

Optimisation and Analysis of Riveted Structure with Aluminium Frame

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ABSTRACT

Disadvantage of rivets is that they form a permanent connection and can only be removed by destroying rivet. This problem can be overcome by usage of Aluminium profiles which offer a wide variety of uses when compared to other conventional methods of structure preparation. With dozens of bolt-together connectors available for virtually any load or application, almost any structure can be quickly assembled without special tools or skills by using the proposed aluminium profile. In addition, the Aluminium structural framing would be resistant to corrosive atmosphere and with ease of transportation and available at cheap price. In this paper the main focus is on the structural stability with special type of machine elements is designed & analysed at various loading condition subjected to tensile & compressive loading along with twisting forces. The cost estimation is also analysed for a comparative condition of riveted frame to aluminium frame and thus arrive to a conclusion of the amount of material, time & labour consumption.

Keywords: Rivet, Aluminium Frame, CAD/CAM, Ansys

I. INTRODUCTION

A rivet is a permanent mechanical fastener. Before being installed, a rivet consists of a smooth cylindrical shaft with a head on one end. The end opposite to the head is called the tail. On installation, the rivet is placed in a punched or drilled hole, and the tail is upset, or bucked (i.e., deformed), so that it expands to about 1.5 times the original shaft diameter, holding the rivet in place. In other words, pounding creates a new "head" on the other end by smashing the "tail" material flatter, resulting in a rivet that is roughly a dumbbell shape. To distinguish between the two ends of the rivet, the original head is called the factory head and the deformed end is called the shop head or buck-tail. Because there is effectively a head on each end of an installed rivet, it can support tension loads (loads parallel to the axis of the shaft); however, it is much more capable of supporting shear loads (loads perpendicular to the axis of the shaft). Bolts and screws are better suited for tension applications.[1,2,3]

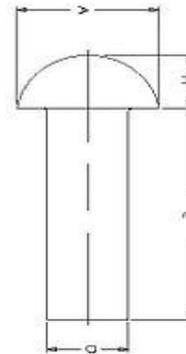


Figure 1. Rivet Design

II. METHODS AND MATERIAL

A. Blind Rivets



Figure 2. Blind Rivets

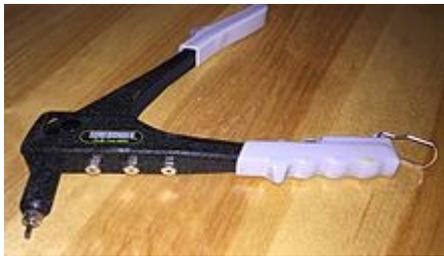


Figure 3. Pop Riveted Gun With Rivet Inserted

Blind rivets, commonly referred to as "pop" rivets (POP is the brand name of the original manufacturer, now owned by Stanley Engineered Fastening, a division of Stanley Black & Decker) are tubular and are supplied with a mandrel through the center. The rivet assembly is inserted into a hole drilled through the parts to be joined and a specially designed tool is used to draw the mandrel into the rivet. This expands the blind end of the rivet and then the mandrel snaps off. These types of blind rivets have non-locking mandrels and are sometimes avoided for critical structural joints because the mandrels may fall out, due to vibration or other reasons, leaving a hollow rivet that has a lower load-carrying capability than solid rivets. Furthermore, because of the mandrel they are more prone to failure from corrosion and vibration. Unlike solid rivets, blind rivets can be inserted and fully installed in a joint from only one side of a part or structure, "blind" to the opposite side.[4]

