Design and Analysis of Battery Hold-Down

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Abstract— Fossil fuels are an incredibly dense form of energy and clearly, they are finite. Due to excessive usage of these resources, they have become scarce and that makes it a necessity to find other alternatives. The automotive industry is slowly moving towards electric powered vehicles. Textron Specialized Vehicles (TSV) are transitioning from gas powered to electric vehicles that cater to their customer requirements. Because the battery plays a vital role, it is essential to examine the mechanical integration of high voltage battery within these vehicles. The most common method that helps the battery to be held rigidly in its position is by using a battery hold-down. Designing improved versions of the battery hold-down would require understanding the range of possible bolt loads acting on it. Specifications of battery (such as weight and dimensions) can help calculate the torque acting on the hold-down and how the stress is spread across the design. Based on these values, alternate hold-downs can be designed that can effectively take higher torque values. And since the battery hold-down must also be cost efficient, it implements value engineering concepts to ensure that the new design is cheaper and performs its intended functions.

Key words: Battery Hold-Down, Design, FEA, Value Engineering, Functional Analysis, Bolt Load, Torque, Cost of Functions

I. Introduction

Battery plays an important role in providing electrical power to a vehicle. It is essential to examine the mechanical integration of high voltage battery within these vehicles. The most common method that helps the battery to be held rigidly in its position is by using a battery hold-down. A battery hold –down is used to hold the vehicle battery in a predetermined position within the vehicle. Since the vehicles travel in various terrains, the battery may undergo a substantial amount of jostling. During such conditions, the hold down must hold the battery with sufficient strength to resist the tipping of battery.

Design of the battery hold down requires knowledge of how and where the larger product will be used. Human factors to be considered include ease of battery exchange, assemble and disassemble, age range etc. While selecting a hold-down, it is important to consider factors such as battery weight, type and configuration of batteries, terrain that the vehicle will be exposed to and the forces transmitted to the on-board electric component. The market offers various kinds of battery hold-down; they may be in the form of clamps, harness, bolts or frames that encase the battery.

TSV currently has one of its vehicles that comprises of a battery hold down supporting the battery. The battery hold-down performs its function by assembling onto the battery with the help of lock nuts and J bolts. The hold-down is a steel sheet that is sheet bended. Due to the design of the hold-down, it features 8 bends that increases the complexity while manufacturing. Also, while screwing the lock nuts onto the hold-down, it induces a bolt pretention load that stresses the hold-down. The company wants to simplify the battery hold-down and increase the load bearing capacity so as to use it over a wider range of vehicles. Although this design has sufficed for the vehicles, the company requires a design improvement for cost savings.

II. Objectives

A. Primary Objectives

- The primary aim is to enhance the existing battery hold-down design, by increasing the hold-down's bolt load bearing capacity and make it a common part across a wider range of vehicles.

B. Secondary Objectives

- Considering other factors such as ease of assembly and disassembly, the battery hold-down would be designed to facilitate ease of use.
- To make effective use of material.
- To make the battery hold-down cost effective.

III. Implementing Value Engineering

With the current competitive scenario in the automotive industries, it is important for the manufacturers to provide customers with improved features of products without any drastic change in prices. To achieve this cost-effective change in their products, the system engineers can perform Functional Analysis to understand the existing relationship of the components and develop new product components using VAVE. The project aims to design a new battery hold-down design by breaking down the product into different functions as shown is *table 1*. Since the hold-down is the components that holds the battery tightly in place, the design is very important. Thereby, Functional analysis can help to identify the places to be concentrated for the next improvement in the hold-down and helps avoid over-engineering and duplication of functions in the product.

FUNCTION		PART	
Verb	Noun	Basic	Secondary
Enables	Clamping	X	
Provide	Protection		X
Protection from	Water		X
Enables	Handling		X
Hold	Parts	X	
Provide	Surface		X

Table 1: Functions for battery hold-down

When analyzing the costs of a product's functions in a cost function matrix, the implementation value of a product's individual function from a costs point of view becomes visible. Here the price of the product was divided and was set based on a market analysis, according to the components of the product and evaluated to what extent each function is present in a component. Based on the costs of the product's components we ascribe a share of the cost, which arise when a function is met, to each function as shown in table 2.

