SUBSYSTEM OF A BATTERY CELL TAB AND METHOD OF MANUFACTURING THE SAME

FIELD OF INVENTION

[0001] The present invention generally relates to the field of battery technology. More specifically, the present invention is related to manufacturing a battery module with bus bar subsystem.

BACKGROUND OF THE INVENTION

[0002] The subject matter discussed in the background section should not be assumed to be prior art merely as a result of its mention in the background section. Similarly, a problem mentioned in the background section or associated with the subject matter of the background section should not be assumed to have been previously recognized in the prior art. The subject matter in the background section merely represents different approaches, which in and of themselves may also correspond to implementations of the claimed technology.

[0003] The battery module (for the sake of brevity hereinafter also referred as 'the battery') is comprised of a plurality of electrochemical cells in common practice. General known methods of electrically connecting these cells in a battery is by using a bus bar. The terminals of each battery cell are connected by a bus bar to collectively form a battery arrangement. The terminals may be arranged in rows to form a bus bar and making it easier to connect electrically.

[0004] These several single battery cells are connected together using multiple techniques to form a battery module, one of which may be welding. Each connection impacts the functionality and efficiency of the entire battery module. The welding techniques frequently used for connecting these battery cells are resistance spot, ultrasonic or laser beam welding, and the like. These techniques differ with respect to the characteristics based on the properties and geometry based on the contact.

[0005] Generally, the welding techniques used are not able to achieve consistency in weld quality leading to uneven depth in the weld or uneven strength at different points of the connections. This leads to reduced quality of the battery modules, affecting the reliability and strength of the welded area.

[0006] In cases of issues in welding, the entire battery module is rendered impracticable, since re-welding is not possible in case of laser welding. In case of resistance welding, even though, re-welding or re-working the same is a possibility, the product quality achieved with respect to the weld strength in such cases generally are poor. Welding at a single cell leads to inconsistency in cell holders at the plastic parts. It also leads to poor welding at the punched parts of bus bar. Such technique may also potentially lead to cell damage, which is in turn responsible for electrolyte leak since the pore holes in weld may lead to leak of electrolyte from the battery pack in the longer run.

[0007] **Fig. 1 and Fig. 2** illustrate a conventionally used technique of battery module assembly process. In such conventional process, a plurality of battery cells may be loaded into a cell holder. The cell holder serves to position and retain the individual battery cells in a structured manner, ensuring proper alignment for subsequent assembly steps. Once the battery cells are arranged within the cell holder, a bus bar is placed over the battery cells to establish an electrical connection between them. The bus bar serves as a conductive medium, allowing for efficient current flow across the battery module. To secure the connection, the bus bar is welded to the individual battery cell terminals using a welding technique such as laser welding, resistance welding, ultrasonic welding, or spot welding.

[0008] In such conventional techniques, in case of any weld fault, the entire battery module or sometimes battery pack, as the case may be, is discarded since the same is impractical & riskier to work with. Such techniques do not achieve consistency in weld quality as these techniques lead to uneven depth of weld, poor welding strength. This in turn makes the same less reliable and efficiency is compromised of the entire battery pack.

[0009] Therefore, there is a need to reduce the variation in battery cell and bus bar that is welded together using the laser or resistance welding as subsystem. It is required that the weld depth and strength should be checked properly. The cells are thoroughly inspected for pore holes. Proper inspection of the cell pack is required before assembly to ensure that extended bus bars can be easily connected from the battery cell tab to the main bus bar. Additionally, this inspection facilitates efficient reworking of connections in case of any necessary updates.

OBJECTS OF THE INVENTION

[0010] An object of the present invention is to provide an efficient bus bar as a subsystem in a battery module with increased consistency and efficiency.

[0011] Another object of the present invention is to provide a bus bar as a subsystem in a battery module with improved strength and even weld depth.

[0012] Yet another object of the present invention is to provide a bus bar capable of being re-worked.

