and bending stress in jack column
F = force at leaf spring eye
L = half-length of leaf spring

REFERENCES

[1] Mufeed Sharholy, Kafeel Ahmad "Municipal solid waste management in Indian cities – A review", science direct, journal of waste management 28 (2008) 459–467.
[2] Vitus M. Tabie, Yesuenyeagbe A. K. Fiagbe "Weight Optimization of A Lift-Tipping Mechanism for Small Solid Waste Collection Truck", International Journal of Scientific & Technology Research Volume 3, Issue 7, july 2014.
[3] Vinkel Arora, Gian Bhushan and M.L. Aggarwal "Eye Design Analysis of Single Leaf Spring in Automotive Vehicles using CAE Tools", International Journal of Applied Engineering and Technology, 2011 Vol. 1 (1) October-December, pp.88-97.
[4] Mouleeswaran SENTHIL KUMAR, Sabapathy VIJAYARANGAN "Analytical and Experimental Studies on Fatigue Life Prediction of Steel and Composite Multi-leaf Spring for Light Passenger Vehicles Using Life Data Analysis", Materials Science (MEDŽIAGOTYRA). Vol. 13, No. 2. 2007.
[5] Tae-Gu KIM, Seong-Beom LEE and Hong-Chul LEE "A Case Study on Engineering Failure Analysis of Link Chain", Safety and Health at Work 2010:1:43-50.
[6] Khaled Al-Fadhalah , Ahmed Elkholy, Majed Majeed, "Failure analysis of Grade-80 alloy steel towing chain links", journal of Engineering Failure Analysis 17 (2010) 1542–1550.
[7] Boris Kržan , Jože Vižintin "Tribological properties of an environmentally adopted universal tractor transmission oil based on vegetable oil", journal of Tribology International 36 (2003) 827–833.
[8] D.J. Hargreaves, R. pai "Performance of environment-friendly hydraulic fluids and material wear in cavitating conditions", journal of Wear 252 (2002) 970–978.
[9] M Osman Abdalla, Nagarajan T. and Fakhruldin M Hashim "Analysis of Innovative Design of Energy Efficient Hydraulic Actuators", International Journal of Engineering
Research and Applications (IJERA), Vol. 3, Issue 1, January-February 2013, pp.001-007.
[10] L.TOMSKI, S. UZNY, "A Hydraulic Cylinder Subjected to Euler's Load in Aspect of The Stability and Free Vibrations taking into Account Discrete Elastic Elements", journal of Archives of Civil and Mechanical Engineering, Vol. XI 2011 No. 3.
[11] P.J.Gamez-Montero, E.Salazar et al. "Misalignment effects on the load capacity of a hydraulic cylinder", International Journal of Mechanical Sciences 51 (2009)105–113.
[12] Leone Corradi and Lelio Luzzi,"Collapse of Thick Cylinders Under Radial Pressure and Axial Load" Department of Nuclear Engineering, Italy, ASME , Vol. 72, JULY 2005.

All rights reserved by *www.ijsrd.com*