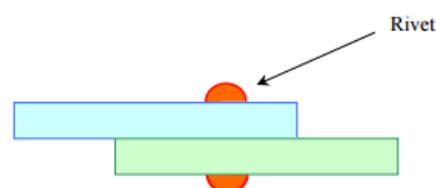
B. Rivets as permanent joints

Often small machine components are joined together to form a larger machine part. Design of joints is as

important as that of machine components because a weak joint may spoil the utility of a carefully designed machine part. Mechanical joints are broadly classified into two classes viz., non-permanent joints and permanent joints.[5] Non-permanent joints can be assembled and disassembled without damaging the components. Examples of such joints are threaded fasteners (like screw-joints), keys and couplings etc. Permanent joints cannot be disassembled without damaging the components. These joints can be of two kinds depending upon the nature of force that holds the two parts.[6] The force can be of mechanical origin, for example, riveted joints, joints formed by press or interference fit etc, where two components are joined by applying mechanical force. The components can also be joined by molecular force, for example, welded joints, brazed joints, joints with adhesives etc. Not until long ago riveted joints were very often used to join structural members permanently.[7]. However, significant improvement in welding and bolted joints has curtailed the use of these joints. Even then, rivets are used in structures, ship body, bridge, tanks and shells, where high joint strength is required.[8]

C. Types Of Riveted Joints

Riveted joints are mainly of two types 1. Lap joints 2. Butt joints 3.1 Lap Joints: The plates that are to be joined are brought face to face such that an overlap exists, as shown below. Rivets are inserted on the overlapping portion. Single or multiple rows of rivets are used to give strength to the joint.[9] Depending upon the number of rows the riveted joints may be classified as single riveted lap joint, double or triple riveted lap joint etc. When multiple joints are used, the arrangement of rivets between two neighbouring rows may be of two kinds. In chain riveting the adjacent rows have rivets in the same transverse line.[10] In zig-zag riveting, on the other hand, the adjacent rows of rivets are staggered. Different types of lap joints are sketched in



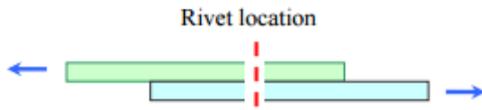


Figure 4. Rivet Location

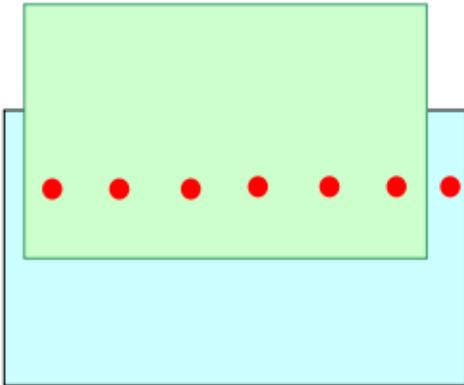


Figure 5. Single Rivet Lap Joint

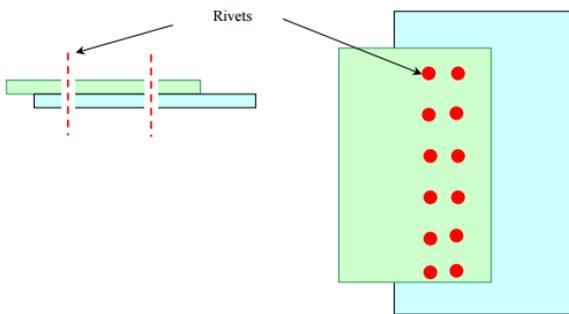


Figure 6. Double Riveted Lap Joint Chain

III. DESIGN AND ANALYSIS

A. Profile Selection

Profile considered in current is shown below as per the standard EN 573-2. The material composition is thus selected to provide stability, resistance to twist, easy mounting etc. Optimization & Analysis of Riveted Structure with aluminum frame.

Auxiliary Circuit Cubicle for Electric Loco
 Auxiliary Circuit Cubicle 1 (HB 1) and Auxiliary Circuit Cubicle 2 (HB2) for Three Phase Locomotive is a cubicle designed to contain contactors, switches, circuit breakers, etc. It controls the input to several auxiliary assemblies of the locomotive like machine room blower, compressors, crew fan, cab heater, switches etc.

Since the present cubicle is of a riveted structure it usually has it has quite a few disadvantages in riveted joints.

