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Electric vehicle battery pack having longitudinal reinforcements

Abstract

An electric vehicle battery pack with a reinforced cover to better support vehicle cabin loads such as seat submerge loads, seat pitch loads, and the like. The cover has a number of reinforcing members affixed thereto and positioned over cross members of the battery pack frame. Loads imposed by the cabin are thus transferred to the reinforcing members and then to the rigid cross members. In this manner, battery packs of embodiments of the disclosure better support cabin loads applied thereto, improving their strength and better protecting more delicate components within the battery pack.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION (1) This application is a continuation application of U.S. application Ser. No. 17/470,969, filed Sep. 9, 2021, which claims priority to, and the benefit of, U.S. Provisional Patent Application No. 63/226,734, filed Jul. 28, 2021, the disclosures of which are hereby incorporated by reference herein in their entireties.

INTRODUCTION

(1) The present disclosure is directed generally to electric vehicle battery packs. More specifically, the present disclosure is directed to electric vehicle battery packs having longitudinal reinforcements.

SUMMARY

(2) Vehicle battery packs perform a number of functions, including providing a protective enclosure to withstand crashes, ground strikes, or other impacts, routing of electrical wires, and containment of battery fires. Battery packs present design challenges for electric vehicles, however. As one example, battery packs often are not strong enough to support certain vehicle loads. When located under vehicle cabins, conventional battery packs are often susceptible to damage from loads such as seat submerge pressure, seat pitch, and the like.

(3) Accordingly, systems and methods are described herein for a battery pack with a reinforced lid or cover that better withstands loads from, e.g., vehicle cabins. In some embodiments of the

disclosure, a number of longitudinal reinforcing members are affixed atop a battery pack cover. The reinforcing members can span multiple cross members of the battery pack, and may be affixed to these cross members in addition to the lid. Seats or other vehicle cabin structures may overlie the reinforcing members when the battery pack is installed. In this manner, loads resulting from seat weight, seat deformation such as seat submerges, seat pitch, and the like are transferred through mounting points of the cabin to the reinforcing members, and in turn to the rigid cross members of the battery pack. Accordingly, loads upon the battery pack are transferred to rigid elements of the battery pack rather than flexible elements such as the cover or sensitive elements such as the battery modules, improving the strength and loadbearing capacity of the battery pack.

(4) To ensure that loads or the energy therefrom are properly transferred from the reinforcing members to the cross members of the battery pack, the cross members may be designed in some embodiments of the disclosure as tall cross members that extend from the bottom of the battery pack up to at least the top of the battery pack frame. In other words, the cross members that bear cabin loads may be sufficiently tall that cover elements such as reinforcing members may be coupled thereto, in any manner that allows for transferring of loads to the cross members rather than the battery modules of the battery pack, thus protecting them from compressive loads imposed on the battery pack by, e.g., the vehicle cabin.

(5) As the reinforcing members are designed to support cabin loads imposed by various cabin structures, in some embodiments of the disclosure at least a portion of the vehicle cabin may contact the reinforcing members, to create a load path extending directly from the cabin to the battery pack cross members. More specifically, vehicle cabins may be designed with mounting points allowing the battery pack to be mounted in the vehicle such that the reinforcing members of the battery pack contact the cabin mounting points.

(6) The reinforcing members may be affixed to the lid or cover in any manner. For example, the reinforcing members may be steel or other metallic members affixed to the cover by welds, bolts, screws, an adhesive, or the like. In some embodiments of the disclosure, additional support members may be affixed under the reinforcing members on the underside of the battery pack cover, to aid in securing the reinforcing members and provide a more direct load path to the battery pack cross members. Reinforcing members may be any other rigid material having sufficient strength, such steel, metallic members, composite material, or the like.

(7) To increase the strength of the reinforcing members and improve load paths, reinforcing members may each extend over at least two different battery pack cross members, so that loads on each reinforcing member are distributed to at least two cross members. In some embodiments of the disclosure, reinforcing members may be affixed to their underlying cross members such as by bolts, screws, or welds, further increasing their strength and improving their load paths.

