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DESIGN AND STATIC ANALYSIS OF THREE AXIS PNEUMATIC DUMPER

Dr. Sushila Rani*

* Assistant Professor, Mechanical Engineering Department, Delhi Technological University, New Delhi, India

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ABSTRACT

Dumpers have always played an important role for carrying bulk loads, often for carrying building loads. To dump the materials at particular site in the proper direction is challenging at a construction site. It is usually time taking and difficult to keep dumper in assigned position in order to dump the materials. To overcome this limitation the modification in the design of existing dumper is necessary for easier dumping of materials. In this work, a new design is proposed for dumper which is movable in any direction to dump the material; the three-dimensional motion is achieved by introducing a pneumatic cylinder along with a chain sprocket mechanism. In this research work a three axis pneumatic dumper has been designed and analyzed using Finite Element based software ANSYS® to overcome the difficulty in unloading the materials in small compact streets and small roads. Static structural analysis is carried to evaluate maximum equivalent stress, shear stress, elastic strain, total deformation of three axis pneumatic dumper. It is observed that the results obtained by computer analysis of three axis dumper are well corroborated with the results obtained in physical aspect on foreground. By using a modified design, the dumper is capable of tilting in three directions without application of any impact force.

KEYWORDS: Three axis pneumatic dumper, Static structural analysis, *ANSYS*® software

I. INTRODUCTION

Dumpers are used to transporting loose material such as sand, gravel or demolition waste for construction site. To dump the materials at particular site in the proper direction is challenging and time consuming at a construction site. In this research work, the modification in the design of existing dumper is carried out for easier dumping. A new design is proposed for dumper which is movable in any direction to dump the material; this three-dimensional motion is achieved by introducing a pneumatic cylinder along with a chain sprocket mechanism. The dump truck is firstly used in late 19th century in the farms of Western Europe. In 1986, Thorny Croft developed a steam dust-cart with a tipper mechanism. The first motorized dump trucks were developed in the United States by small equipment company, The Fruehauf Trailer Corporation. Many researchers proposed changes in dumper design for easy dumping of materials.

Tupkar et al. [1] used a system consisting of electric motor, worm & worm gear mechanism to rotate the dumper horizontally in required direction. They used two chassis frames where the first frame is attached to the worm and worm gear that rotates the trolley horizontally and the second chassis frame is hinged to the pneumatic cylinder which provides the vertical movement. *Prasath et al.* [2] used hydraulic jack mechanism to unload the trailer in the three axes without applying any impact force. They used control valves to activate the ram of the cylinder and by a suitable arrangement of knee joint in the trailer and universal joint in the hydraulic cylinder they could dispatch the load in the trailer in the three axes. The design of this research makes it easier for the driver to unload the trailer and helps in reducing time and fuel consumption. *Slivinskii et al.* [3] performed force calculations on devices used in tipper trailers to determine their kinematic and geometric parameters. *Ganar et al. [4]* developed and tested multidirectional dumper to unload the materials in the trolley for all 1800 possible angles by using pneumatic cylinder and chain drive. *Deshmukh et al.* [5] designed an arrangement in which the engine drive is coupled to the compressor engine such that the compressed air is stored when the engine is running. *Praveen et al.* [6] designed and fabricated a tripper where they have placed a pneumatic cylinder longitudinally at one end of the truck and connected the piston end of the hydraulic cylinder by a pivot joint to the chassis of the trunk. in the foreword stroke the cylinder pushes the truck body upwards and thus the truck gets unloaded. *Pachpore et al.* [7] designed and fabricated a trolley mechanism in which they used a hydraulic jack to lift the trolley for unloading. They used a system of ball and socket joint for lifting the trailer in the