[0013] Yet another object of the present invention is to provide a cost-efficient bus bar for a battery cell tab.

SUMMARY OF THE INVENTION

[0014] This summary is provided to introduce aspects related to the present invention of manufacturing a battery module with bus bar subsystem and the aspects are further described below in the detailed description. This summary is not intended to identify essential features of the claimed subject matter nor is it intended for use in determining or limiting the scope of the claimed subject matter.

[0015] In an embodiment of the present disclosure, a battery module is disclosed. The battery module comprises a plurality of battery cells. Each battery cell having a positive cell tab and a negative cell tab. The battery module further comprises a first bus bar coupled to the positive cell tab. The battery module further comprises a second bus bar coupled to the negative cell tab. The battery module further comprises a battery cell holder configured to secure the plurality of battery cells. Furthermore, the battery module comprises a connector bus bar coupled to the first bus bar and the second bus bar of each battery cell.

[0016] In an aspect of the present disclosure, the first bus bar, the second bus bar, and the connector bus bar are made of copper plating and nickel plating.

[0017] In another aspect of the present disclosure, the first bus bar and the second bus bar are coupled to the positive cell tab and the negative cell tab respectively using welding technique and the connector bus bar is coupled to the first bus bar and the second bus bar of each battery cell using welding technique.

[0018] In another aspect of the present disclosure, the welding technique is selected from a group comprising laser welding, resistance welding, ultrasonic welding, arc welding and spot welding.

[0019] In another aspect of the present disclosure, the first bus bar and the second bus bar are coupled on same side of the battery cell.

[0020] In another aspect of the present disclosure, the first bus bar and the second bus bar are coupled on opposite side of the battery cell.

[0021] In another aspect of the present disclosure, wherein the plurality of battery cells is arranged in a parallel manner or in a series manner in the battery cell holder.

[0022] In another aspect of the present disclosure, the battery cell holder is configured to securely retain the plurality of battery cells in a predetermined alignment.

[0023] In another aspect of the present disclosure, the connector bus bar is detachably mounted to the first bus bar and the second bus bar.

[0024] In another aspect of the present disclosure, welded connections of the first bus bar, the second bus bar, and the connector bus bar have a predetermined weld depth and weld strength.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The accompanying drawings constitute a part of the description and are used to provide further understanding of the present invention. The drawings illustrate exemplary embodiments of the present invention and, together with the description, serve to explain the principles of the present invention.

[0026] **Fig. 1** illustrates a flowchart depicting a conventional battery module assembly process in accordance with a prior art.

[0027] **Fig. 2** illustrates a schematic representation of a conventional battery module assembly process, in accordance with a prior art.

[0028] **Fig. 3** illustrates a system depicting a detailed view of welded connections between bus bars coupled to a plurality of battery cells and a connector bus bar, in accordance with an embodiment of the present invention.

[0029] **Fig. 4** illustrates a schematic representation of welding of individual cells, in accordance with an embodiment of the present invention.

[0030] **Fig. 5** illustrates a schematic representation of different configurations of busbars welded to cell tabs, in accordance with an embodiment of the present invention.

[0031] **Fig. 6** illustrates a schematic representation of a battery module assembly process, in accordance with an embodiment of the present invention.

[0032] A more complete understanding of the present invention and its embodiments thereof may be acquired by referring to the following description and the accompanying drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0033] Exemplary embodiments now will be described with reference to the accompanying drawings. The disclosure may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey its scope to those skilled in the art. The terminology used in the detailed description of the particular exemplary embodiments illustrated in the accompanying drawings is not intended to be limiting. In the drawings, like numbers refer to like elements.

[0034] It is to be noted, however, that the reference numerals used herein illustrate only typical embodiments of the present subject matter, and are therefore, not to be considered for limiting its scope, for the subject matter may admit to other equally effective embodiments.