COST OF FUNCTIONS			
Component	**Cost (In dollars)**	**Quantity**	**Total cost (In dollars)**
Holding device	20	1	20
Clamping Inserts	3	2	6
Fixation nuts	0.43	2	0.86
Total			26.86
Conversion to Rupees	26.86 X 64.65		1736.499 Rupees

Table 2: Cost of functions for current hold-down

IV. Problem Identification

Considering that the company requires to use one common battery hold down among its range of vehicles, design improvements is a necessity and this would require understanding the possible bolt loads acting on it. Calculating the torque acting on the hold down and its load bearing capacity based on battery specifications, the range can be determined and as a result, it acts as a basis for developing alternate designs. The design for the battery hold-down must have a larger load bearing capacity and have lesser cost.

V. Methodology

As the main concern is to make the battery hold down common among the range of vehicles, the problem that is encountered is that the current design is specific to only one of the vehicle and as a result, design improvement is required. This requires adequate information about the hold down such as weight and dimensions, type and configuration of batteries, terrain that the vehicle will be exposed to and the forces transmitted to the on-board electric component. This information would enable us to decide if the problem can be solved or not. Once that is studied, Specifications of battery can help calculate the torque acting on the hold-down and then the analysis of the current design would yield the result whether it can withstand the torque required and also how the stress is spread across the design. Based on these values, alternate hold-downs can be designed that can effectively take higher torque values. The alternate designs are then analyzed and evaluated to obtain the expected output.

The concepts that were used for the project were:

- Concept 1: Design modification
- Concept 2: New design
- Concept 3: Material change
- Concept 4: Addition of components

The concept 2 was selected because of the cost effectivity and performance of functions.

VI. Design and Drafting

After identifying the most efficient concept, new designs were developed around the battery. The different type of designs that were created are:

A. *Design 1 (Welded part) using NX 10.0*

The design 1 was a 4 L-angle weld part. As compared to the current battery hold-down, the design-1 is simpler and lesser in cost. The design is show in fig 1.

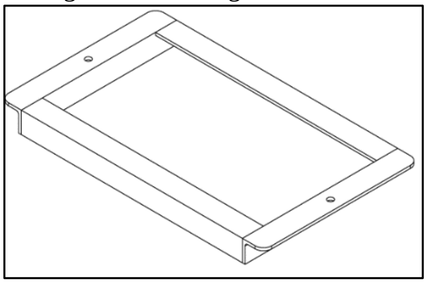

Fig. 1: Design 1

B. *Design 2 (Sheet Bended) using NX 10.0*

The design consists of two parts that are mirror images of each other as shown in *figure 2*. The advantage of the hold-down is that when the lock nuts are torqued into the hold-down, the part slightly bends inward and holds the battery tightly.

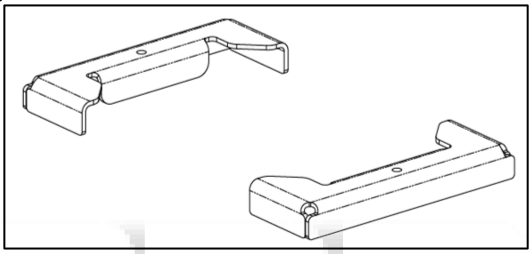

Fig. 2: Design 2

VII. Testing

Since the analysis requires the consideration of torque values, the load will be applied in the form of bolt load pretension. It is necessary to calculate the torque values and they will vary with the factor of safety, FOS concerned. The analysis for the battery hold-downs were simulated for a FOS value of 16 using equation 1.

$$\text{Torque} = \frac{F \times K \times D}{\mu} \qquad (1)$$

Finite element analysis is a numerical approach of solving the complex problems. It is a computational method used to obtain approximate solution for the boundary value problems. In this project, static structural analysis was carried out on the battery hold down designs. The battery hold-down assembly was designed to meet bolt pretention loads of 520 lbf. Hence various models are created using CAD software NX 10.0 and structural analysis was carried out using ANSYS 18.0

The analysis involves following steps:

- Importing the model
- Defining the material properties
- Meshing
- Defining the Boundary conditions
- Solve the model
- Result analysis

The main objective of the FEA here in this step is to find the deformation and various stresses acting on the battery hold down and its components under various loading conditions. The structural analysis was carried out to withstand a load of 2313.08N.