(8) In some embodiments of the disclosure, covers may include raised portions that form ridges or other raised elements that increase the bending stiffness of the cover and thereby improve its strength and manufacturability. In particular, increased cover bending stiffness allows for more reliable gripping by robots or other handlers during battery pack assembly.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The above and other objects and advantages of the disclosure will be apparent upon consideration of the following detailed description, taken in conjunction with the accompanying drawings, in which like reference characters refer to like parts throughout, and in which:

(2) FIG. **1** is an isometric exploded view of an exemplary battery pack constructed in accordance with some embodiments of the disclosure;

(3) FIG. **2** is a plan view of a battery pack cover and reinforcing members constructed in

accordance with some embodiments of the disclosure;
(4) FIG. **3** is a cutaway side view of a vehicle cabin and battery pack constructed in accordance with some embodiments of the disclosure;
(5) FIG. **4** is an isometric closeup view of battery pack reinforcing members constructed in accordance with some embodiments of the disclosure;
(6) FIG. **5** illustrates further details of battery pack reinforcing members of FIG. **4**, constructed in accordance with some embodiments of the disclosure;
(7) FIG. **6** is an isometric closeup view illustrating affixing of battery pack reinforcing members constructed in accordance with some embodiments of the disclosure;
(8) FIG. **7** is a cutaway side view illustrating the attachment of battery pack covers and reinforcing members to cross members, in accordance with some embodiments of the disclosure;
(9) FIGS. **8**A and **8**B are plan views illustrating a method of affixing reinforcing members and battery modules to cross members, in accordance with some embodiments of the disclosure;
(10) FIG. **9** is a block diagram representation of an exemplary vehicle having a battery pack constructed in accordance with some embodiments of the disclosure;
(11) FIG. **10**A is a plan view of an exemplary battery pack cover constructed in accordance with further embodiments of the disclosure;
(12) FIG. **10**B is an isometric view of the exemplary battery pack cover of FIG. **10**A; and
(13) FIG. **11** is a simplified cross-sectional view of an exemplary battery pack cover constructed in accordance with further embodiments of the disclosure, taken along section A-A of FIG. **10**A.

DETAILED DESCRIPTION

(14) In one embodiment, the disclosure relates to an electric vehicle battery pack with longitudinal reinforcements to better support vehicle cabin loads such as seat submerge loads, seat pitch loads, and the like. The cover has a number of reinforcing members affixed thereto and positioned over cross members of the battery pack frame. Loads imposed by the cabin are thus transferred to the reinforcing members, which in turn transfer the loads to the rigid cross members. In this manner, battery packs of embodiments of the disclosure better support cabin loads applied thereto, improving their strength and better protecting more delicate components within the battery pack.
(15) FIG. **1** is an isometric exploded view of an exemplary battery pack constructed in accordance with some embodiments of the disclosure. Here, an electric vehicle battery pack **10** includes a cover **20** or lid, frame **30**, and strike shield **40**. The cover **20** and strike shield **40** are affixed to opposing sides, e.g., top and bottom surfaces, of the frame **30** to collectively define spaces within the frame **30** for receiving and protecting a number of battery modules and other electrical elements that provide power for an electric vehicle.
(16) Frame **30** may be constructed with opposing sides or walls **50**, **60** that have a number of cross members **70** extending therebetween for added strength and rigidity. Frame **30** may be made of any sufficiently rigid, strong and non-flammable material, such as a metal, e.g., an extruded aluminum, a steel, or the like, or any composite material.
(17) Cover **20** may be any generally flat structure that provides sufficient heat resistance and structural rigidity to support reinforcing members as further described below. For example, cover **20** may be constructed of a metal such as a stamped aluminum or steel sheet, a molded plastic, a composite material, or the like. Cover **20** may have an upper surface **80** that faces the cabin of the vehicle within which battery pack **10** is installed, and an opposite lower surface **90** that faces the frame **30** and interior of the battery pack **10**.
(18) FIG. **2** is a plan view of a battery pack cover and reinforcing members constructed in accordance with some embodiments of the disclosure. In the view of FIG. **2**, cover **20** is shown placed over frame **30**. Here, upper surface **80** of cover **20** may have a number of longitudinal reinforcing members **100** thereon, and lower surface **90** may have a number of lateral support members **110** thereon. In some embodiments of the disclosure, longitudinal reinforcing members **100** may be affixed to the upper surface **80** of cover **20** such as by bolts, welds, adhesive, or in any