[0035] The specification may refer to "an", "another", "one" or "some" embodiment(s) in several locations.

[0036] This does not necessarily imply that each such reference is to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

[0037] As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless expressly stated otherwise. It will be further understood that the terms "include", "comprises", "including" and/or "comprising" when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It will be understood

that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. Furthermore, "connected" or "coupled" as used herein may include operatively connected or coupled. As used herein, the term "and/or" includes any and all combinations and arrangements of one or more of the associated listed items.

[0038] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure pertains. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0039] The detailed description includes specific details for the purpose of providing a thorough understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced without these specific details.

[0040] The present invention relates to a battery module with a bus bar subsystem designed to improve electrical connectivity, structural integrity, and inspection efficiency in battery pack assemblies. The battery module comprises a plurality of battery cells, each having a positive and negative cell tab, interconnected via a first and a second bus bars using welding technique. The battery cells welded to the bus bars are placed in a cell holder. Further after placing the battery cells into the cell holder, a connector bus bar is further integrated to establish a uniform electrical pathway and ensure balanced current distribution across the battery module. The invention addresses prior art limitations by providing a structured welding approach, enabling early-stage inspection of weld depth and strength, thereby minimizing defects such as weak joints or pore holes. Additionally, the bus bar subsystem facilitates efficient reworking and repairability, ensuring long-term reliability and modular scalability.

[0041] **Fig. 3** illustrates a system **300** depicting a detailed view of welded connections between bus bars coupled to a plurality of battery cells **302** and a connector bus bar **304**, in accordance with an embodiment of the present invention. The system **300** may comprises a plurality of battery cells **302**. (Hereinafter, for ease of explanation, the plurality of battery cells **302** and each battery cell may cumulatively refer as battery cell **302**). The battery cell **302** serves as fundamental building blocks of battery module. The battery cell **302** may comprises

a positive cell tab **502** and a negative cell tab **504** (illustrated in **Fig. 5**), which are essential for establishing electrical interconnections. Only tested and high-quality battery cell **302** proceeds to the assembly line, minimizing the possibility of defects in forming the battery module. Further to establish a structured and efficient electrical connection, a first bus bar **506** and a second bus bar **508** (illustrated in **Fig. 5**) are provided for each battery cell **302**. The first bus bar **506** is electrically coupled to the positive cell tab **502** and the second bus bar **508** is electrically coupled to the negative cell tab **504** of the battery cell **302**.

[0042] In one implementation, the first bus bar **506** and second bus bar **508** are placed on the same side of the battery cell **302**. Such arrangement simplifies manufacturing process and electrical routing, making it ideal for compact designs. In another implementation, the first bus bar **506** is placed on one side, while the second bus bar **508** is placed on opposite side of the battery cell **302**. Such configuration enhances current balance, heat dissipation, and structural stability, making suitable for high-power applications.

[0043] The bus bars function as primary conductive pathways, enabling the efficient flow of electrical energy from each battery cell **302** to output terminals of the battery module. The bus bars are typically made of high-conductivity materials, such as copper plating and nickel plating, to ensure low electrical resistance, minimal power loss, and enhanced durability. The presence of the bus bars facilitates the uniform distribution of electrical current, preventing localized heating or voltage drops.

[0044] To establish a robust and reliable electrical connection, the first bus bar **506** and the second bus bar **508** are coupled to the positive cell tab **502** and the negative cell tab **504** of the battery cell **302** respectively using welding technique. The welding technique employed is selected from a group comprising laser welding, resistance welding, ultrasonic welding, arc welding and spot welding. The welding process is meticulously controlled to achieve a predetermined weld depth and weld strength, thereby ensuring a consistent, high-quality connection throughout the battery module. This prevents weak welds, improper bonding, and defects such as pore holes or microcracks, which could otherwise compromise the structural integrity of the battery module. The bus bars and cell tabs of the battery cell **302** are first welded together as a subsystem, prior to integrating them together into complete battery module. Such process allows for preliminary inspection, defect detection, and reworking of welds before final assembly, thereby significantly improving the reliability and quality of final battery module.

