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Design and Optimization of Three Stages Hydraulic Cylinder Used In Dump Trucks

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Abstract:

Dump Trucks are widely used. Multistage hydraulic cylinder is the key device that it is directly related to the main performances of dump trucks. With Pro/E, the parametric modeling of the three-stage hydraulic cylinder was completed. The supporting stability of the three-stage hydraulic cylinder was studied with ANSYS. The pressure is applied on the cylinder and the deformation, strain and stress are acquired as results.Here the conventional stainless steel is optimized by different materials like EN8, Composite Matrix (Ti-6Al-4V-12TiC) and carbon fiber (high Strength). The results of the above materials are compared and the best suitable material can be chosen.

INTRODUCTION:

The vast majority of bulk cargo can be transported by heavy dump trucks, so they are widely used in many industries. Hydraulic cylinder is a key device of the dump trucks which plays an important role in the unloading process. With the center of gravity constantly rising, the stability of the dump truck decreases. The quality of the hydraulic cylinder is directly related to the safety of the dump truck. It also has some influence on the loading efficiency, work efficiency, reliability and the maintenance cost.

So the design and development of multistage hydraulic cylinder is very important in the whole design of dump trucks. Generally, the working environment of the dump trucks is severe, therefore the hydraulic cylinder needs high performance. It should have enough strength, stiffness and supporting stability to ensure the normal operation of the device. The traditional test method of the hydraulic cylinder in real situation is costly and the quantitative analysis of force is very difficult.

Moreover the traditional method of physical prototype-manufacture-test greatly increases the cycle and the cost of new product development. The process of research and development is very long. The technology of CAD was introduced to the design and development of multistage hydraulic cylinder in this paper. The three-dimensional digital model of the multistage hydraulic cylinder was established. This way is significant to improving the design quality, shortening the design cycle and reducing the development cost.

II.ESTABLISHMENT AND ASSEMBLING OF THREE-STAGE HYDRAULIC CYLINDER MODEL:

With the increase of long truck body market demand, the proportion of dump truck is growing. In engineering, front lifting- up type is often chosen in the dump truck that the carriage length is more than 6 mile. Because centre of gravity of the structure of the front lifting-up multistage hydraulic cylinder is lower, stability is better in driving, and the impact resistance is better, the application of front lifting- up multistage hydraulic cylinder brings a great breakthrough to the dump truck body. The hydraulic cylinder designed in this paper is a three-stage telescopic cylinder which is used in front lifting- up dump truck.

OPERATION :

Hydraulic cylinders get their power from pressurized hydraulic fluid, which is typically oil. The hydraulic cylinder consists of a cylinder barrel, in which a piston connected to a piston rod moves back and forth. The barrel is closed on each end by the cylinder bottom (also called the cap end) and by the cylinder head where the piston rod comes out of the cylinder.

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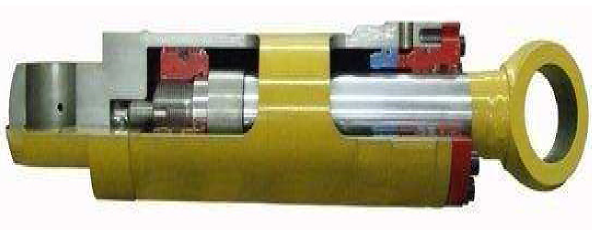
The piston has sliding rings and seals. The piston divides the inside of the cylinder in two chambers, the bottom chamber (cap end) and the piston rod side chamber (rod end). The hydraulic pressure acts on the piston to do linear work and motion.Flanges, trunnions, and/or clevisses are mounted to the cylinder body. The piston rod also has mounting attachments to connect the cylinder to the object or machine component that it is pushing.A hydraulic cylinder is the actuator or “motor” side of this system. The “generator” side of the hydraulic system is the hydraulic pump which brings in a fixed or regulated flow of oil to the bottom side of the hydraulic cylinder, to move the piston rod upwards. The piston pushes the oil in the other chamber back to the reservoir. If we assume that the oil pressure in the piston rod chambe r is approximately zero, the force F on the piston rod equals the pressure P in the cylinder times the piston area A: $F = P \times A$
.

