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Design of a bus battery box

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ABSTRACT
The paper examines the problems associated with current design of a bus battery box and presents the new design to mitigate the existing drawbacks. Solid models of the battery box are developed using NX10 software. Load cases as per Mercedes-Benz bus standards are considered for analysis. Stress and deformation values of the battery box structure are obtained with use of Hypermesh 13 and Ansys softwares. The new design is found to be better than the existing one.
Keywords - Ansys, Battery box, Hypermesh, Mount bracket, Drawer slide

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I. INTRODUCTION

Automotive industry is rapidly growing in emerging markets. There are on and off road vehicles that serve different purposes. Heavy commercial vehicles such as trucks and buses have to run on even or uneven terrains. As the result, the under body components of the automobile like the battery box assembly are subjected to impact loads. Since in modern buses the battery box is covered by the body, it is important to have easy access to the batteries for their servicing or replacement as and when the need arises. In the existing design, poor accessibility of batteries is of concern. Keeping these issues in view, the objective of the present paper is to design a new battery box arrangement that is strong enough to withstand impact loads and is easily accessible for dismantling and servicing as well.

Several solid models of the battery box are designed in the present work using NX10 software. Load cases in conformity with Daimler standards of Mercedes-Benz bus are considered for analysis. Stress and deformation values of the battery box structure are obtained with use of Hypermesh 13 and Ansys software. The analysis reveals that cast steel bracket design of the battery box is the most feasible concept for sustaining loads in all three directions. The new design is found to be better than the existing one.

II. LITERATURE REVIEW

Research work published on the topic is mostly in the form of patents. Interesting work reported in the field is summarised as follows:-

In the preferred embodiments, a novel system and method for mounting a battery box within a vehicle is presented [1]. The system and method includes, among other things, a novel battery box that is mounted between two chassis frame members that extend lengthwise along the vehicle. The battery box is supported on the frame members via a plurality of uniquely designed and arranged bracket members. A battery box device [2] for use on an electric vehicle includes a drive power supply having a plurality of storage batteries for supplying the electric energy to drive the electric vehicle, a circuit breaker device having a controller for producing a power supply control signal based on conditions of the electric vehicle, and a circuit breaker for turning off the drive power supply in response to the control signal from the controller. A battery box houses the storage batteries and the circuit breaker device. The battery box device also has a breaker box housing at least the controller and the circuit breaker device with the storage batteries and the circuit breaker device being separate from each other. A circuit breaker switch is operable from outside of the battery box. A battery box [3] which is suitable for use in an electric vehicle comprises a box body and a reinforcement member. The box body accommodates therein a plurality of batteries for powering the electric vehicle and is mounted to the electric vehicle. The reinforcement member is provided with the box body and supports at least respective portions of all the batteries in the box body. The reinforcement member is mounted to the frame of the electric vehicle whereby the weight of each of the batteries is reliably supported by the reinforcement member on the vehicle frame. The weight is reduced and yet the rigidity of the battery box is improved.

Some work has also been reported on fixing brackets used in an automobile. J. Selvamani et al. [4] suggested that the bracket design is an important aspect of heavy commercial vehicles. Most of the components are held by brackets. Hence brackets have to be reliable and durable so that bracket failure doesn't take place. Umesh Ghorpade et al. [5] identified that modal analysis is best suited for bracket design along with other analysis such as static and dynamic. Williams et al. [6] was able to achieve better bracket design by considering the frequency analysis of the system in addition to noise path and mobility analysis.

Literature survey indicates that most of the research work is carried out on design of engine and air tank brackets. Research on bracket design for battery box assembly in heavy commercial vehicles such as trucks and buses is scarcely reported. Moreover, the current/existing battery box is designed in such a way that the entire assembly takes place in two stages which increases the assembly lead time besides necessitating additional labour. This paper therefore, in view of above, presents the design aspects of a new battery box arrangement for Mercedes Benz bus. Conceptual designs are taken up to try and reduce the problems associated with the existing design.