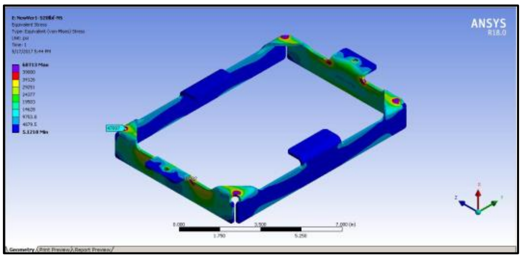

Fig. 3: Maximum Von-mises stress for current hold-down

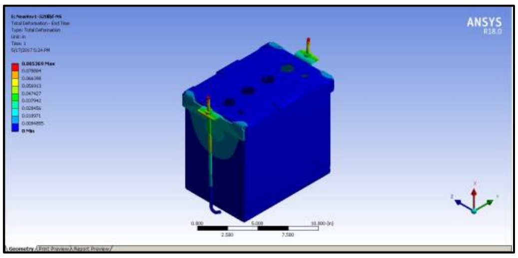

Fig. 4: Deformation for current hold-down

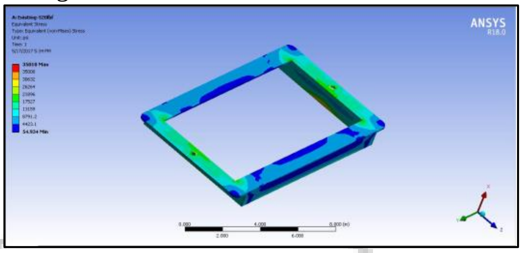

Fig. 5: Maximum stress plot for Design 1

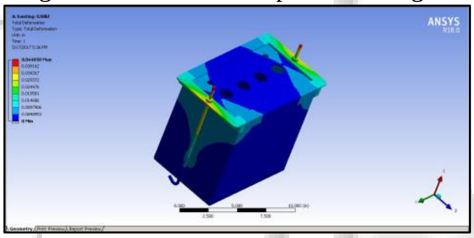

Fig. 6: Maximum deformation plot for Design 1

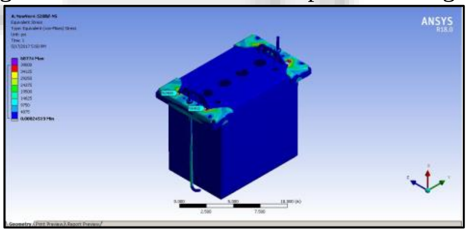

Fig. 7: Maximum stress plot for Design 2

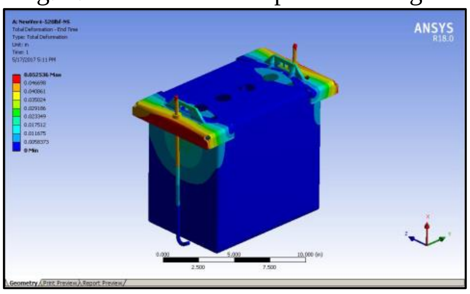

Fig. 8: Maximum deformation plot for Design 2

The summarized results for the hold-downs are shown in table 3.

Design	Deformation (mm)	Induced von-mises stress (Mpa)
Design 1 (welded part)	1.079 (0.044 inches)	241.31 (35000psi)
Design 2(sheet bended part)	1.286 (0.05253 inches)	382.53 (55482psi)

Table 3: Results of deformation and stress

VIII. Results and Discussion

From analysis, it was observed that for Design 1, the value of maximum deformation is 1.079mm. The maximum average von-mises stress is 241.44Mpa. Considering the design 2, the maximum von-mises stress is 382.53Mpa. Maximum deformation is 1.286mm.

