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Finite Element Analysis and Optimization of CNG Cylinder Mounting Cradle for Four Wheeler Cargo Vehicle

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ABSTRACT

The finite element analysis of CNG cylinder mounting cradle is done for checking the strength of mounting arrangement. The results obtained from the analysis of the existing proposal are used for creating the new CNG cylinder mounting proposal. The new proposal is based on optimization process. The finite element analysis for new proposal is also carried out for checking the strength for the loading conditions. By comparative study of analyses the best proposal is suggested for the CNG cylinder mounting cradle.

Keywords: *CNG cylinder mounting cradle, FE analysis, Gravity Analysis.*

I. INTRODUCTION

The CNG cylinder mounting cradle is an arrangement for holding the CNG cylinder on vehicle itself. The existing arrangement of CNG cylinder mounting cradle for four wheeler cargo vehicle is analyzed for its strength. The FE analysis is necessary to make the design safer in all the loading conditions. On the basis of obtained results the new optimized proposal for the mounting cradle is made and again it is checked for its strength and the manufacturability.

The steps involved in FEA process are pre- processing, processing and post- processing. In the pre- processing the geometry of the model is defined and mastering is done for any error in the geometry then constrains, mechanical properties and load are defined. Altair Hypermesh 17.2 is used for the pre- processing of the mounting cradle analysis. In processing geometry, properties, materials, loading conditions are applied to generate matrix equation for each element. Using the value of deflection the stress, strain is calculated. The results are stored and can be used in post processing. Altair Optistruct 17.2 solver is used for processing analysis. In post processing Results obtained in solving step are usually in the form of raw data and difficult to interpret. In post processing means post analysis, a computer aided designing program is utilized to manipulate the data for generating deflected shape of the structure. We can also get stress plots and also animation result. Altair Hyperview 17.2 is used for post- processing of analysis.

II. METHODOLOGY

In this work, linear static analysis and gravity analysis were done to determine the behavior of the CNG cylinder mounting bracket.

A. Gravity Analysis

Gravity analysis determines the strength of the components to withstand against the gravity loads. It also gives the location of failure on the component. 3G bump, 2G braking and 1G cornering these gravity loads are analyzed. These loads are calculated in R&D department by various testing on vehicle on pave.

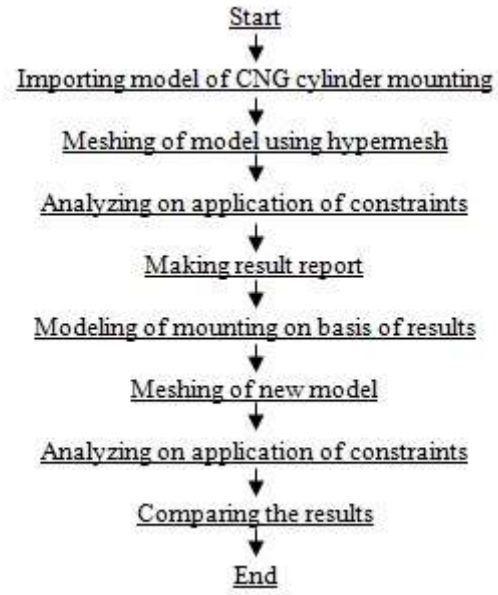

Fig.1 Methodology of analysis

B. Finite Element Analysis

The basic of FEA is to make calculations only at limited numbers of nodes and then interpolate the results for the same surface. The component is divided into number of small elements and all elements are connected to each other by nodes. This converts the infinite degrees of freedom of component to finite degrees of freedom and makes the problem easy to solve.

C. Hyperworks

Hyperworks is one of the most used software in computer aided engineering. It provides surface meshing, solid meshing then the solvers like Optistruct which is used for this analysis. Altair Hyperworks provide many features for mastering the geometry or geometry cleanup tools. There are many more solvers in Hyperworks which are used as per the conditions.