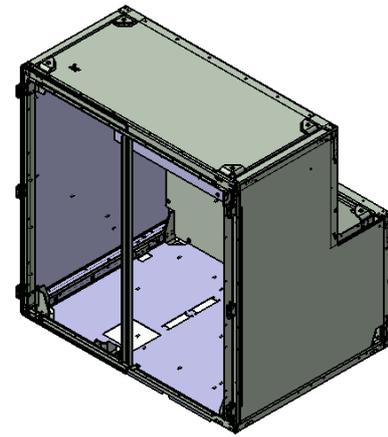


Figure 7. Existing Frame for the Electric Locomotive

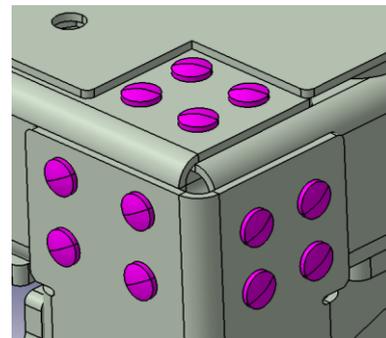


Figure 8. Riveted Joint

The cubicle is of frameless design made from riveted galvanised steel sheets. It is provided in the form of multi compartment cubicle whose walls and partitions form a self-supporting structure. The following compartments can be identified in a single switchgear cubicle: connections, bus bars, apparatus with a withdrawable module and an auxiliary circuitry compartment. Cubicle doors and side shields of the end panels (rear shields for Technical description wall mounted cubicles) are powder-painted in grey (RAL7032) or other colour specified by the customer.

Here the scope is to introduce a aluminum frame.

B. Design of Aluminum Frame

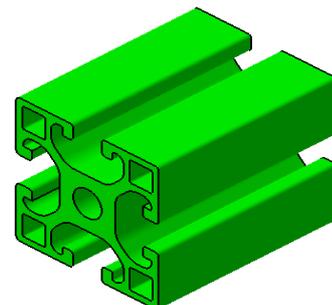


Figure 9. Aluminium Frame

Aluminium is remarkable for the metal's low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium and its alloys are vital to the aerospace industry and important in transportation and structures, such as building facades and window frames. The oxides and sulphates are the most useful compounds of aluminium. It is the protrusion of the aluminium frame which is designed in the CAD/CAM software

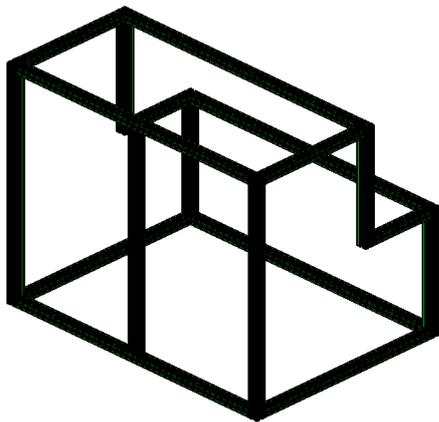


Figure 10. Aluminium Frame constructed using aluminium Extruded Profile

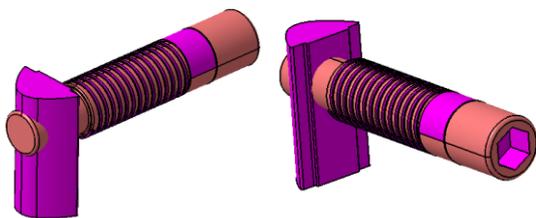


Figure 11. Type of T Slot Nut and Special Counter Sunk Screw

The jointing procedure of the Al-Profile using T-slot nut and Screw.

A typical and simple assembly procedure of this assembly includes the following steps:

- 1) Inserting the T-Slot nut either from the end or inserting directly into the Gap in aluminium profile by holding at 45 degrees.
- 2) Since the T-slot consists of a spring-loaded ball at the rear end it automatically starts exerting pressure on the inner surface of the Al-Profile and thus avoids slipping down during vertical assembly.



