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Design and Analysis of Rigid Body Truck

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Abstract: **The objective of paper is to find out best material and most suitable sub-frame for CATERPILLER 797F mining truck with the constraints of maximum shear stress, equivalent stress and deflection of the chassis under maximum load condition. In present the chassis which are used for making buses and trucks are C and I cross section type, which are mostly made of Steel alloy. The Chassis with high strength cross section is needed to minimize the failures including factor of safety in design assurance to optimize the life chassis. In the present work, we have taken higher strength as the main issue, so the dimensions of an existing vehicle chassis of a CATERPILLER 797F mining truck is taken for analysis with materials namely ASTM A710 Steel, ASTM A302 Alloy Steel and Aluminum Alloy 6061 subjected to the same load. The different vehicle chassis have been modeled by considering three different cross-sections namely C, I and Rectangular Box (Hollow) type cross sections. The problem to be dealt for this dissertation work is to Design and Analyze the new Sub-frame as support for the existing chassis of CAT 797F mining truck. The report is the work performed towards the optimization of the automobile chassis by new design of sub-frame with constraints of stiffness and strength. The modeling is done using Catia, and analysis is done using Ansys.**

INTRODUCTION

The chassis is considered to be one of the significant structures of an automobile. It is the frame which holds both the Truck body and the power train. Various mechanical parts like the engine and the drive train, the axle assemblies including the wheels, the suspension parts, the brakes, the steering components, etc., are bolted onto the chassis. The chassis provides the strength needed for supporting the different vehicular components as well as the payload and helps to keep the automobile rigid and stiff. Consequently, the chassis is also an important component of the overall safety system. Another supporting member of the chassis is sub frame. So our objective is to change the existing model sub frame into a new model sub frame and the material used for sub-frame. By changing sub frame the life of the hydraulic system can be increased. Furthermore, it ensures low levels of noise, vibrations and harshness throughout the automobile.

Creating a Solid Model

A Three Dimensional solid model of sub-frame is created on the computer using CATIA, Inventor and Ansys

Finite Element Analysis

There are three main steps, namely: pre-processing, solution and post processing. In pre-processing (model definition) includes: define the geometric domain of the problem, the element type(s) to be used, the material properties of the elements, the geometric properties of the elements (length, area, and the like), the element connectivity (mesh the model), the physical constraints (boundary conditions) and the loadings.

In solution phase, the governing algebraic equations in matrix form are assembled and the unknown values of the primary field variable(s) are computed. The computed results are then used by back substitution to determine additional, derived variables, such as reaction forces, element stresses and heat flow. Actually, the features in this step such as matrix manipulation, numerical integration and equation solving are carried out automatically by commercial software. In post processing, the analysis and evaluation of the result is conducted in this step

A. *Theoretical Results for C & I Cross-Section*

MATERIAL	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	425	239.7	3.06
ASTM A302 Alloy Steel	330	182.08	2.98
Aluminum alloy 6061	152.7	86.75	7.84

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B. ***Theoretical Results for Rectangular Box Cross-Section***

MATERIAL	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	414.35	227	3.06
ASTM A302 Alloy Steel	326.28	178.36	2.98
Aluminum alloy 6061	148	82.54	7.1

C. ***FEA (Ansys) Results for C Cross-Section type***

MATERIAL	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	180.32	67.82	5.54
ASTM A302 Alloy Steel	153.6	63.54	7.8
Aluminum alloy 6061	133.44	58.9	19.56

D. ***FEA (Ansys) Results for I Cross-Section type***

MATERIAL	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	187.4	97.6	7.3
ASTM A302 Alloy Steel	173	86.55	10.27
Aluminum alloy 6061	156.5	78.5	15.33

E. ***FEA (Ansys) Results for Rectangular Box Cross-Section type***

MATERIAL	Von Mises Stress (MPa)	Max. Shear Stress (MPa)	Deformation (mm)
ASTM A710 Steel	78	18.55	2.81
ASTM A302 Alloy Steel	63.44	13.04	2.4
Aluminum alloy 6061	58.72	6.56	7.82