III. FINITE ELEMENT ANALYSIS OF CNG CYLINDER MOUNTING CRADLE PROPOSAL 1

A. CNG cylinder mounting cradle proposal 1

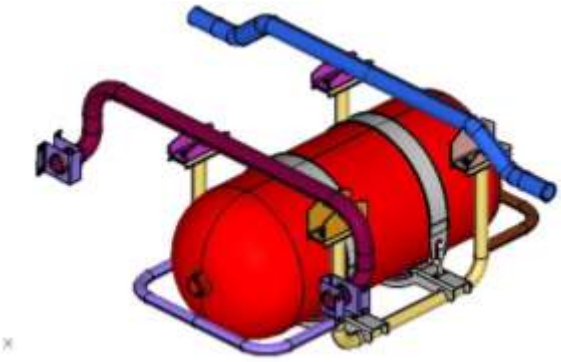

Fig.2 CNG cylinder mounting cradle proposal 1

The weight of the CNG cylinder mounting cradle proposal 1 is 101.6 kg with CNG filled cylinder. This mounting cradle with CNG filled cylinder is fixed to the chassis of four wheeler cargo vehicle from bottom side. The front LH & RH bracket is bolted to chassis and the backside cradle pipe is mounted inside the already existing bracket on chassis.

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B. Meshed model of proposal 1

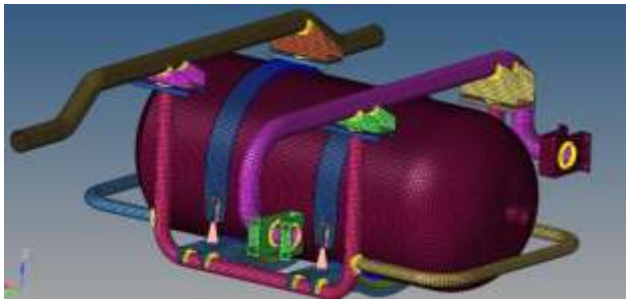

Fig.3 Meshed model of proposal 1

Element details for meshed model:
No. of elements =77212
No. of nodes = 71234
No. of trias = 377
Average size of elements = 5 mm

To check the model for node to node connectivity and to ensure the equal load distributions along the model following model checks are performed.

1. Element quality checks
2. Free edge checks
3. Property checks
4. Material checks

C. Boundary conditions and load cases

The holes which are bolted on front LH & RH bracket are fixed by using single point constraints. The faces of cradle pipe in contact with existing brackets on chassis are also fixed for 6 degrees of freedom by using single point constraints.

The load cases for gravity analysis are as follows

1. 3G bump: 3 × gravity loads is applied on mounting cradle while the cargo vehicle goes under the bump on road. This force is calculated on pave test.
2. 2G braking: 2 × gravity loads is applied on mounting cradle while cargo vehicle applies brakes in running condition. This force is calculated on pave test.
3. 1G cornering: 1 × gravity load is applied on mounting cradle while the vehicle takes turn on corner. This force is also measured on pave test.

D. Results and discussion for analysis

After giving all boundary conditions and load case the generated .HM file is put in Optistruct solver desk to get the results by performing the run. The counter plot for gravity analysis of model is get after the run is performed successfully without any error. The counter plot shows the red color for the area where the stresses are more than the yield strength of material i.e.196 Mpa. The stress results are as follows

1. Stress result for 3G bump loading condition

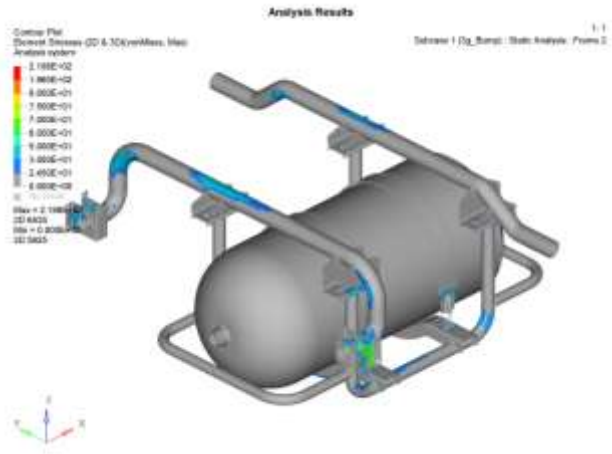

Fig.4 Stress result plot for 3G bump loading.

As the counter plot shows the maximum stress value is 219 Mpa which is above the yield strength of material. Hence the model fails in 3G bump loading condition.