other suitably secure manner. Similarly, lateral support members **110** may be affixed to the lower surface **90** of cover **20**, also by bolts, welds, adhesive, or in any other suitably secure manner.
(19) In the exemplary embodiment shown, longitudinal reinforcing members **100** extend between adjacent cross members **70** of frame **30**, so that each end of a reinforcing member **100** lies over, and is supported by, a cross member **70**. Lateral support members **110** extend underneath ends of their respective longitudinal reinforcing members **100** and along underlying cross members **70**. The longitudinal reinforcing members **100** are positioned to align with mounting points or other contact points on the underside of a vehicle cabin, so that loads from the cabin are transferred to the longitudinal reinforcing members **100** rather than another portion of upper surface **80**. The longitudinal reinforcing members **100** then transfer these loads to the rigid cross members **70** such that cross members **70** support compressive forces upon battery pack **10**, rather than any components within.
(20) With reference to FIG. **3**, operation of a battery pack **10** having longitudinal reinforcing members **100** is now shown. FIG. **3** is a cutaway side view of a vehicle cabin and battery pack constructed in accordance with some embodiments of the disclosure. Battery pack **10** is affixed to the underside of a vehicle, in part by affixing the battery pack **10** to a chassis of the vehicle. As shown, the underside of vehicle cabin **190** is also attached to battery pack **10**. More specifically, longitudinal reinforcing members **100** of battery pack **10** are affixed to a floor panel **200** of cabin **190**, such as via bolts **230** and **240** of seats **210** and **220** respectively. Longitudinal reinforcing members **100** may have features for aligning with mounting points of the floor panel **200** or another intermediate structure, to facilitate proper placement of the battery pack **10** with respect to floor panel **200**. Battery pack **10**, as above, has longitudinal reinforcing members **100** affixed to its cover **20** and to cross members **70** of its frame **30** by, e.g., bolts **120**.
(21) Longitudinal reinforcing members **100** may be affixed to any portion of cabin **190**, in any manner. In some embodiments, members **100** and seats **210**, **220** may both be bolted to floor panel **200** via bolts **230**, **240**. This provides direct load paths from seats **210**, **220** to longitudinal reinforcing members **100**, which may be desirable to direct loads onto longitudinal reinforcing members **100** rather than, for example, floor panel **200**. In other embodiments, members **100** may be bolted or otherwise affixed to other structures placed between floor panel **200** and members **100**, and/or between seats **210**, **220** and floor panel **200**. Members **100** may also be affixed to any portion of cabin **190** in any manner besides via bolts **230**, **240**, such as by welding or application of adhesive to floor panel **200** or any other structure. That is, seats **210**, **220** and members **100** may be affixed to any portion of cabin **190** in any manner allowing transfer of loads from, for example, seats **210**, **220** to longitudinal reinforcing members **100** rather than to another portion of the battery pack **10**.
(22) Accordingly, loads from seats **210**, **220**, such as submerging loads acting to push seats **210**, **220** down in the view of FIG. **3** and toward floor panel **200**, or pitching loads acting to tilt seats **210**, **220** forward or backward, are transferred through bolts **230**, **240** to longitudinal reinforcing members **100** of battery pack **10**. The longitudinal reinforcing members **100** substantially transfer these loads via bolts **120** to cross members **70**, rather than other portions of battery pack **10**.
(23) FIG. **4** is an isometric closeup view of battery pack reinforcing members constructed in accordance with some embodiments of the disclosure, and FIG. **5** illustrates further details of battery pack reinforcing members of FIG. **4**, constructed in accordance with some embodiments of the disclosure. As shown, longitudinal reinforcing members **100** may be rigid members sized such that opposite ends each overlie a cross member **70**. Members **100** may have any sizes and shapes suitable for supporting loads from cabin **190** and/or seats **210**, **220**. In some embodiments, members **100** may have an arcuate shape in cross-section, such that the center portion containing holes **280** is raised for coupling with mounting points of, e.g., the cabin **190**. The holes **280** may be sized and shaped to accept bolts **230**, **240** or other fasteners for coupling members **100**, and thus battery pack **10**, to a vehicle. In some embodiments, members **100** may also have holes **250** formed