Figure 12. T Slot Nut

- 3) The mounting plate of panel needs to have a slot or hole equivalent to the slot nut chose since various types of sizes are available. The T-slot nut comes in various threaded models i.e. M5, M6, M8, M10, M4
- 4) A panel is then mounted and washer and bolt is used to fix all the elements together.
- 5) Depending on the Size of the screw the relevant Torque is to be applied or as per the device mounting instructions the torque is applied on the screw.

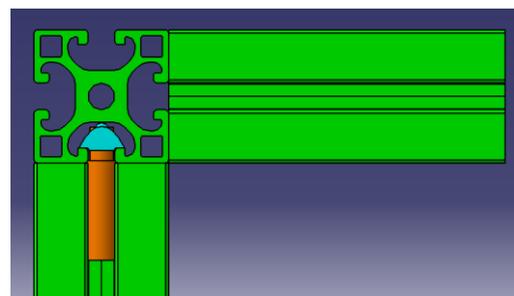


Figure 13. Prepared Model for Structural Analysis

C. Structural Analysis of Aluminum frame using Ansys

1. Meshing the Fixture:

The fixture consists of 6 assembled parts which were assembled in CATIA V5 R20. The assembled product was made compatible for ANSYS11.0 by making a copy in STEP format. STEP-File is the most widely used data exchange form of STEP. Due to its ASCII structure it is easy to read with typically one instance per line. The format of a STEP-File is defined in ISO 10303-21 Clear Text Encoding of the Exchange Structure. "STEP", stands for "Standard for the Exchange of Product model data". Because of its complex assembly structure in ANSYS 14.5.0 WORKBENCH is used to mesh the product (free mesh).

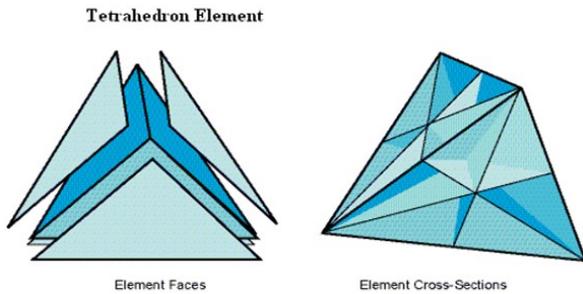


Figure 14. Tetrahedron Meshing

"Tetrahedron Element Cross-Section Construction", each tetrahedron cross-section is constructed by passing a plane through one of the edges and the closest point on the straight line containing the opposite edge.

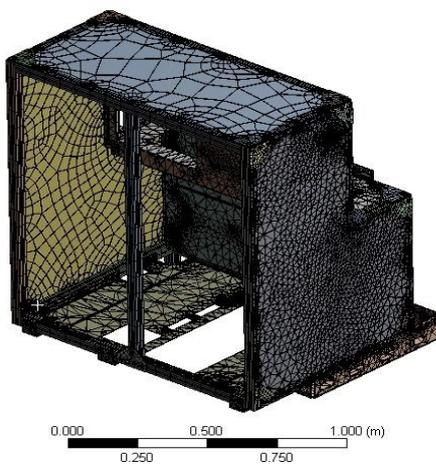


Figure 15. Meshing

Table 1 Meshing Components

Object Name	Mesh
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	1.9878e-005 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition

Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	213922
Elements	78435

2. Static Structural Analysis

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. A static structural load can be performed using the ANSYS or Samcef solver. The types of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)