CAT 797F mining truck

Dimensions

Front Canopy Height – Empty	7 709.0 mm
Loaded Ground Clearance	786.0 mm
Height to Top of ROPS – Empty	6526.0 mm
Loading Height – Empty	6998.0 mm
Inside Body Depth – Maximum	3363.0 mm
Overall Height – Body Raised	1 5701.0 mm
Engine Guard Clearance – Loaded	1025.0 mm
Rear Axle Clearance – Loaded	947.0 mm
Overall Body Length	1 4802.0 mm
Inside Body Length	9976.0 mm
Overall Length	15080.0 mm
Wheelbase	7195.0 mm
Rear Axle to Tail	3944.0 mm

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 9, September 2017

Dump Clearance	2017.0 mm
Centerline Front Tire Width	6534.0 mm
Overall Canopy Width	9116.0 mm
Outside Body Width	9755.0 mm
Inside Body Width	8513.0 mm
Centerline Rear Dual Tire Width	6233.0 mm
Overall Tire Width	9529.0 mm

Material and specification of

material of the chassis is ASTMA A710 steel

front overhang (a)	= 1972 mm
rear overhang (c)	= 2380 mm
wheel base (b)	= 7195 mm
Modulus of Elasticity, E	= 2.10 x 10^5 N/mm^2
Poisson Ratio	= 0.28
capacity of truck	= 4000 kg = 39240 N
capacity of truck with 1.25%	= 49050 N
weight of the body and engine	= 2000 kg =19620 N

Chassis has two beams. So load acting on each beam is half of the Total load acting on the chassis.

Load acting on the single frame

= capacity of the chassis + weight of the body and engine

= 49050 + 19620 = 68670 N/Beam

A. Calculation for Reaction

Beam is simply clamp with shock absorber and leaf spring. So, beam is considered as a simply supported beam supported at C and D with uniform distributed load.

Load acting on the entire span of the beam

= 68670 N

Length of the beam

= 9936 mm

Uniformly Distributed Load

= 68670 / 9936 = 3.45 N/mm

For getting the load at reaction C and D, taking the moment about C and we get the reaction load generate at the support D. Calculation of the moment are as under.

Moment about C:

3.45 ×1972×1972/2

= 3.45×7195×7195/2) - (Rd×7195) + (3.45×2380×9167)

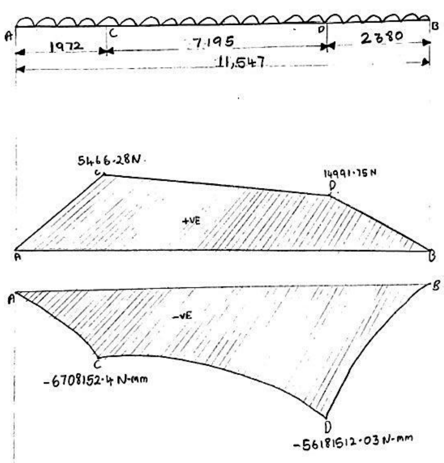
Rd = 21940.50 N

Total load acting on the beam

= 3.45 × 9936 = 34279.2 N

Rc + Rd = 34279.2

Rc = 12338.7 N



B. Calculation of shear force and bending moment:

Shear force calculations:

Fa = 0 N

Fc = (-3.45x1972) + 12338.7 = 5466.28 N

Fd = (-3.45x9167) + 34279.2 + 12338.7 = 14991.75N

Fb = 0 N

Bending moment calculations:

Ma = 0 Nmm

Mc = (-3.45x1972x1972)/2 = -6708152.4 Nmm

Md = [(-3.45x9167x9167)/2] + (12338.7x7195)

= -56181512.03 Nmm

Mb = 0 Nmm

C. Bending Stress Calculations

Moment of inertia about x-x axis,

$I = \frac{bh^3}{12} - \frac{b_1 {h_1}^3}{12}$ = 382050000 mm4

Basic bending equation is given by, $\frac{M}{I} = \frac{\sigma}{Y} = \frac{E}{R}$

Maximum bending moment acting on the beam, Mmax = 56181512.0 Nmm

Bending stress acting on the beam = 296.18 N/mm2

D. Shear Stress Calculations

Assume angle of twist = 1°

$\theta = 1° \times \frac{\pi}{180}$ = 0.017452 rad.

By considering the whole system as a one rotational body and as per following data, when in twist from its support.