[0045] Further the plurality of battery cells **302** coupled with respective bus bars are loaded to a battery cell holder (not shown in the figure). The battery cell holder is configured to provide mechanical support, structural alignment, and secure positioning of the battery cells **302** throughout the assembly process. The cell holder ensures that each battery cell **302** remains in a fixed and uniformly spaced arrangement, preventing displacement. The design of the cell holder fixture plays a crucial role in maintaining electrical and mechanical uniformity within the battery module. The cell holder allows for consistent alignment of the battery cells **302**, thereby ensuring that integration of the bus bars and final welding processes are carried out with precision. The use of a dedicated fixture also facilitates automation in the assembly process, reducing manual errors and improving production efficiency. The the plurality of battery cells **302** arranged in a parallel manner or in a series manner in the battery cell holder.

[0046] The system **300** further comprises a connector bus bar **304** is electrically coupled to the first bus bar **506** and the second bus bar **508** of each battery cell **302** using welding technique. The welding technique employed is selected from a group comprising laser welding, resistance welding, ultrasonic welding, arc welding and spot welding. The connector bus bar **304** serves as a crucial interconnection element, ensuring balanced current distribution and enhanced structural stability. The connector bus bar **304** is detachably mounted to the bus bars. The integration of the connector bus bar **304** allows for the formation of a unified conductive path, thereby minimizing voltage drops and localized electrical imbalances. Such connection of the connector bus bar **304** facilitates early-stage inspection of weld depth and strength. This is particularly advantageous in preventing electrical inefficiencies, mechanical failures, and safety hazards, as any inconsistencies in welding can be identified and corrected before the final module assembly.

[0047] The connector bus bar **304** is composed of a high-conductivity material, such as copper plating and nickel plating, which enhances electrical efficiency, prevents oxidation and corrosion, and improves thermal dissipation. The integration of the connector bus bar **304** ensures a uniform electrical potential across the battery module, thereby increasing its overall performance, durability, and rework ability.

[0048] **Fig. 4** illustrates a schematic representation of welding of individual battery cells **302**, in accordance with an embodiment of the present invention. In this stage, the cell tabs of each battery cell **302** is welded to the corresponding bus bars using a precision welding technique, such as laser welding, resistance welding, ultrasonic welding, arc welding, or spot

welding. Such welding technique ensure a strong, reliable, and conductive joint. The welding technique is carefully controlled to achieve a predetermined weld depth and strength, preventing weak bonds, microcracks, or pore holes that could compromise the integrity of the electrical connection. Such step plays a crucial role in ensuring consistent electrical conductivity, minimal resistance, and uniform current distribution across the battery module. A pre-welded subsystem approach allows for early-stage inspection and defect detection, enabling any faulty welds to be identified and corrected before the final battery module assembly. The individual battery cell welding process significantly enhances the structural stability, reliability, and performance of the battery module, ensuring long-term operational efficiency and safety.

[0049] **Fig. 5** illustrates a schematic representation of different configurations of bus bars welded to cell tabs, in accordance with an embodiment of the present invention. The figure depicts two primary welding implementations. In the first implementation, the positive cell tab **502** is welded to the first bus bar **506**, and the negative cell tab **504** is welded to the second bus bar **508** separately in two different sides of the battery cell **302**. Such implementation enhances current balance, heat dissipation, and structural stability, making suitable for high-power applications. In the second implementation, both the positive cell tab **502** and the negative cell tab **504** are welded to the first bus bar **506** and the second bus bar **508** respectively on the same side of the battery cell **302**. Such implementation simplifies manufacturing process and electrical routing, making it ideal for compact designs. The figure further highlights the use of a copper bus bar for interconnecting multiple cells individually in series or parallel configurations, thereby enabling balanced current distribution and enhanced conductivity. The welding techniques employed include laser welding and resistance welding, ensuring strong, low-resistance connections with precise weld depth and strength. Such process enhances electrical efficiency, mechanical robustness, and manufacturability of the battery module.