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required direction. For unloading the goods on a particular side the pins of the other two sides are removed and the hinge of that side is fixed with pin. *Reddy et al.* [8] designed a container chassis and analyzed bending stress and deflection to improve its load carrying capacity. To reduce the failure of chassis by bending they added stiffeners between the cross members of the chassis by means of bolts. *Belendez et al.* [9] analyzed the deflection of a cantilever beam of linear elastic material under the action of uniformly distributed load and an external load at its free end. *Gaikwad et al.* [10] designed and analysed multisided tilting mechanism in dump trucks. They proposed placing three hydraulic cylinders each on front side, right side and lift side of trolley to unload loose material on back side, left side and right side of the trolley respectively. *Shinde et al.* [11] have designed and constructed a porotype of 3-way dropping dumper in which the vehicle can be unloaded from the trailer in three axes without application of any impact force. In this research work, a prototype of the pneumatic cylinder arrangement mounted on a chain sprocket mechanism is designed. This prototype allows the entire three axis dumper pneumatic dumper assembly to rotate and achieve motion in three axes. The dimensions of the mild steel chassis are calculated for a sample load of 25 kg based on strength considerations. Structural analysis is done on chassis structure to determine its maximum shear stress, maximum principal stress, principal strain, total deformation. The chassis design is further modified to reduce stress concentrations.

II. THREE DIMENSIONAL MODEL OF THREE AXIS PNEUMATIC DUMPER

The three dimensional cad model of three axis pneumatic dumper is generated by using finite element based software *ANSYS*® as shown in Fig.1. The material properties and dimensions of three axis pneumatic dumper are listed in Table1 and Table 2 respectively. The design obtained has two possible motions: rotational motion of dumper box achieved by gear mechanism and the fixture being suspended on the gear and translational motion of the pneumatic cylinder which pushes the box in such a way as to tilt it at an angle, for the dumper to function. These 2 motions can happen simultaneously and allow the dumper to tilt the box in any direction over 360 degrees. Thus, the dumper has motion along all three axes, constrained only by the length of cylinder rod in pneumatic cylinder.

Fig. 1: CAD model of three axis pneumatic dumper

Table 1: Material properties of structural steel

Material properties	**Structural steel**
Young's Modulus, (N/m^2)	$2.1x10^{11}$
Density (Kg/m^3)	7850
Compressive yield strength, (MPa)	250
Tensile Yield Strength, (MPa)	250
Tensile Ultimate Strength, (MPa)	460

Table 2: Dimensions of three axis pneumatic dumper

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Dimensions	Dumper Box
Length, L,(mm)	247.5
Breadth, b,(mm)	165
Depth, h,(mm)	65.607

2.1 MESHING

During the meshing procedure of the model and in order to increase the calculative capability fine grids were applied to some parts of the volume according to stress concentration in the preliminary examination and coarse grid to the rest of the part. Fig. 2 illustrates the geometry and meshing grids of the numerical model. The mesh was generated using proximity on option. The finite element model generated has 98150 nodes and 63560 elements.

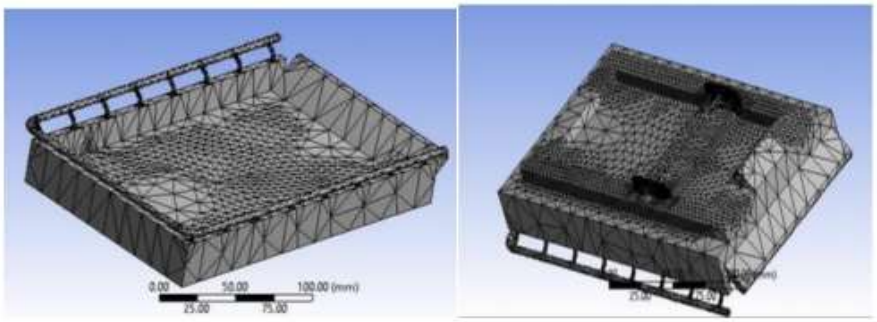

Fig. 2: Coarse and fine meshing of dumper box

III. STATIC ANALYSIS OF THREE AXIS PNEUMATIC DUMPER

Static analysis was carried out to ascertain the critical region of three axis pneumatic dumper. It is also performed to evaluate Equivalent stress, Maximum principal stress, shear stress, total deformation and Equivalent elastic strain. A distributed force of 200 N is applied in the negative Y direction. The loading conditions of dumper box for performing static analysis are shown in Fig. 3.