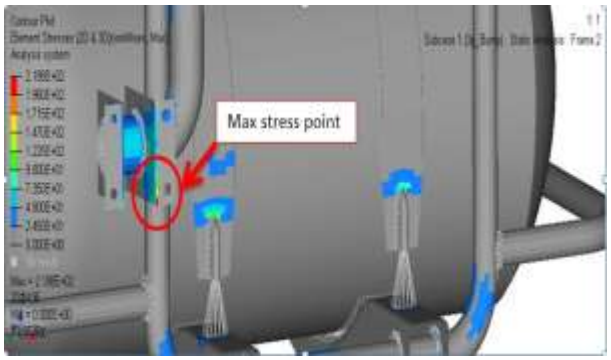

Fig.5 The location of failure in model is at LH bracket.

2. Stress plot for 2G braking loading condition

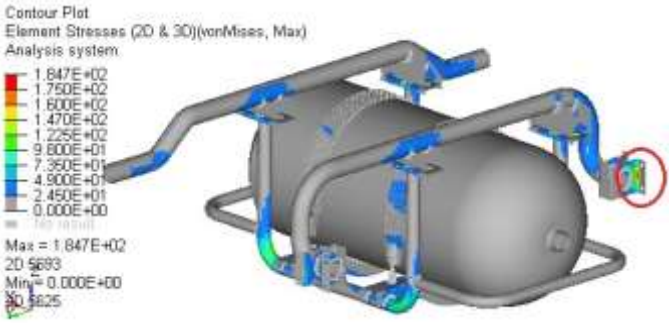

Fig.6 Stress plot for 2G braking loading

The maximum stress in 2G braking condition is 184 Mpa. The stresses in 2G braking loading condition is within the limits.

3. Stress plot for 1G cornering loading condition

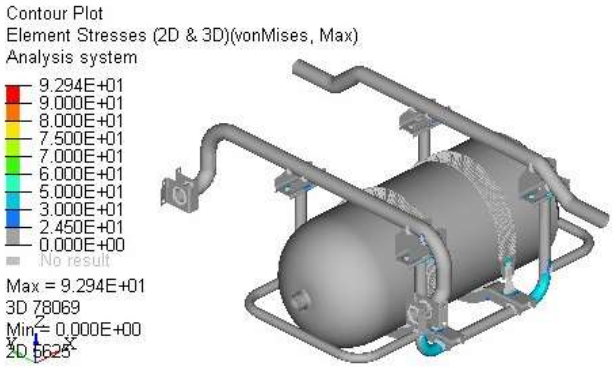

Fig.7 stress plot for 1G cornering loading condition.

The maximum stress in 1G braking loading condition is 92.9 Mpa. The stresses in 1G cornering loading condition is within the limits.

As the result shows the model is not safe in 3G braking loading conditions. Hence this model cannot be used for mounting the CNG cylinder on four wheeler cargo vehicle.

IV. FINITE ELEMENT ANALYSIS OF CNG CYLINDER MOUNTING CRADLE PROPOSAL 2

As the proposal 1 is not safe for mounting the CNG cylinder on four wheeler cargo vehicle we have to change the model for making it safe for mounting CNG cylinder.

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A. CNG cylinder mounting cradle proposal 2

The slight change is made in proposal 1 to make the design safe without changing the whole design and arrangement. The small changes in the previous design to make design safe is always good idea instead of changing the all the design and the arrangement required for fixing the model on vehicle when the model is safe in another conditions.

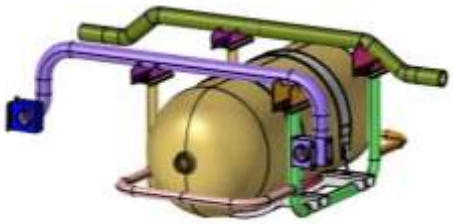

Fig.8 CNG cylinder mounting cradle proposal 2

The LH bracket has stresses above the yield point hence we decided to increase the thickness of LH bracket by 0.5 mm.

The meshing of proposal 1 is used as it is for the proposal 2 the only change made is the thickness of LH bracket is increased by 0.5mm. All the load cases and the constraints are same for the proposal 2. Hence we go directly to the solver run in Optistruct.