[0050] **Fig. 6** illustrates a schematic representation of a battery module assembly process, in accordance with an embodiment of the present invention. The assembly process begins with preparing the battery cells **302** that serves as fundamental building blocks of the battery module. Only tested and high-quality battery cells **302** proceed to the assembly line to minimize the possibility of defects in the final battery module. The battery cells **302** comprises a positive cell tab **502** and a negative cell tab **504**, which are essential for establishing electrical interconnections.

[0051] The assembly process further includes providing a first bus bar **506** and a second bus bar **508** to establish a structured and efficient electrical connection. The first bus bar **506** is electrically coupled to the positive cell tab **502**, and the second bus bar **508** is electrically coupled to the negative cell tab **504** of each battery cell **302**. In one implementation, the first bus bar **506** and second bus bar **508** are placed on the same side of the battery cell **302**, simplifying manufacturing and electrical routing. In another implementation, the first bus bar **506** is placed on one side, while the second bus bar **508** is placed on the opposite side of the battery cell **302**, enhancing current balance, heat dissipation, and structural stability.

[0052] The assembly process further includes utilizing the bus bars as primary conductive pathways for enabling efficient electrical energy flow from each battery cell **302** to the battery module's output terminals. The bus bars are typically made of high-conductivity materials such as copper plating and nickel plating, ensuring low electrical resistance, minimal power loss, and enhanced durability. The presence of the bus bars facilitates uniform current distribution, thereby preventing localized heating and voltage drops.

[0053] To establish a robust and reliable electrical connection, the bus bars are coupled to the respective cell tabs of the battery cell **302** using welding technique. The welding technique employed is selected from a group comprising laser welding, resistance welding, ultrasonic welding, arc welding and spot welding. The welding technique is meticulously controlled to achieve a predetermined weld depth and weld strength, thereby ensuring a consistent, high-quality connection throughout the battery module. This prevents weak welds, improper bonding, and defects such as pore holes or microcracks, which could otherwise compromise the structural integrity of the battery module. The bus bars and cell tabs of the battery cell **302** are first welded together as a subsystem, prior to integrating them into the complete battery module. Such process allows for preliminary inspection, defect detection, and reworking of welds before final assembly, thereby significantly improving the reliability and quality of final product.

[0054] The assembly process further includes loading the battery cells **302** coupled with respective bus bars into a cell holder. The battery cell holder is configured to provide mechanical support, structural alignment, and secure positioning of the battery cells **302** throughout the assembly process. The cell holder ensures that each battery cell **302** remains in a fixed and uniformly spaced arrangement, preventing displacement. The design of the cell holder fixture plays a crucial role in maintaining electrical and mechanical uniformity within

the battery module. The cell holder allows for consistent alignment of the battery cells **302**, thereby ensuring that integration of the bus bars and final welding process is carried out with precision. The use of a dedicated fixture also facilitates automation in the assembly process, reducing manual errors and improving production efficiency.

[0055] The assembly process further includes coupling the connector bus bar **304** to the bus bars of each battery cell **302** using welding technique. The welding technique employed is selected from a group comprising laser welding, resistance welding, ultrasonic welding, arc welding and spot welding. The connector bus bar **304** serves as a crucial interconnection element, ensuring balanced current distribution and enhanced structural stability. The connector bus bar **304** is detachably mounted to the bus bars. The integration of the connector bus bar **302** allows for the formation of a unified conductive path, thereby minimizing voltage drops and localized electrical imbalances. Such connection of the bus bar **304** facilitates early-stage inspection of weld depth and strength. This is particularly advantageous in preventing electrical inefficiencies, mechanical failures, and safety hazards, as any inconsistencies in welding can be identified and corrected before the final module assembly.