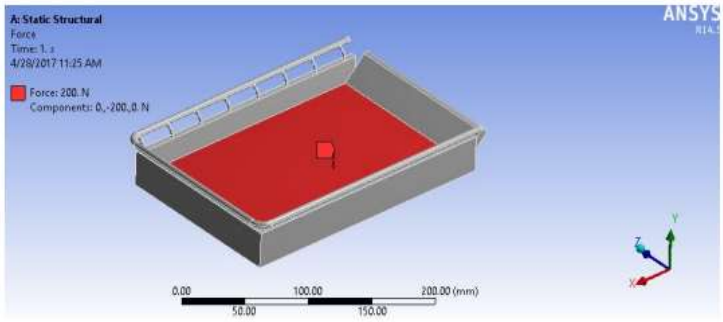

Fig. 3: Loading condition for Static structural analysis

IV. RESULTS AND DISCUSSION OF STATIC ANALYSIS FOR THREE AXIS PNEUMATIC DUMPER

(a) Equivalent stress

The collected value of equivalent stress is 0.79678MPa as shown in Fig. 4.

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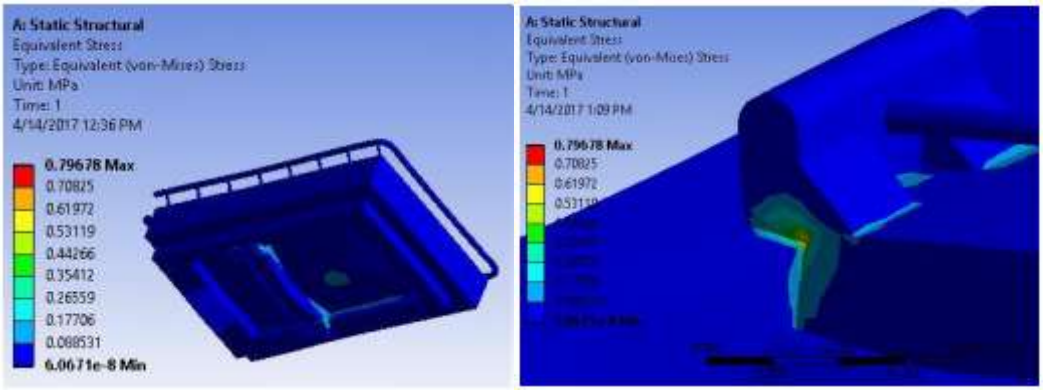

Fig. 4: Equivalent (Von-Mises) stress of three axis pneumatic dumper

(b) Equivalent elastic strain

The collected value of equivalent elastic strain is 6.1582e-6 mm/mm as shown in Fig. 5.