III. EXISTING/CURRENT DESIGN-ISSUES AND CONCERNS

Refer Fig. 1 to 4. The components of the existing battery box of Mercedes Benz bus and

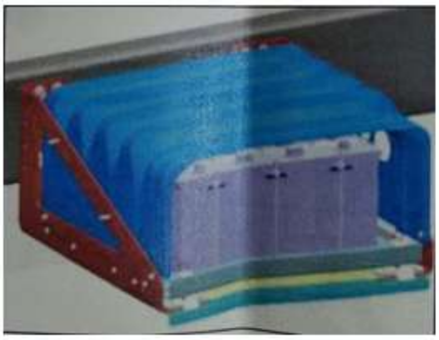


Fig. 1 Existing battery box assembly

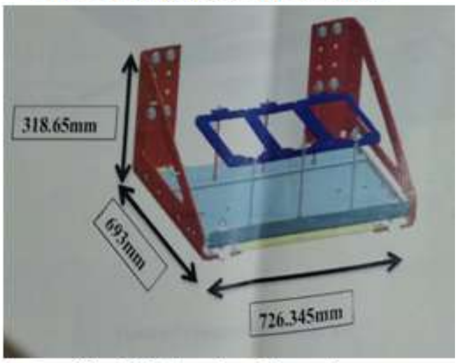


Fig. 2 Battery box dimensions

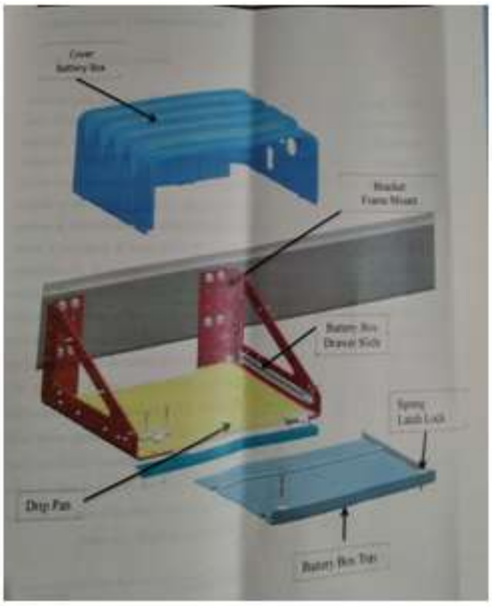


Fig. 3 Components of the battery box

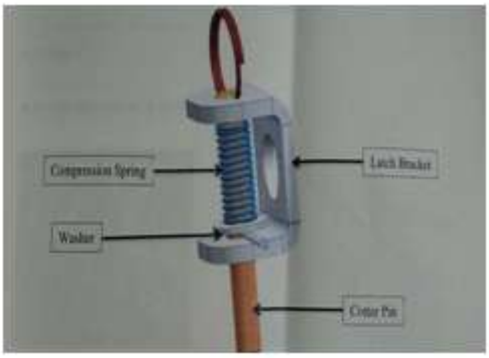


Fig. 4 Spring latch lock

their assembly arrangement are shown in the figures. Major structural parts are:-

a) Frame mounting bracket:- It connects the battery box unit with the frame/chassis of the vehicle. It has to withstand the weight of the batteries and bending moments besides sustaining the vibrations and extra stresses generated during running condition of the vehicle.

b) Drip pan:- During running condition, sometimes the battery fluids may spill out due to over filling. The main purpose of the drip pan is to catch and channelize the fluid out of the battery box arrangement without affecting the surrounding parts. The material of the drip pan is corrosion resistant.

c) Battery tray:- It is the plate on which the batteries are placed. It has to be structurally stable to resist the battery weight and deformations.

d) Roller bearing drawer slides:- Since battery box is fastened to the chassis, it is difficult for labour to get under the vehicle and do any kind of servicing. Hence a slider arrangement is required to pull out and push in the battery tray. The drawing slides have fixed and movable members. The fixed member is connected to the mount brackets on both side walls and the movable member is attached to bottom of battery tray. The sliding motion is achieved by nylon rollers that slide inside the channel provided in the fixed member. Slider needs to be smooth with low friction, durable and vibration resistant.

e) Locking arrangement:- It is meant to lock the battery tray with the bracket to prevent any movement of the tray during running condition of the vehicle.