Width of the chassis = 4580mm

Length of chassis = 99760mm

Distance between two reactions = 7195mm

Modulus of rigidity for mild steel = 78.125 N/mm2

Now basic rule for Twisting Moment is: $\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L}$

Shear stress, τ = 346.919 N/mm2

According to Von Mises Stress Theory,

Von Mises Stress

$= \sqrt{\sigma^2 + 3\tau^2}$ = 669.911 MPa

Principal Stresses, $\sigma_{1,2}$

$= \frac{1}{2}\left[(\sigma x + \sigma y) \pm \left(\sqrt{(\sigma x - \sigma y)^2}\right) + 4\tau xy^2\right]$

Where σ1 and σ2 are the major & minor Principle Stresses respectively

Maximum Shear Stress = $\frac{\sigma_1 - \sigma_2}{2}$ = 70.739 MPa

Deflection of Chassis

$= \frac{W \times (b-X)}{24EI}[X(b-X) + b^2 - 2(c^2 + a^2) - \frac{2}{b}[Xc^2 + a^2(b-x)]]$

Where W= Weight of Chassis

= 68670 N

a, b and c are the front overhang, wheel base and rear overhang respectively.

X = Total length/2

Deflection of Chassis = ± 4.87 mm

$\cong 5mm$

DESIGN OF CHASIS FRAME USING CATIA

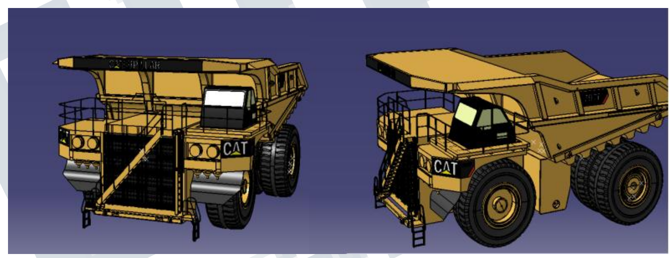


Fig 1 Catia Model Of Caterpiller 797f Mining Truck

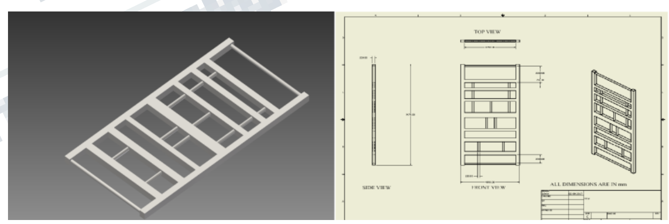


Fig 2 Model And Dimensions Of Sub Frame

FINITE ELEMENT ANALYSIS OF CHASIS USING ANSYS WORK BENCH

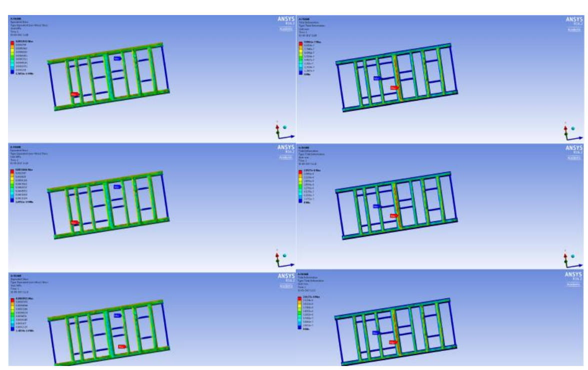


Fig 3 Von Mises Stress And Total Deformation Of ASTM A710 Steel, ASTM A302 Alloy Steel, Aluminum Alloy 6061

CONCLUSION :

In the present work, new model sub frame for CATERPILLAR 797f mining truck was analyzed using ANSYS 16.2 software. From the results, it is observed that the Sub frame is more in strength when compared to the existing one. Von Mises stress and Maximum Shear stress i.e., 58.72MPa & 6.56MPa respectively for Aluminum Alloy 6061 in all the three types of chassis of different cross section. Finite element analysis is effectively utilized for addressing the conceptualization and formulation for the design stages. Based on the analysis results of the present work, the following conclusions can be drawn.

1) Part is safe under the given loading condition.

2) To improve performance, geometry has been modified which enables better withstanding capability and increases the life of the hydraulic system

3) The generated Von Mises Stress & Maximum Shear Stress is less than the permissible value so the design is safe for all three materials

4) Shear stresses were found minimum in Aluminum alloy 6061 and maximum in ASTM A710 steel under given boundary conditions.

5) Von Mises stresses were found minimum in Aluminum alloy 6061 and maximum in ASTM A710 Steel under given boundary conditions.

6.Von Mises stress and Maximum Shear stress for Aluminum Alloy 6061 in all the three types of materials of three different cross section type of LadderChassis.

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