in their ends to overlie cross members **70**, the holes **250** being sized and placed to accept bolts, screws, or other fasteners for affixing the members **100** to cross members **70**.
(24) Members **100** may be affixed to upper surface **80** of cover **20** in any manner. In some embodiments, members **100** may be affixed to upper surface **80** by a number of welds, such as those that may be formed at weld points **260**. Alternatively, or in addition, members **100** may be affixed to upper surface **80** by an adhesive, or by screws, bolts, other fasteners, or the like.
(25) In some embodiments of the disclosure, support members **110** are positioned between the cover **20** and cross members **70**, underneath ends of the longitudinal reinforcing members **100**. In some other embodiments of the disclosure, support members **110** may be omitted, and longitudinal reinforcing members **100** and/or cover **20** may be affixed directly to cross members **70**. Support members **110** may be rigid members of any size and shape suitable for coupling to cover **20**, cross members **70**, and/or longitudinal reinforcing members **100**. In some embodiments, support members **110** may have an arcuate shape in cross-section, such that the outer edges of support members **110** are raised above the center portion containing holes **270**. Holes **270** may be sized and shaped to accept fasteners such as bolts, screws, or the like, for coupling support members **110** to cross members **70**. Accordingly, cover **20** may have holes overlying holes **270**, so that bolts or other fasteners may be inserted through holes of cover **20**, through holes **270** and into cross members **70** for securing of support members **110** and cover **20** to cross members **70**.
(26) Support members **110** may be affixed to the lower surface **90** of cover **20** by a number of welds, such as at positions indicated by weld points **260**, although embodiments of the disclosure contemplate coupling of support members **110** to cover **20** in any manner, e.g., by adhesive, bolts, screws, other fasteners, or the like. In some embodiments of the disclosure, bolts or other fasteners may be employed to couple support members **110** to longitudinal reinforcing members **100** through cover **20**, such as via bolts that extend through both longitudinal reinforcing members **100** and support members **110**.
(27) FIG. **6** is an isometric closeup view illustrating affixing of battery pack reinforcing members constructed in accordance with some embodiments of the disclosure. A gasket **290** or other moisture resistant sealant may be applied to the upper surface **80** of cover **20**, and a longitudinal reinforcing member **100** may be applied thereon and welded to upper surface **80** such as at weld points **260**. In some embodiments, an adhesive may be applied to affix longitudinal reinforcing members **100** to upper surface **80** (instead of or in addition to welds). In such embodiments reference **290** may represent an adhesive, rather than a gasket or other sealant. In other embodiments, both a gasket or other sealant, as well as an adhesive, may be employed. The gasket/sealant and/or adhesive may be applied to both upper surface **80** and lower surface **90**, to affix and/or seal both the longitudinal reinforcing members **100** as well as support members **110**.
(28) It is noted that longitudinal reinforcing members **100** and support members **110** may be affixed to cover **20**, and coupled to cross members **70**, in any manner. FIG. **7** is a cutaway side view illustrating the attachment of battery pack covers and reinforcing members to cross members, in accordance with some embodiments of the disclosure. As shown, longitudinal reinforcing members **100** may be affixed to cover **20** such as by welds as above. Support member **110** may also be affixed to cover **20** by welds, and additionally affixed to its underlying cross member **70** by a bolt **300** or other fastener. In some embodiments, bolt **300** may extend through cover **20** and hole **270** of support member **110**, into cross member **70**. In this manner, a load path is provided allowing loads on longitudinal reinforcing members **100** to be transferred through support member **110** and into cross member **70**, avoiding damage to other components of battery pack **10**.
(29) Bolt **300** may also affix other components of battery pack **10** to cross members **70**. For example, battery modules **310** may have flanges **320** that extend over cross members **70**, between cross members **70** and support members **110**. The flanges **320** may then be secured to cross members **70** by bolt **300**, so that bolt **300** extends through cover **20**, support member **110**, flange **320**, and into cross member **70**. In this manner, bolt **300** may provide the additional function of