For new design 1, profile is simple and it is economical. The stress distribution is better and has a high degree of safety.

From the cost comparison in *Table 4*, the reference has the highest cost of Rs. 1736.499. The lowest cost is that of Design 1 is Rs. 452.55. Thus, it can be concluded that Design 1 is both cost effective and safe in terms of design.

Reference design	Design 1	Design 2
1736.499 Rupees	1283.949 Rupees	1348.60
Cost difference	1736.499 – 1283.949 = Rs 452.55	1736.499 – 1348.60= Rs 387.899

Table 4: Cost comparison

For the cost savings estimation, each vehicle uses 3 battery hold-downs of the reference design. The cost savings are calculated to determine what the cost estimation would be when the current hold-down is replaced with the design 2 (welded part). The bar chart is shown in *figure 9.*

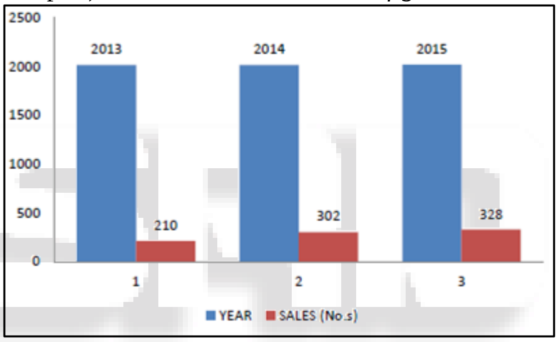

Fig. 9: Bar graph for average sales of 280

In summary, Design 1 has a cost savings estimation of Rs. 3,80,142 per year. Since Design 1 has a good load bearing capacity and a higher FOS of 16, Design 1 can be selected as the new design implementation for the large range of vehicles at TSV.

IX. Conclusion and Scope for Future Work

For new design 1, profile is simple and it is economical. The stress distribution is better and has a high degree of safety. It yearly cost saving is estimated to be Rs. 3,80,142. Hence, the rectangular frame profile is recommended.

The design and development of hold-down was done to fulfill the requirement of protecting the battery from jostling and hence sparking. The selected concept can further be optimized by providing reinforcement which results in cost and weight reductions. The critical regions where chances of failure are more should be considered for modification. Concepts like DFM (Design for manufacture) and DFA (Design for assembly) must be effectively used for designing more effective model.

References

[1] Tim Gilles, "Automotive Service: Inspection, Maintenance, Repair", 5th Edition Cengage Learning, Pg 437- 440

[2] Richard B. Platt “Battery hold-down structure”,US 4926953 A
[3] Teresa M. Browning , Joseph W. Staniszewski “Battery hold down strap”,US 5228532 A
[4] L. Duane Swayze “Mounting apparatus for a battery”,US 5040627 A
[5] Bergman Robert T “Battery hold-down”,US 2853143 A
[6] Subhas Chandra Chalasani, Keith Bruce Kelley, Roy Kuipers,Yehoshua Mandelcorn “Battery having recessed posts and stand system”,US 6190796 B1
[7] Marjan Leber, Majda Bastič, Marko Mavrič, Andrea Ivanišević “Value Analysis as an Integral Part of New Product Development”, Elsevier
[8] H. Y. Yang, M. L. Wang and X. M. Chen “Structural Finite Element Analysis with new interface model”, Journal of Engineering Mechanics, pp. 321-326, March 1997.
[9] Mario R.T. Arruda, Luis Manuel and Santos Castro, “Structural dynamic analysis using hybrid and mixed finite element models”, Finite Elements in Analysis and Design 57, pp. 43–54, 2012.
[10] D. P. Jones , J. L. Gordon , D. N. Hutula, J. E. Holliday and W. G. Jandrasits, “Application of Equivalent Elastic Methods in Three-Dimensional Finite Element Structural Analysis”, Journal of Pressure Vessel Technology, Vol. 121, pp. 121-128, 1999.