[0056] The connector bus bar **304** is composed of a high-conductivity material, such as copper plating and nickel plating, which enhances electrical efficiency, prevents oxidation and corrosion, and improves thermal dissipation. The integration of the connector bus bar **304** ensures a uniform electrical potential across the battery module, thereby increasing its overall performance, durability, and rework ability.

[0057] The present invention offers significant technical advantages, enhancing electrical efficiency, structural stability, and manufacturing reliability in battery module assembly. The use of high-conductivity nickel-plated copper bus bars and the connector bus bar ensures uniform current distribution, minimizing voltage drops and thermal imbalances. The structured arrangement of battery cells within a dedicated holder prevents displacement, ensuring precise alignment for automated assembly. The controlled welding process, employing techniques such as laser or resistance welding, ensures strong, defect-free interconnections with consistent weld depth and strength, preventing microcracks or weak bonds. The modular welding approach enables early-stage inspection, defect detection, and reworking, improving manufacturing yield and reliability. Configurable bus bar placement supports both compact and high-power applications, optimizing current balance and heat dissipation. The integration of the connector bus bar enhances electrical uniformity and stability while reducing power

losses. The automation-compatible process improves production efficiency, minimizes manual errors, and ensures scalable, high-quality manufacturing, making the invention highly suitable for electric vehicles, renewable energy storage, and industrial applications.

[0058] Although implementations of manufacturing a battery module with bus bar subsystem have been described in language specific to structural features and/or methods, it is to be understood that the appended claims are not necessarily limited to the specific features or methods described. Rather, the specific features and methods are disclosed as examples of implementations of manufacturing a battery module with bus bar subsystem.

[0059] The invention has been described above with reference to numerous embodiments and specific examples. Many variations will suggest themselves to those skilled in this art in light of the above detailed description. All such obvious variations are within the full intended scope of the appended claims.

WE CLAIM:

1. A battery module, comprises:

a plurality of battery cells (302), wherein each battery cell having a positive cell tab (502) and a negative cell tab (504);

a first bus bar (506) coupled to the positive cell tab (502);

a second bus bar (508) coupled to the negative cell tab (504);

a battery cell holder configured to secure the plurality of battery cells (302); and

a connector bus bar (304) coupled to the first bus bar (506) and the second bus bar (508) of each battery cell (302).

2. The battery module as claimed in claim 1, wherein the first bus bar (506), the second bus bar (508), and the connector bus bar (304) are made of copper plating and nickel plating.

3. The battery module as claimed in claim 1, wherein the first bus bar (506) and the second bus bar (508) are coupled to the positive cell tab (502) and the negative cell tab (504) respectively using welding technique, and wherein the connector bus bar (304) is coupled to the first bus bar (506) and the second bus bar (508) of each battery cell (302) using welding technique.

4. The battery module as claimed in claim 3, wherein the welding technique is selected from a group comprising laser welding, resistance welding, ultrasonic welding, arc welding and spot welding.

5. The battery module as claimed in claim 1, wherein the first bus bar (506) and the second bus bar (508) are coupled on same side of the battery cell (302).

6. The battery module as claimed in claim 1, the first bus bar (506) and the second bus bar (508) are coupled on opposite side of the battery cell (302).

7. The battery module as claimed in claim 1, wherein the plurality of battery cells (302) is arranged in a parallel manner or in a series manner in the battery cell holder.

8. The battery module as claimed in claim 1, wherein the battery cell holder is configured to securely retain the plurality of battery cells (302) in a predetermined alignment.

9. The battery module as claimed in claim 1, wherein the connector bus bar (304) is detachably mounted to the first bus bar (506) and the second bus bar (508).

10. The battery module as claimed in claim 1, wherein welded connections of the first bus bar (506), the second bus bar (508), and the connector bus bar (304) have a predetermined weld depth and weld strength.