securing internal battery pack **10** components, such as battery modules **310**, to cross members **70**.
(30) FIGS. **8**A and **8**B are plan views illustrating a method of affixing reinforcing members and battery modules to cross members, in accordance with some embodiments of the disclosure. In FIG. **8**A, battery modules are affixed to cross member **70** by affixing flanges **320** to cross members **70**. Flanges **320** may be affixed to cross members **70** in any manner, such as by bolting through bolt holes as shown. More specifically, those flanges **320** that are not used in subsequent bolting of support members **110**, i.e., the two leftmost flanges **320** and two rightmost flanges **320** of FIG. **8**A, are bolted or otherwise affixed to cross member **70**. As shown in FIG. **8**B, cover **20** and support member **110** are then bolted or otherwise affixed to both the middle two flanges **320** and the cross member **70**, such as via bolts passing through cover **20**, holes **270** of support member **110**, the middle two flanges **320**, and the upper surface of cross member **70**. Longitudinal reinforcing member **100** may then be affixed to cover **20** as above. Alternatively, longitudinal reinforcing member **100** may be affixed to cover **20** prior to attachment of cover **20** to either support members **110** or frame **30**.
(31) FIG. **9** is a block diagram representation of an exemplary vehicle having a battery pack constructed in accordance with some embodiments of the disclosure. In FIG. **9**, an exemplary vehicle **400** is shown, which may be any vehicle, including as examples a car, truck, van, recreational vehicle, sports utility vehicle, any commercial vehicle such as a delivery vehicle, tractor-trailer or semi-trailer truck, or the like.
(32) Vehicle **400** includes a vehicle body **602** which may include a frame or chassis **406** that may in turn support one or more seats **404**, as well as a battery pack **408**. As above, seats **404** may be coupled to longitudinal reinforcing members **100** of battery pack **408**, so that seats **404** may apply loads to battery pack **408** through reinforcing members **100**. In some embodiments of the disclosure, longitudinal reinforcing members **100** transfer load from seats **404** to cross members **70** within battery pack **408**, so that loading from seats **404** is borne by structural elements such as cross members **70**, rather than other more delicate or sensitive components of battery pack **408**. This reduces damage to battery pack **408**, increasing its safety and reliability.
(33) FIGS. **10**A and **10**B are a plan view and an isometric view, respectively, of an exemplary battery pack cover or lid constructed in accordance with further embodiments of the disclosure. Here, cover **500** may be similar to cover **20** above, but may include features such as raised portions **510**, **520**, and **530**. Raised portions **510**, **520**, **530** may be any elevated portions of cover **500**, and may be formed in any manner. For example, in some embodiments, cover **500** may be a sheet metal cover with stamped portions **510** and **530**, and a reinforcement portion **520** affixed thereto. The portions **510**, **520**, **530** may each extend along any portion of the length of cover **500**, to increase the bending stiffness of cover **500** along its length and thus allow it to be picked up and handled more easily by, e.g., a robot, during battery pack and vehicle assembly. In some embodiments, reinforcement portion **520** may be, for example, a stamped longitudinal sheet metal piece that is bolted, welded, or otherwise affixed to the upper surface of cover **500**. In other embodiments, reinforcement portion **520** may be formed integral to the cover **500**, e.g., may be a stamped portion of cover **520**. In some embodiments, portion **520** may extend generally longitudinally along substantially the entire length of cover **500**, as shown. While the portion **520** has a longitudinal and generally rectangular shape in plan view, embodiments of the disclosure contemplate any shape which may contribute to increased bending stiffness of cover **500**.
(34) Cover **500** may further include a raised portion **510** positioned to the left of raised portion **520** in the view of FIG. **10**A and extending generally longitudinally along one side of cover **500**. The raised portion **510** may have any shape in plan view. In some embodiments, raised portion **510** may have a number of sections, including a section **510-1** which extends along a left lower side of cover **500** and which may have a curved portion conforming to a lower left corner of cover **500**. Similarly, raised portion **510** may also include a section **510-2** which is wider than section **510-1** and extends toward portion **520** in plan view. Section **510-2** may add bending stiffness along the

width of cover **500** to prevent it from bowing when handled. Section **510-2** may be positioned at any location along the length of cover **500**, and its widened portion may be of any shape which acts to increase bending stiffness and prevent bowing. Raised portion **510** may further include a section **510-3** positioned above section **510-2** in the view of FIG. **10**A and integrally extending therefrom, so that sections **510-1**, **510-2**, and **510-3** are each sections of the same unitary raised portion **510**. Each of sections **510-1**, **510-2**, and **510-3** may have the same elevation, or may have differing elevations. Raised portion **510**, including its sections **510-1**, **510-2**, and **510-3**, may be sized and shaped to extend along any portion of the length of cover **500**. In some embodiments, raised portion **510** extends along at least three quarters of the length of the cover **500**, to sufficiently increase bending stiffness thereof.