The drawer system used is regular extension roller bearing slide. It limits the extension up to 75% of slider length. Hence the battery tray can come up to 75% out of the arrangement. The current dimensions of the battery box is 693 mm length and 726 mm width. But the standard dimensions of roller bearing slides is 550 mm length and 450 mm width. Since the battery box design has higher dimensions than the standard roller bearing slide, there is a significant effect on the slider load carrying capacity. Other issues associated with the existing battery box system are as follows:-

i) It is difficult to maintain parallelism between frame mounting brackets.

2) Assembly of the battery box takes place in two stages. Both of them are offline subassemblies. So unwanted material movements and requirement of additional labor are the concerns. This can be reduced by redesigning the battery box arrangement such that all the assemblies are made off line at one stage and then quickly assembled with the frame rail as the main assembly.

3) There is need for a new and ergonomically designed locking feature to lock and unlock the battery tray.

IV. NEW DESIGNS

Three new designs are proposed in which the slider box can come out fully in all the arrangements. A separate lock arrangement in the form of horizontal spring latch is proposed in all designs. These designs are as follows:-

Concept 1

Refer Fig. 5. The brackets in the base model are modified into a triangular link using a connecter link. It forms a closed loop with frame brackets and drip pan making the arrangement as a single unit. The brackets are maintained parallel all the time.

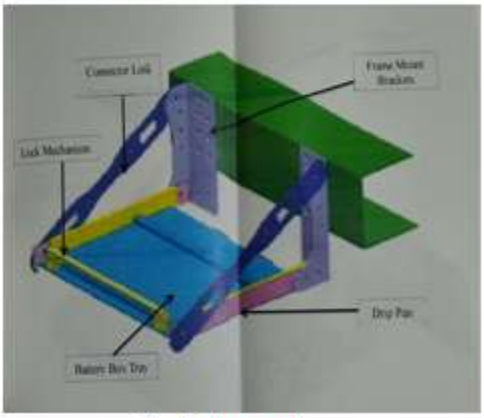


Fig. 5 Concept 1

Concept 2

Refer Fig. 6. The connector link is eliminated and the frame bracket is extended to form the closed loop

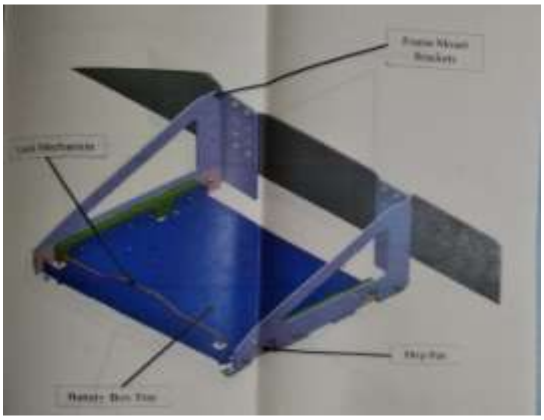


Fig. 6 Concept 2

Concept 3

Refer Fig. 7. The cast bracket is used so that it eliminates the spring back effect of sheet metal after bending. Misalignment of the brackets is reduced.

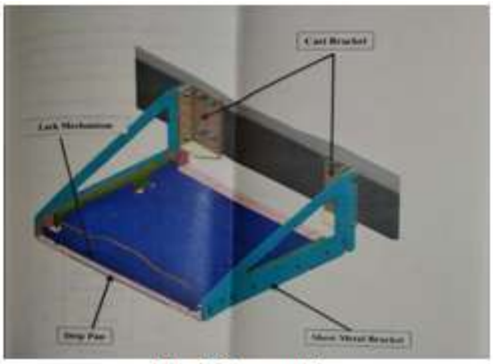
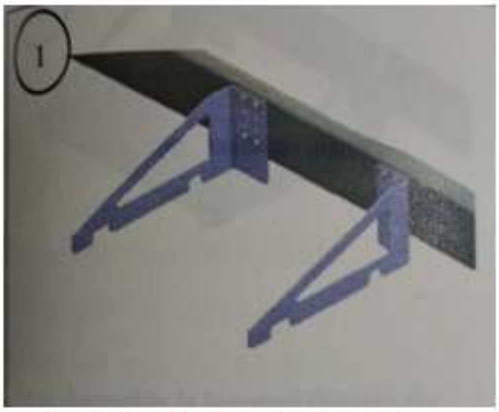
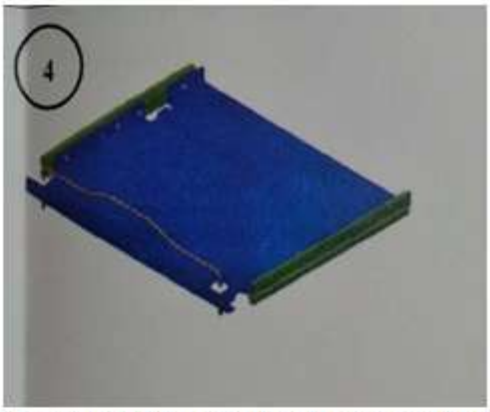