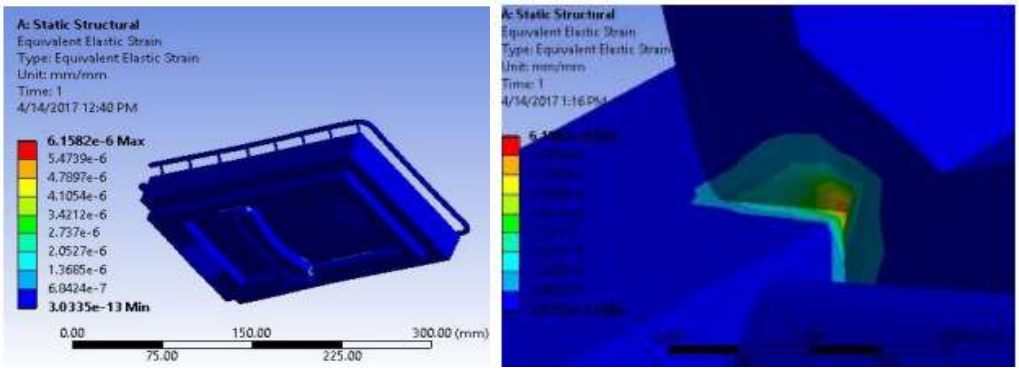

Fig. 5: Equivalent elastic strain of three axis pneumatic dumper

(c) Shear stress

The collected value of shear stress is 0.33058 MPa as shown in Fig. 6.

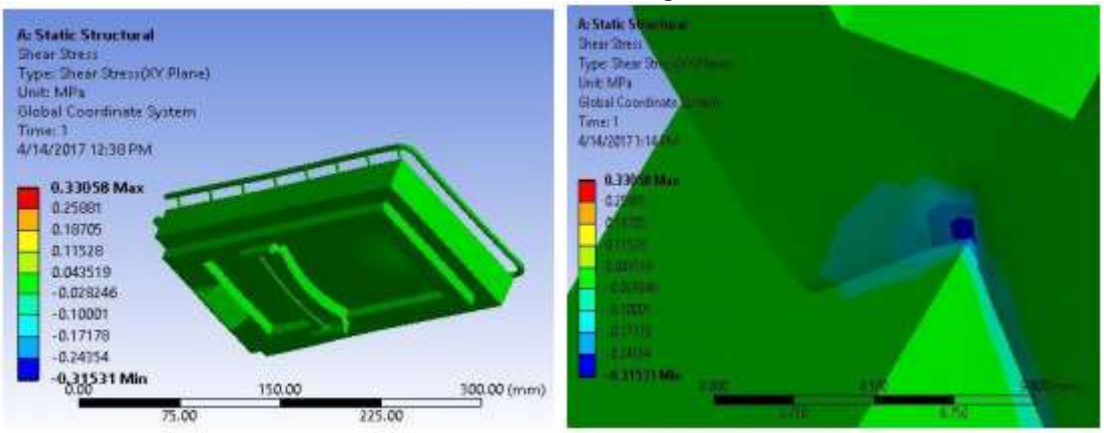

Fig. 6: Shear stress of three axis pneumatic dumper

(d) Total deformation

The collected value of total deformation is 0.0074952 m as shown in Fig. 7.

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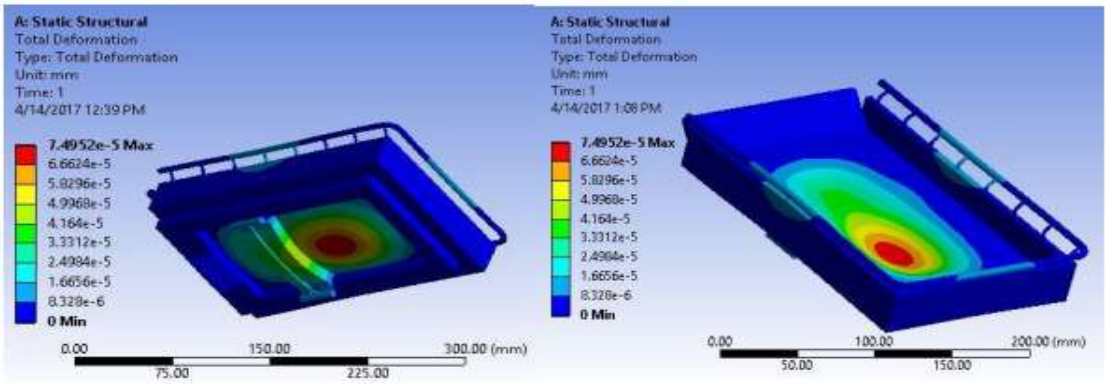

Fig. 7: Total deformation of three axis pneumatic dumper

(e) Maximum principal stress

The collected value of maximum principal stress is 0.47605 MPa as shown in Fig. 8.