The piston moves instead downwards if oil is pumped into the piston rod side chamber and the oil from the piston area flows back to the reservoir without pressure. The pressure in the piston rod area chamber is (P ull Force) / (piston area - piston rod area).



Material used:

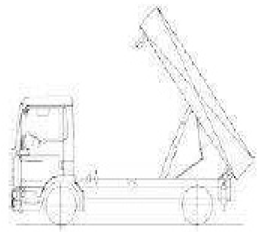
NBR
VITON
HNBR

Tipping Mechanism:

Hydraulic cylinder: A hydraulic cylinder is placed below the body of truck longitudinally at one end of the truck; the piston end of the hydraulic cylinder is connected by the means of a pivot joint to the trolley of truck as well as with the chassis. In the forward stroke of the cylinder it pushes the truck trolley upward thus gives necessary lift for tipping. So, in forward stroke of the cylinder truck gets unloaded. In the return stroke of the cylinder the body of the truck comes to its original position figure shows working of existing mechanism. The geometric features in the automotive system are first reviewed in this project. The parameters regarding various driveline components are reviewed.

The material properties of driveline components are referred from design data handbooks, material handbooks. The failure theories for different load condition are considered in analyzing the driveline components. The ultimate strengths that are exhibitedby the materials are taken into consideration to predict about the failure criteria.

Existing Tipper Trolley



Existing Tipper Mechanism

How Typical Tipper Trucks Works:

The tipping mechanism is the heart of a three way tipper construction truck. Tipping mechanism works basically on the followings:

Hydraulic cylinder:

A hydraulic cylinder is placed below the body of truck longitudinally at one end of the truck; the piston end of the hydraulic cylinder is connected by the means of a pivot joint to the chassis of truck as well as with the chassis. In the forward stroke of the cylinder it pushes the truck body upward thus gives necessary lift for tipping.

CALCULATIONS OF CYLINDER DESIGN:

Design procedure for hydraulic power pack Considering tipper trolley size for calculating in hydraulic design as follows:

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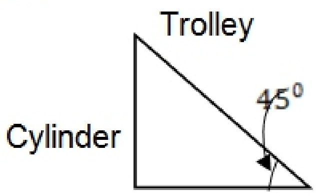
Capacity of tipper = 16 MT Load / weight of body is body – 1150 kg, tipper gear – 200 Kg, sheet system – 1650 kg Total weight for design of pin and hinge is 19000 kg. Width of trolley = 2000 mm Length of trolley = 3600 mm (12 feet) Maximum load to be operated including trolley weight = 19 MT .

Assumptions:

Right & left side tilting hydraulic cylinder will be kept in the centre of trolley length on their respective edges as indicated. Cylinder will be of fixed/rigid type mounting in vertical position. Though two guide rods can be provided Backside tilting hydraulic cylinder will be kept in the centre of trolley width. Cylinder will be of intermediate trunnion mounting type.

Calculation of Stroke for Cylinder:

$$L = tan45^0 \times 3600$$



$$L = 1 \times 3600$$

$$L = 3600mm$$

Length of trolley = 3.6 meter Cylinder will be operated at full length and thus stroke of hydraulic cylinder will be calculated accordingly. Therefore, Stroke of hydraulic of hydraulic cylinder (L) To find working pressure: Considering max working pressure of 210 bar (3000 psi) due to limitation of working of many hydraulic valve at 250bar To calculate area of hydraulic cylinder

As per ISO standards for hydraulic cylinder of standard boresizes Therefore, Bore dia. will be equal = 100 mm as per std sizes Exact working pressure = 19000 / 90.76 = 208 kg/cm2 To calculate volume flow – liter/min : Assuming the maximum evacuation time of 2 min in which the complete hydraulic cylinder will operate to its maximum stroke. Also the stroke of backside tilting hydraulic cylinder is being considered for flow calculation (Q) owing to maximum oilvolume usage.