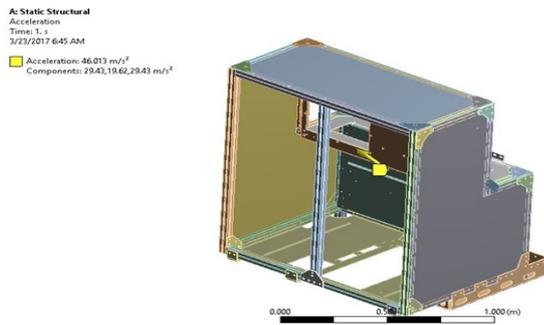


Figure 16. Static Structural

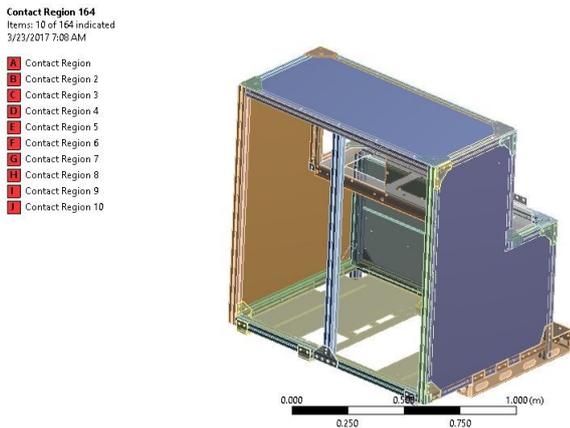


Figure 17. Contact Region

Since the plates, profiles, fastening elements are in contact with each other the stress are carried in Ansys with the contact that simulate situation. The above picture shows the contacts established between the various parts of the frame.

The boundary conditions are subjected as per the scope of the project and are designated to the Imported model. The fixed support is applied as the initial boundary condition on the model. The picture below shows the applied boundary condition on the model. For ease of understanding the wireframe model is also displayed.

- 1) Thus, under the specific acceleration loading conditions that a locomotive exerts during running conditions are applied and analysed for Hence an acceleration load of $X=+/-3g$, $Y=+/-2g$, $Z=+/-3g$: where $g=9.81m/s^2$ the end results are as follows.
- 2) The von Mises yield criterion suggests that the yielding of materials begins when the second deviatoric stress invariant reaches a critical value. It is part of a plasticity theory that applies best to ductile materials, such as metals. Prior to yield, material response can be assumed to be anything i.e. nonlinear elastic, viscoelastic or simply linear elastic.

3) In materials science and engineering the von Mises yield criterion can be also formulated in terms of the von Mises stress or equivalent tensile stress, a scalar stress value that can be computed from the Cauchy stress tensor. In this case, a material is said to start yielding when its von Mises stress reaches a critical value known as the yield strength. The von Mises stress is used to predict yielding of materials under any loading condition from results of simple uniaxial tensile tests. The von Mises stress satisfies the property that two stress states with equal distortion energy have equal von Mises stress.

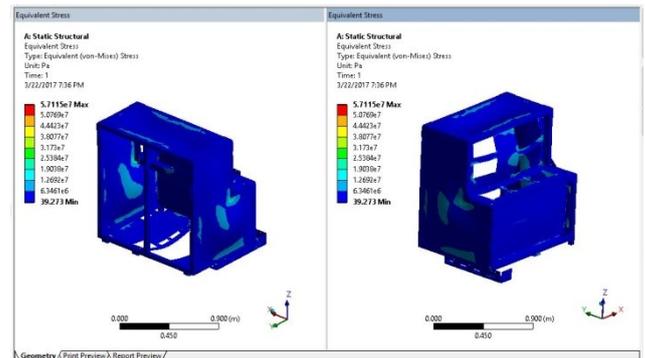


Figure 18. Experimental Stress

The stresses are bound to be with thin the limit as many stiffeners and ribs were added to provide extra stability against the aluminium profile which alone cannot with stand the g-forces.

The Directional Deformation are as achieved.