B. Result and discussion for proposal 2

1. Stress plot 3G bump loading condition

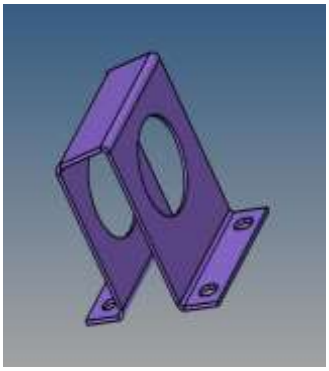

Fig.9 LH bracket with increased thickness

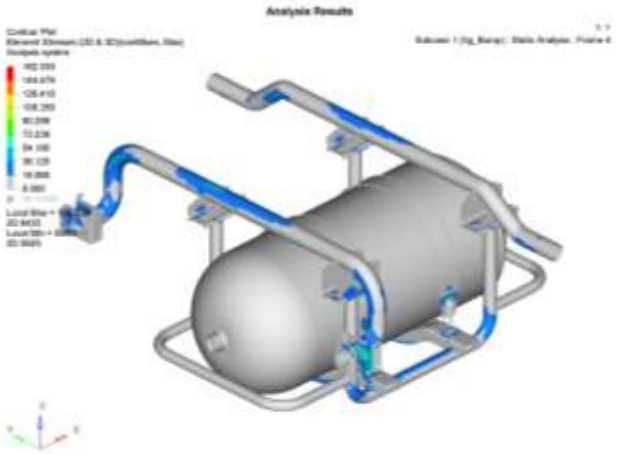

Fig.10 stress plot for 3G bump loading condition.

The max stresses in 3G bump loading condition for proposal 2 is 162.53 Mpa. The stress values are within the limit for proposal 2 in 3G bump loading condition.

2. Stress plot for 2G braking loading condition

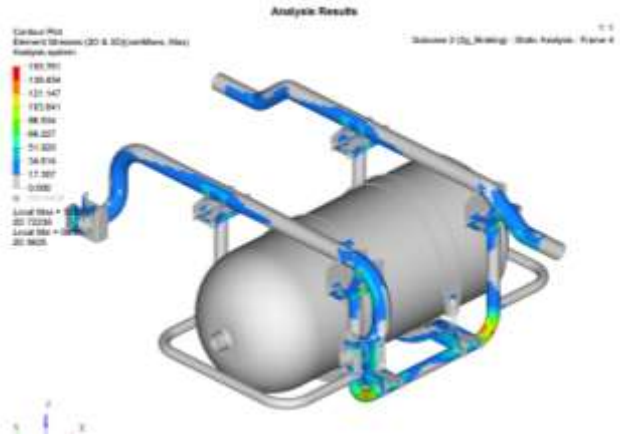

Fig.11 stress plot for 2G braking loading condition.

The maximum stress value in 2G braking loading condition is 155.67 Mpa. Stress values are within the limits for this loading condition.

3. Stress plot for 1G cornering loading condition

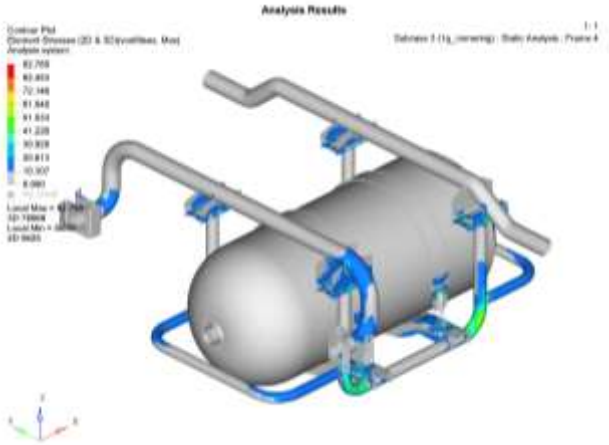

Fig.12 stress plot for 1G cornering loading condition.

The maximum stress values for 2G braking loading condition is 92.76 Mpa.

As the results shows the stress values for all the loading conditions are below the yield strength of the material. Hence the proposal 2 is safe for CNG cylinder mounting cradle for four wheeler cargo vehicle.