$$speedV = \frac{\text{max storke of backside tilting hydraulic cylinder}}{\text{max. evacuation time}}$$

$$= \frac{3600}{3}$$

$$=1200mm$$

$$=120cm$$

$$\therefore \text{Flow Quantity} \qquad Q - \text{Area} \times \text{Speed}$$

$$-90.76x\frac{120}{1000}$$

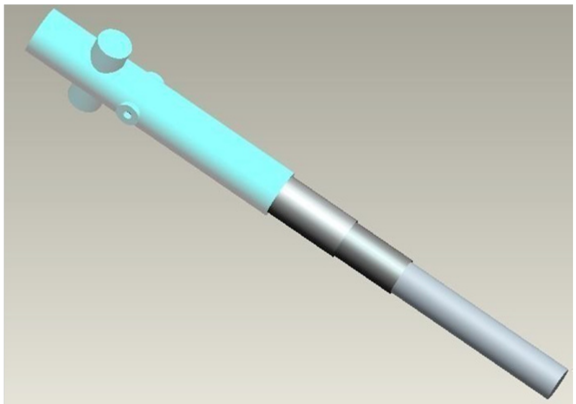
$$= 10.89 \text{ lpm}$$

Q=10 lpm considering ISO Std for hydraulics

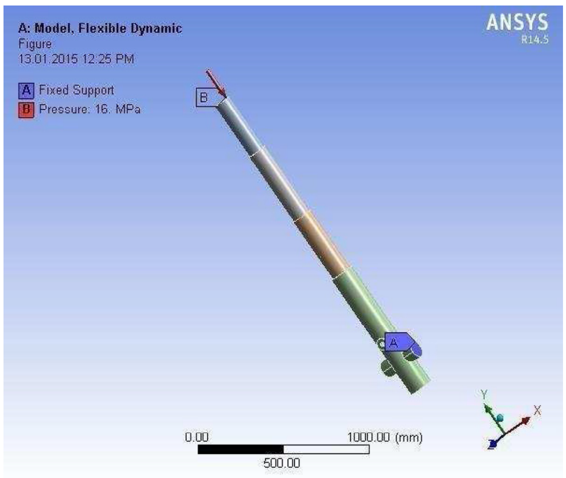
Power calculation for Motor:

Backside tilting hydraulic cylinder will be telescopic type in nature having each step stroke of 800 mm as per bore diameter mentioned below. Borediameters of backside tilting hydraulic cylinders are 50,63 & 100 mm as per ISOstandard for hydraulics. This will be the HP of motor needed for operating 10 lpmhydraulic pump at std. 1440 rpm and no load condition.

3 DIMENSIONAL VIEW OF 3 STAGE CYLINDER IN Pro-E



STATIC STRUCTURAL LOADS APPLIED ON THE TOP FACE



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MATERIAL PROPERTIES:

Stainless Steel > Constants

Structural	
Young's Modulus	1.93e+011 Pa
Poisson's Ratio	0.31
Density	7750. kg/m³
Thermal Expansion	1.7e-005 1/°C
Tensile Yield Strength	2.07e+008 Pa
Compressive Yield Strength	2.07e+008 Pa
Tensile Ultimate Strength	5.86e+008 Pa
Compressive Ultimate Strength	0. Pa
Thermal	
Thermal Conductivity	15.1 W/m·°C
Specific Heat	480. J/kg·°C
Electromagnetics	
Relative Permeability	10000
Resistivity	7.7e-007 Ohm·m

EN8 STEEL > Constants

Structural	
Young's Modulus	2.e+011 Pa
Poisson's Ratio	0.29
Density	7845. kg/m³
Thermal Expansion	1.21e-005 1/°C
Thermal	
Thermal Conductivity	48.1 W/m·°C
Specific Heat	515. J/kg·°C
Electromagnetics	
Resistivity	2.21e-003 Ohm·m