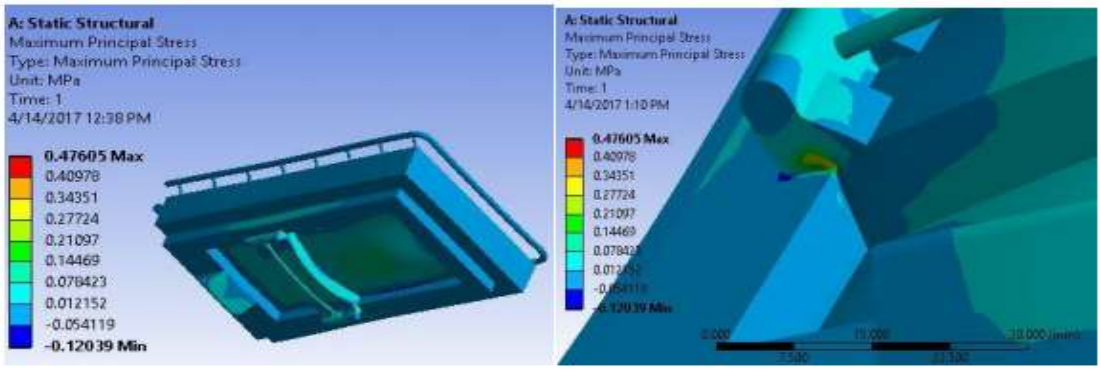

Fig. 8: Total deformation of three axis pneumatic dumper

Static structural analysis represents spike in equivalent stress, maximum principal stress, shear stress in certain regions. These regions are prone to failure. In order to reduce stress concentrations in these regions modifications are needed in the proposed design of three axis pneumatic dumper. The regions for maximum deformation and equivalent strain have also been identified. In these regions, extra metal can be added or cross-sectional area can be increased in order to compensate the effect of deformation. Ribs can also be added in order to reduce the strain. To reduce the stress concentration and prevent chances of failure, fillets have been added in the dumper box geometry as shown in Fig. 9.

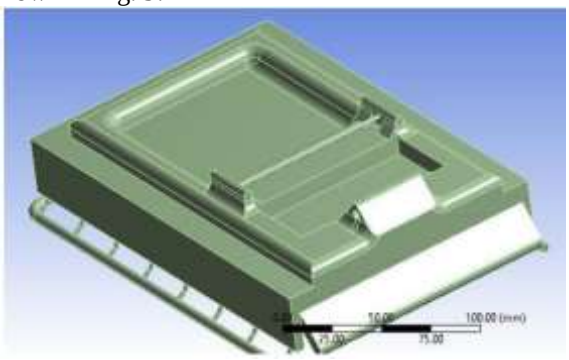

Fig. 9: Modified design of three axis pneumatic dumper

By performing static structural analysis of modified design, the values of Equivalent stress, shear stress, elastic strain and total deformation are 0.40313 Mpa, 0.13307Mpa, 3.4652e-6mm/mm and 0.1176058m respectively as shown in Fig. 10. Table 3 shows the comparison of structural analysis of three axis of pneumatic dumper and modified design of three axis of pneumatic dumper. It is observed that the values of Equivalent stress, shear stress, elastic strain are reduced by 49.41%, 59.75% and 43.73% respectively while the value of total deformation is increased by 1.46%.