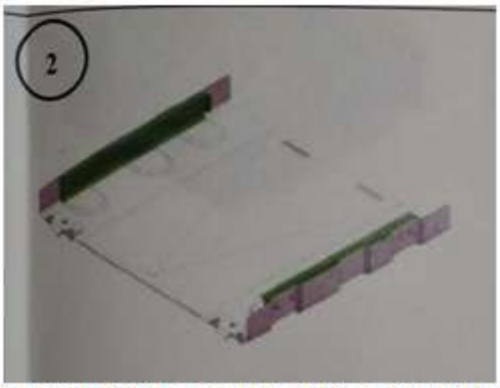
Fig. 7 Concept 3



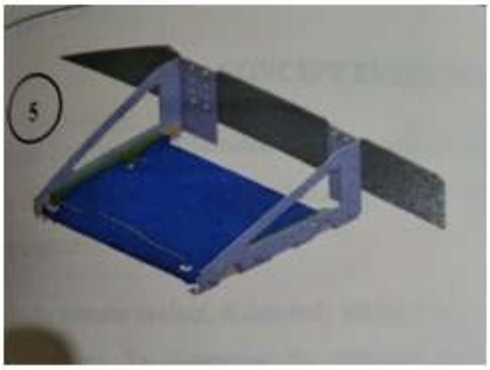
Brackets connected to the chassis frame



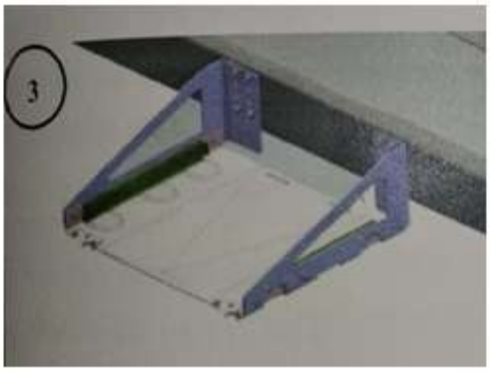
Sub assembly of tray, drawer slide and spring latch Is prepared separately



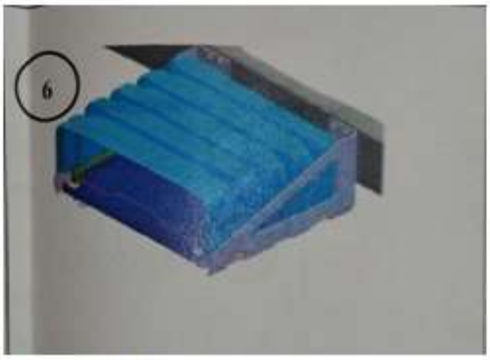
Assembly of drip pan, cabinet slide and vertical pin bracket



Insertion of tray assembly through the cabinet slide



Drip pan assembly fastened to the frame brackets



Placement of batteries and fastening of battery cover with frame brackets

Fig. 8 Assembly sequence of new design battery box

The assembly sequence of the components is shown in Fig. 8. Out of three designs, basic structure of concept 3 is preferred. It possesses the following advantages:- i) Supports brackets at 90 deg and ii) Does not interfere with packaging