(35) Cover **500** may also include a raised portion **530** positioned to the right of raised portion **520** in the view of FIG. **10**A and extending generally longitudinally along a side of cover **500**. The raised portion **530** may have any shape in plan view. In some embodiments, raised portion **530** may have a number of sections, including a section **530-1** which extends along a right lower side of cover **500**. Raised portion **530** may also have a section **530-2** which is wider than section **530-1** and extends toward portion **520** in plan view to add bending stiffness and prevent bowing. Raised portion **530** may further have a section **530-3** which is wider than section **530-1** but which may or may not be as wide as section **530-2**. Sections **530-1**, **530-2**, and **530-3** may be integral extensions of each other, and may be sections of a unitary raised portion **530**. Each of sections **530-1**, **530-2**, and **530-3** may have the same elevation, or may have differing elevations. Raised portion **530**, including sections **530-1**, **530-2**, and **530-3**, may be sized and shaped to extend along any portion of the length of cover **500**. In some embodiments, raised portion **530** extends along at least three quarters of the length of the cover **500**, to sufficiently increase bending stiffness thereof.

(36) Cover **500** may include additional raised portions besides those described above, which extend longitudinally along a substantial portion of the length of cover **500** to increase bending stiffness. As one example, a raised ridge may be formed to extend along fastener holes **560**. This raised ridge may be formed to have any shape, such as a longitudinal ridge extending along one side of fastener holes **560** and generally parallel to an outer edge of cover **500**. The raised ridge may also, or alternatively, extend between holes **560**, or in any other manner which acts to increase bending stiffness.

(37) FIG. **11** is a simplified cross-sectional view of an exemplary battery pack cover constructed in accordance with further embodiments of the disclosure, taken along section A-A of FIG. **10**A. FIG. **11** is not to scale.

(38) As shown, raised portions of cover **500** may have various elevations. For example, raised portion **520** may have an elevation h**2** that is greater than the elevations h**1**, h**3** of raised portions **510-1** and **530-1**, respectively. Here, elevations h**1** and h**3** may be equal or may differ. Embodiments of the disclosure also contemplate any number and location of additional raised portions, such as raised portions **540** and **550** having elevations h**4** and h**5** respectively. In some embodiments, elevations h**4** and h**5** may be lower or lesser than elevations h**2** and h**3**, although this need not necessarily be the case. Indeed, any values of any elevations h**1**-h**5** are contemplated, to increase the bending stiffness of cover **500**.

(39) The foregoing description, for purposes of explanation, used specific nomenclature to provide a thorough understanding of the disclosure. However, it will be apparent to one skilled in the art that the specific details are not required to practice the methods and systems of the disclosure. Thus, the foregoing descriptions of specific embodiments of the present disclosure are presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. For example, any shape or geometry or positions of longitudinal reinforcing members and support members are contemplated, so long as they act to transfer seat loading or other cabin loads to battery pack cross members rather than other battery pack components such as

battery modules. Longitudinal reinforcing members and support members may also be affixed to battery pack lids/covers and cross members in any suitable manner. The embodiments were chosen and described in order to best explain the principles of the disclosure and its practical applications, to thereby enable others skilled in the art to best utilize the methods and systems of the disclosure and various embodiments with various modifications as are suited to the particular use contemplated. Additionally, different features of the various embodiments, disclosed or otherwise, can be mixed and matched or otherwise combined so as to create further embodiments contemplated by the disclosure.