V. FINITE ELEMENT ANALYSIS OF CNG CYLINDER MOUNTING CRADLE PROPOSAL 3

The proposal 2 is safe for CNG cylinder mounting but let's check for the optimum design we can make for better arrangement with low cost. Hence we decided to make an optimized solution for CNG cylinder mounting.

A. CNG cylinder mounting cradle proposal 3

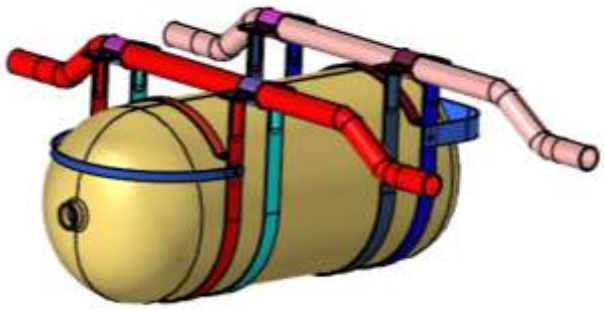

Fig.13 CNG cylinder mounting cradle proposal 3

The front and back movement of cylinder is restricted by the two simple plates. The cylinder is supported by using 4 U plates which restrict the downward motion of cylinder and to restrict the motion in upward direction the two light weight plates are bolted. The side plate and upper plates both are bolted in U plate. The main support of mounting arrangement is the cradle pipes which are used to fix the mounting arrangement to chassis. The total weight of the mounting cradle is 91 kg.

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B. Meshing of proposal 3

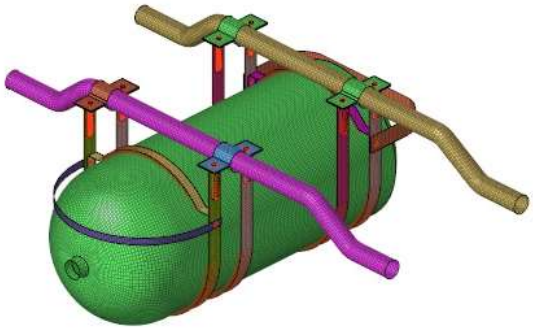

Fig.14 Meshed model of proposal 3

Element details for meshed model:

No. of elements =51838
No. of nodes = 52705
No. of trias = 360
Average size of elements = 5 mm

The loading conditions are same as proposal 1 and 2.

C. Results and discussion

After the loading conditions are applied the .HM file of proposal 3 is put in Optistruct solver for processing the run to get the results.

1) Stress plot for 3G bump loading condition

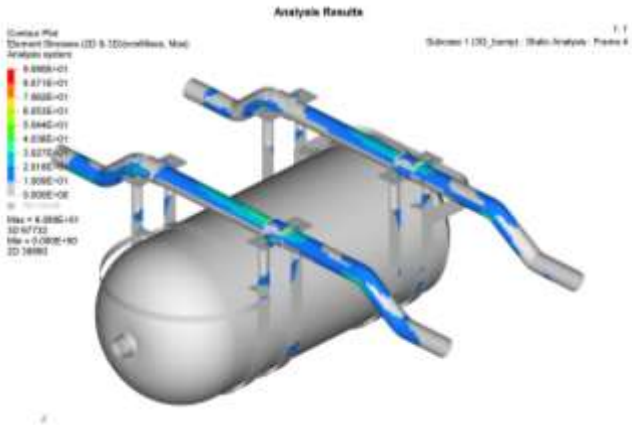

Fig.15 Stress plot for 3G bump loading.

The maximum stress for 3G bump loading condition for proposal 3 is 90.80 Mpa. This stress values are within the safety limits. The locations of the high stresses are spotted by red color spots. The stresses are high at the cradle pipes which supports the whole arrangement.

2) Stress plot for 2G braking loading condition

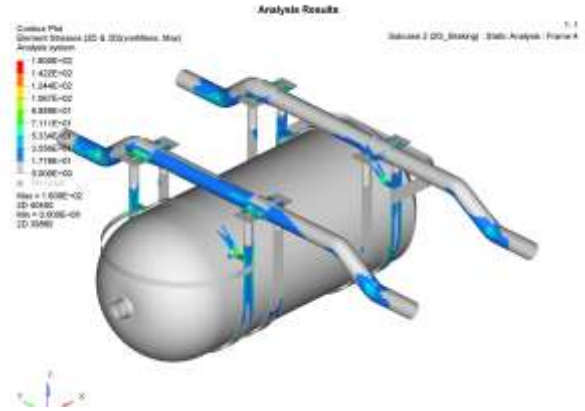

Fig.16 Stress plot for 2G braking loading condition.