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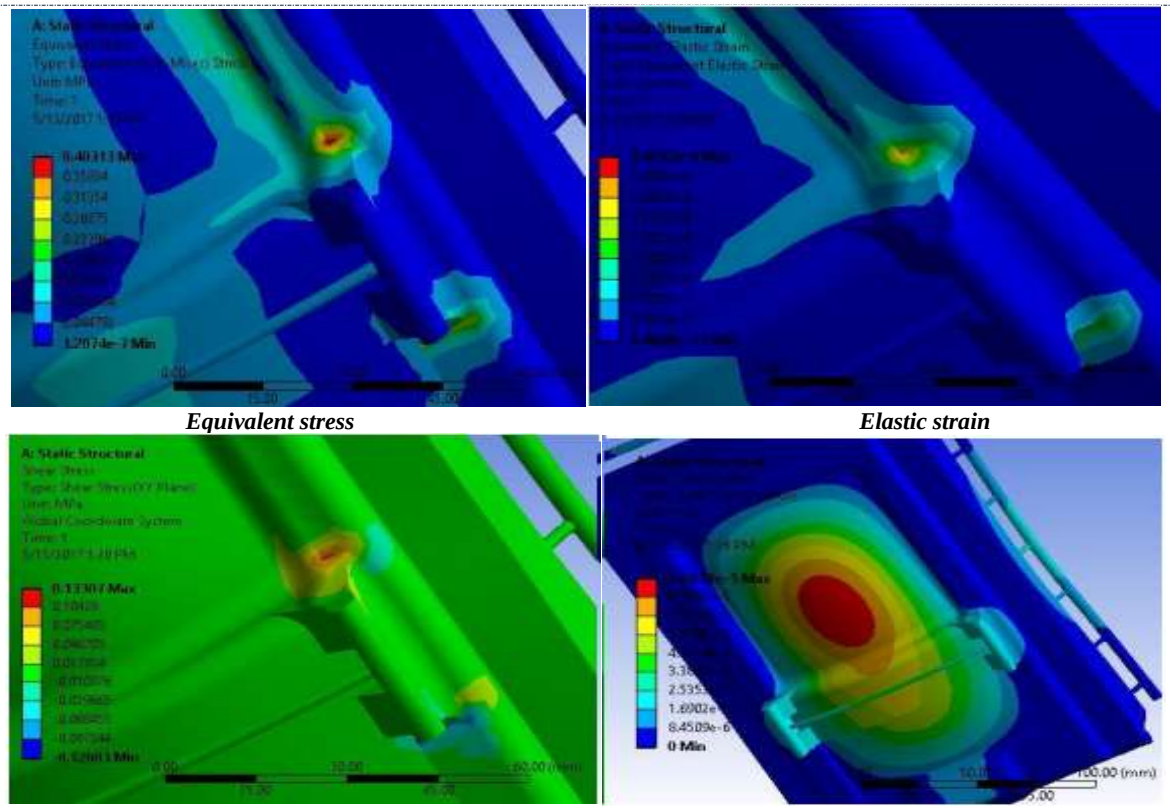

Equivalent stress *Elastic strain*

Shear stress *Total deformation*

Fig. 10: Static structural analysis of modified design of three axis pneumatic dumper

Table 3: Comparison of structural analysis of three axis pneumatic dumper and its modified design

	Static analysis of three axis pneumatic dumper	Static analysis of modified design three axis pneumatic dumper (with fillet)	Percent change
Equivalent stress	0.79678	0.40313	-49.41%
Shear Stress	0.33058	0.13307	-59.75%
Elastic Strain	6.1582e-6	3.4652e-6	-43.73%
Total Deformation	0.1179452	0.1176058	1.46%

V. CONCLUSIONS

The Three axis pneumatic dumper assembly was designed and the dumper box is analyzed computationally. The following conclusions are drawn:

- The new proposed design dumper is operational in narrow space and having applications in all the directions which are not possible by existing dumper design.
- Static structural analysis is performed to evaluate maximum equivalent stress, shear stress, elastic strain and total deformation.
- Results from computer analysis of three axis dumper are well corroborated with the results obtained in physical aspect on foreground.
- Filleting of the dumper box geometry has been done to reduce the stress concentration. The percentage reduction in equivalent stress, shear stress, elastic stain with the filleted geometry is found to be 49.41%, 59.75%, 43.73% respectively.

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