Claims

1. An apparatus, comprising: a panel coupled to a battery pack frame; a plurality of lateral reinforcing members, each comprising at least one respective hole for receiving a respective fastener, affixed directly by welding along their lengths to an outer surface of the panel, wherein each of the plurality of lateral reinforcing members transfer loads to the battery pack frame; and a plurality of longitudinal reinforcing members affixed directly by welding along their lengths to the outer surface of the panel.
2. The apparatus of claim 1, wherein: the battery pack frame comprises a plurality of members; at least one member of the plurality of members is a cross member; and the cross member extends between opposing sides of the battery pack frame.
3. The apparatus of claim 1, wherein each lateral reinforcing member of the plurality of lateral reinforcing members comprises an arcuate cross section.
4. The apparatus of claim 3, wherein each arcuate cross section has outer edges raised above the at least one respective hole that receives the respective fastener that couples an end of a respective lateral reinforcing member to a cross member of the battery pack frame.
5. The apparatus of claim 1, wherein each longitudinal reinforcing member of the plurality of longitudinal reinforcing members comprises a metal member that is one or more of welded or bolted to the panel.
6. The apparatus of claim 1, wherein each longitudinal reinforcing member of the plurality of longitudinal reinforcing members contact at least a portion of an electric vehicle cabin when the battery pack frame is coupled to an electric vehicle.
7. The apparatus of claim 1, wherein: each longitudinal reinforcing member of the plurality of longitudinal reinforcing members is configured to extend across one or more cross members of the battery pack frame; and each longitudinal reinforcing member of the plurality of longitudinal reinforcing members is configured to be affixed to at least one of the one or more cross members.
8. The apparatus of claim 1, wherein: each longitudinal reinforcing member of the plurality of longitudinal reinforcing members comprises a pair of opposite longitudinal ends; and each respective pair of opposite longitudinal ends are affixed to surfaces of adjacent pairs of the plurality of lateral reinforcing members.
9. The apparatus of claim 1, wherein each longitudinal reinforcing member of the plurality of longitudinal reinforcing members transfer loads to adjacent crossmembers of the battery pack frame.
10. An electric vehicle battery pack, comprising: a frame having opposing sides and a plurality of cross members each extending between the opposing sides; a lid having an inner surface facing the frame and an opposing outer surface; a plurality of lateral reinforcing members, each comprising at least one respective hole for receiving a respective fastener, affixed directly by welding along their lengths to the outer surface of the lid, wherein each of the plurality of lateral reinforcing members transfer loads to the frame; and a plurality of longitudinal reinforcing members affixed directly by welding along their lengths to the outer surface of the lid.
11. The battery pack of claim 10, wherein each lateral reinforcing member of the plurality of lateral

reinforcing members comprises an arcuate cross section.
12. The battery pack of claim 11, wherein each arcuate cross section has outer edges raised above the at least on respective hole that receives the respective fastener that couples an end of a respective lateral reinforcing member to a cross member of the frame.
13. The battery pack of claim 10, wherein each longitudinal reinforcing member of the plurality of longitudinal reinforcing members comprises a metal member that is one or more of welded or bolted to the lid.
14. The battery pack of claim 10, wherein each longitudinal reinforcing member of the plurality of longitudinal reinforcing members contact at least a portion of an electric vehicle cabin when the battery pack is coupled to an electric vehicle.
15. The battery pack of claim 10 wherein: each longitudinal reinforcing member of the plurality of longitudinal reinforcing members is configured to extend across one or more of the plurality of cross members; and each longitudinal reinforcing member of the plurality of longitudinal reinforcing members is configured to be affixed to at least one of the plurality of cross members.
16. The battery pack of claim 10 wherein: each longitudinal reinforcing member of the plurality of longitudinal reinforcing members comprises a pair of opposite longitudinal ends; and each respective pair of opposite longitudinal ends are affixed to surfaces of adjacent pairs of the plurality of lateral reinforcing members.
17. The battery pack of claim 10, wherein each longitudinal reinforcing member of the plurality of longitudinal reinforcing members transfer loads to adjacent crossmembers of the frame.
18. A vehicle, comprising: a vehicle frame; a vehicle cabin with mounting points coupled to the vehicle frame; and a battery pack coupled to the vehicle frame below the vehicle cabin, the battery pack comprising: a panel coupled to a battery pack frame; a plurality of lateral reinforcing members, each comprising at least one respective hole for receiving a respective fastener, affixed directly by welding along their lengths to an outer surface of the panel, wherein each of the plurality of lateral reinforcing members transfer loads to at least one member of the battery pack frame; and a plurality of longitudinal reinforcing members affixed directly by welding along their lengths to the outer surface of the panel.
19. The vehicle of claim 18, wherein each lateral reinforcing member of the plurality of lateral reinforcing members comprises an arcuate cross section.
20. The vehicle of claim 18, wherein: each longitudinal reinforcing member of the plurality of longitudinal reinforcing members comprises a pair of opposite longitudinal ends; and each respective pair of opposite longitudinal ends are affixed to surfaces of adjacent pairs of the plurality of lateral reinforcing members.