V. STRUCTURAL ANALYSIS AND RESULTS

Finite element analysis of basic structures of existing and concept 3 designs is undertaken. The material of frame mount brackets is ASTM A572 high strength low alloy steel (HSLAS) whereas the material for drip pan is ASTM A653 Type B commercial steel. The battery box has to meet the Daimler standards of Mercedes Benz bus i.e., it has to withstand the load equal to 10 times the gravity and five times in other two directions. without any static failure (-10Z, 5Y and 5X). The stress in z direction is found to be higher than the stresses in x and y direction due to development of bending stress of the brackets in z direction. Refer Fig. 9. The maximum localized stress in z direction of bracket of the existing design is 1070 MPa. The stresses in other parts are well within the yield strength of the bracket steel (i.e. 345 MPa). Maximum displacement along x direction is of the order of 8.4 mm. Importantly, these stress states correspond to the position when drawer slider and tray with batteries are in fully out position that happens once in a while for momentary period during maintenance. In regular positions when the battery is at rest, the stress shall be much lesser and safe. On the other hand, Fig. 10, the maximum localized stress in z direction of bracket of concept 3 design is 1040 MPa. The stress in other parts are equally well within the yield strength of the bracket frame (i.e. 345 MPa). Maximum displacement along x direction is 0.3 mm only. Since high stresses are localised to small region and moreover the current design is not reported to fail under the localised stresses that develop for small durations, concept 3 design is felt to be safe under the operating loads. Importantly, the displacement is drastically less in concept 3 design.

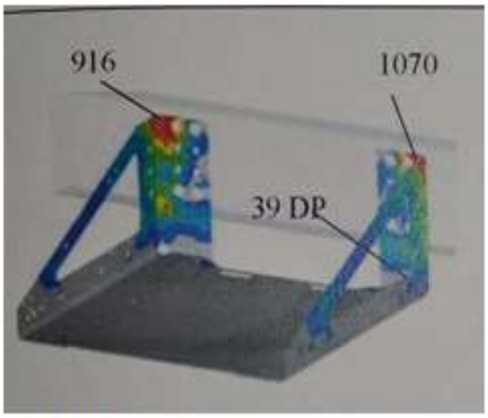


Fig. 9 Stress plot of existing battery box structure

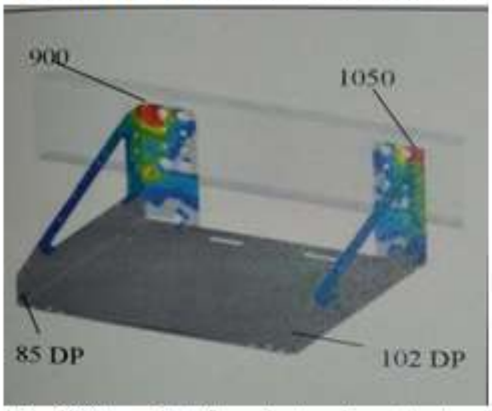


Fig. 10 Stress plot of new battery box structure

The comparison of brackets and drip pans of existing and new designs in terms of stress and weight are consolidated as follows:-

Table 1 Comparison of frame mount brackets

MODEL	THICK-NESS	YIELD STRENGTH	MAXIMUM STRESS	Wt
Current Design	6.35 mm	345 MPa	1070 MPa	10.7 kg
New Design (Concept 3)	6.35 mm	345 MPa	1040 MPa	7.2 kg

MODEL	THICK-NESS	YIELD STRENGTH	MAXIMUM STRESS	Wt
Current Design	1.5 mm	245 MPa	96 MPa	5.45 kg
New Design (Concept 3)	1.8 mm	245 MPa	169 MPa	7.45 kg

Table 2 Comparison of drip pans

It is observed from the results that overall weight of bracket and drip pan of new design is slightly lower in comparison with that of the current design. The stress values are nearly similar. Besides, the problems associated with the current design, as discussed in Section III, are addressed. Hence the new design is confirmed to be feasible from structural and operational points of view.

VI. CONCLUSION

The existing and a new battery box assembly for Mercedes Benz bus are investigated. Conceptual designs are taken up to try and reduce the problems associated with the existing design. The new design is found to be better than the existing one.

ACKNOWLEDGEMENT

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