CARBON FIBER(high strength) > Constants

Structural	
Young's Modulus	2.e+011 Pa
Poisson's Ratio	0.2
Density	7850. kg/m³
Thermal Expansion	0. 1/°C

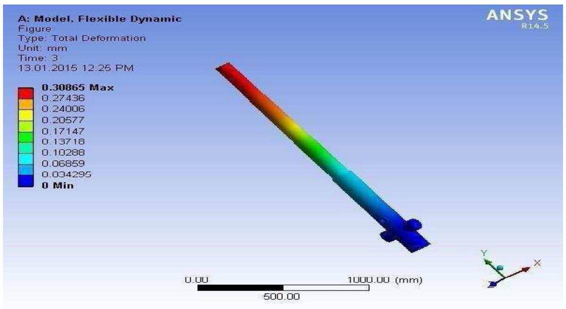
Ti-6Al-4V+12% TiC > Constants

Structural	
Young's Modulus	1.14e+011 Pa
Poisson's Ratio	0.342
Density	4430. kg/m³

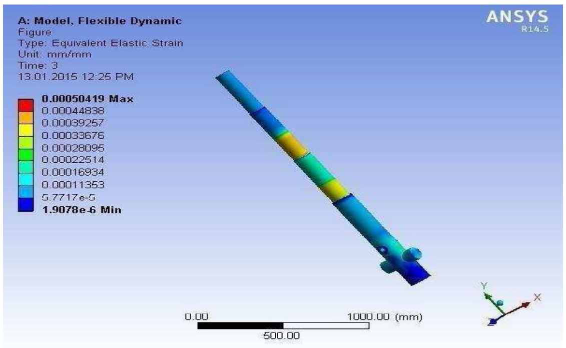
RESULTS:

THREE STAGE CYLINDER (Stainless steel)

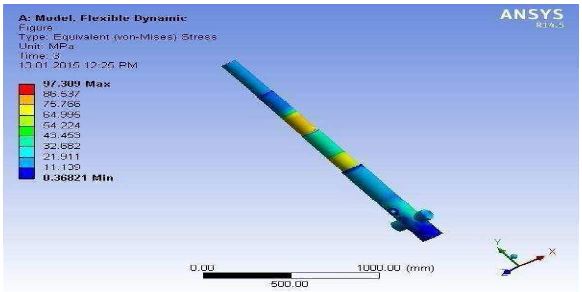
TOTALDEFORMATION:



EQUIVALENT ELASTIC STRAIN:



EQUIVALEN T STRESS:



TABULATION:

RESULTS AND COMPARISON OF ABOVE MATERIALS

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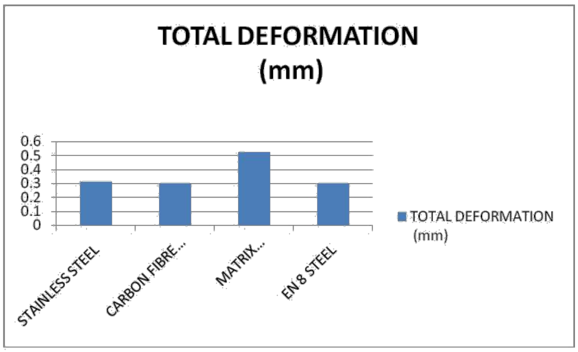
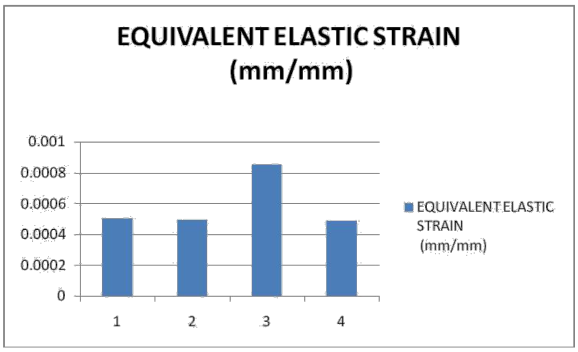
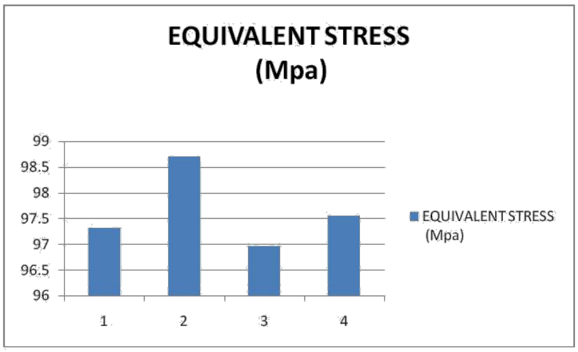
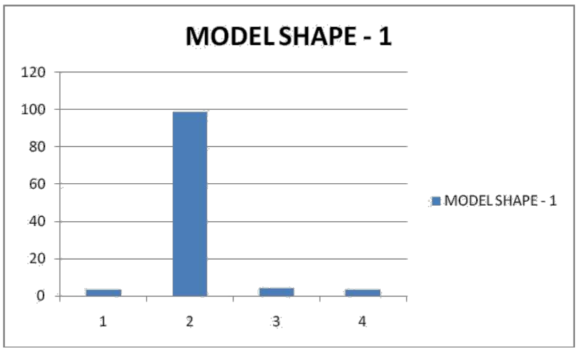
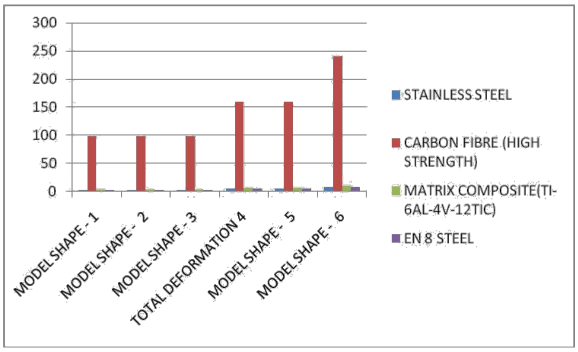
S.N O.	PARTICUL ARS	STAINLESS STEEL	CAR BONFIBRE (HIGHSTRE NGTH)	MA TR IXCO MP OSITE (TI- 6AL- 4V-12 TIC)	EN 8STE EL
1	TOT ALDEFO RMAT ION (mm)	0.30865	0.29901	0. 52145	0. 298 15
2	EQU IVA L ENT ELASTICST RAIN (mm/ mm)	0.000 50 419	0.000 49 354	0.000 85 05	0. 000 48 77
3	EQU IVA L ENT STRESS(M pa)	97.309	98.708	96.95 7	97.5 47
4	MODELSH APE - 1	3.1397	98.65	4.152 7	3.12 06
5	MODELSH APE - 2	3.1397	98.65	4.152 7	3.12 06
6	MODELSH APE - 3	3.1397	98.65	4.152 7	3.12 06
7	MODELSH APE - 4	5.0604	159.04	6.692 7	5.02 99
8	MODELSH APE - 5	5.0737	159.46	6.710 5	5.04 31
9	MODELSH APE - 6	7.6754	241.11	10.15 3	7.62 84











CONCLUSION:

The three-stage hydraulic cylinder here is analyzed with different materials. The conventional material, stainless steel is compared with the optimizing materials under same load and the results are obtained and compared. Based on the Pro/E and ANSYS, the task of modeling and analyzing of hydraulic cylinder used in dump trucks can be completed quickly and efficiently.

From this method, we conclude that EN8 has low values of deformation compared to conventional and other optimized materials. Also carbon fiber can be considered as it has the deformation value nearer to EN8.Thus from this project, we are able to understand the materials effect in mechanical application and also we gain knowledge in pro-Engineer and ansys workbench.

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