The maximum stress in 2G braking loading condition is 160 Mpa. This stress values are within the safety limits for proposal 3. The maximum stresses are in the plate which is restricting the upward motion of the cylinder. This shows that the loading condition and boundary conditions given are in correct sequence. In 2G braking loading conditions the CNG cylinder tries to move upward when the vehicle is in running condition and suddenly applies the brake on the road. Due to the inertia force cylinder tries to move in forward and upward direction. The stress plot shows the red area in upper plates and on front plate supporters.

3) Stress plot for 1G cornering loading condition

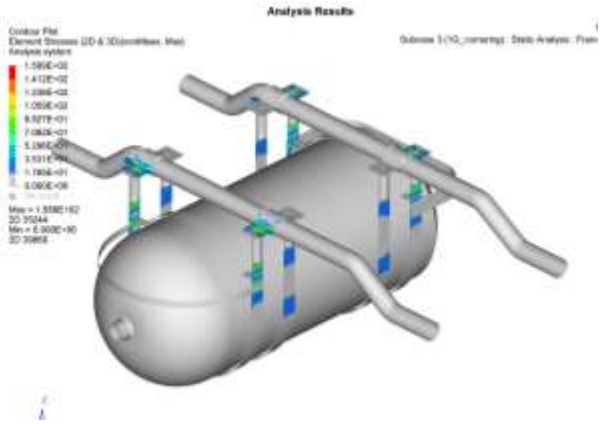

Fig.17 Stress plot for 1G cornering loading condition.

The maximum stress for 1G cornering loading condition is 158.9 Mpa. This stress values are within the limits. Hence the model is safe in 1G cornering loading condition.

The stress values for all the loading condition are within the safety limits. Hence proposal 3 is safe for using s the CNG cylinder mounting cradle for four wheeler cargo vehicle.

VI. COMPARATIVE ANALYSIS

A. Comparative sheet of proposal 1 vs. proposal 2 vs. proposal 3 for stress values

Table no.1 Comparative sheet

Sr. no	Load case (Mpa)	Proposal 1	Proposal 2	Proposal 3
1	**3G bump**	219	162.53	90.80
2	**2G braking**	184	155.67	160
3	**1G cornering**	92.9	92.76	158.9

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The table shows the comparative stress values for proposal 1, proposal 2 and proposal 3. The yield strength of the material is 196 Mpa. The stress values for proposal 1 in 3G bump loading condition is not safe it is above the yield strength of the material. For proposal 2 and proposal 3 stress values for all the loading conditions are within the safety limits. All the stress values are in Mpa.

The proposal 1 is not safe in the 3G bum loading condition. The proposal 2 and proposal 3 are safe in all the loading condition. The weight of proposal 1, 2 and 3 are 101.6kg, 101.8 kg and 91 kg respectively. The weight of proposal 3 is 10.61% less than the proposal 1 and 2.

VII. CONCLUSION

Initial study of mounting cradle proposal is done to understand the mounting cradle design. Linear static analysis is performed to obtain the maximum stress plot for all the 3 proposals.

From the comparative analysis we can conclude that,

1) The maximum stress for proposal 1 in 3G bump, 2G braking and 1G cornering are 219 Mpa, 184 Mpa and 92.9 Mpa respectively.
2) The maximum stress for proposal 2 in 3G bump, 2G braking and 1G cornering are 162.53 Mpa, 155.67 Mpa and 92.76 Mpa respectively.
3) The maximum stress for proposal 2 in 3G bump, 2G braking and 1G cornering are 90.80 Mpa, 160 Mpa and 158.9 Mpa respectively.

The weight of proposal 3 is nearly 10.61% less than the proposal 1 and proposal 2 and the proposal 3 is safe in all the loading condition. Hence it is suggested to use proposal 3 for CNG cylinder mounting cradle for four wheeler cargo vehicle.

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