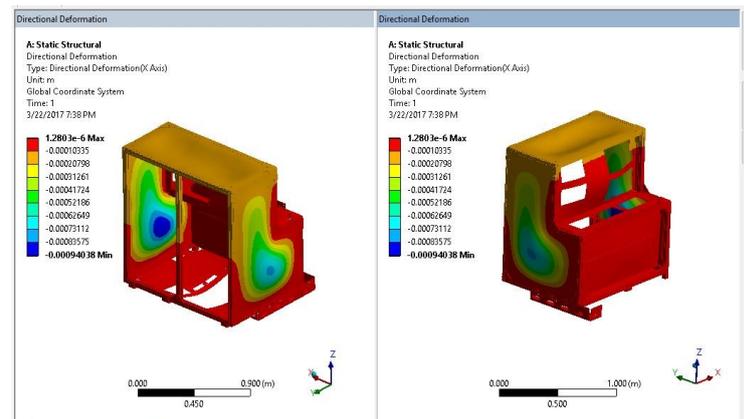


Figure 19. X-Axis Deformation is observed to have very minimal effect in X-Axis inertia force

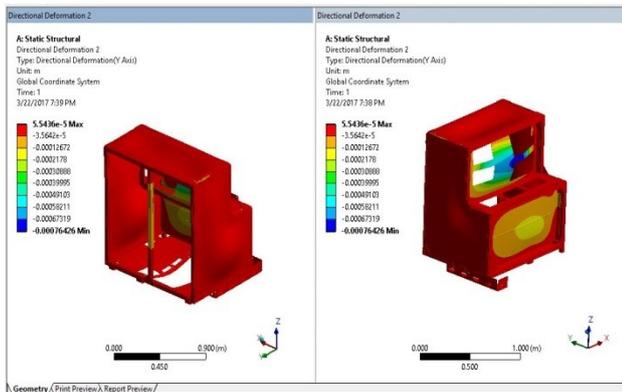


Figure 20. The Y-axis deformation is observed to also be under control with min deformation

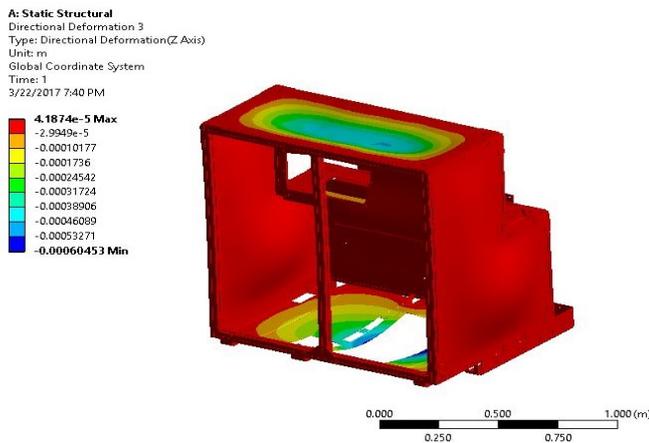


Figure 21. The Z-axis deformation is observed to also be under control with min deformation

The resultant deformation for overall structure is shown below.

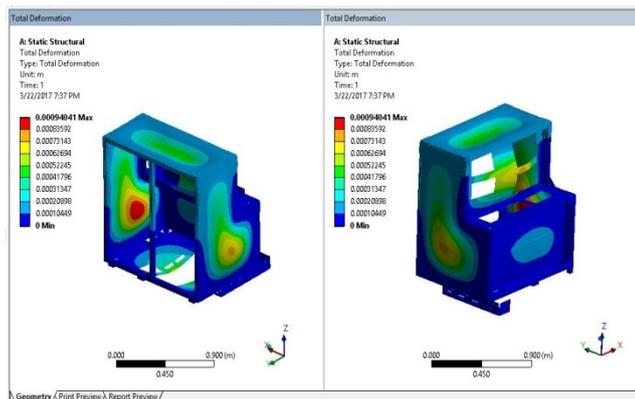


Figure 22. Total deformation

IV. CONCLUSION

Aluminium frame has been modelled and analysed for structural stability and stiffness. The results are obtained than the earlier frame. The newly designed rivet joint can be used in the place of older type rivet joint which will increase the stability and also reduces the costs.

V. ACKNOWLEDGEMENT

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