United States Patent Application Publication 20250260092
Kind Code A1
Publication Date August 14, 2025
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COOLING ASSEMBLY FOR BATTERY SYSTEM

Abstract

A cooling assembly for a battery system includes an inlet system. The inlet system includes an inlet manifold, an inlet connecting tube, a first inlet connecting member defining a first surface and at least one first inlet fluid port, and a second inlet connecting member defining at least one second inlet fluid port in fluid communication with the at least one first inlet fluid port of the first inlet connecting member. The cooling assembly also includes an outlet system in fluid communication with the inlet system. The outlet system includes an outlet manifold, a first outlet connecting member defining at least one first outlet fluid port, an outlet connecting tube, and a second outlet connecting member defining at least one second outlet fluid port.

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Appl. No.: **18/438617**

Filed: **February 12, 2024**

Publication Classification

Int. Cl.: **H01M10/6568** (20140101); **H01M10/613** (20140101); **H01M50/209** (20210101)

U.S. Cl.:

CPC **H01M10/6568** (20150401); **H01M10/613** (20150401); **H01M50/209** (20210101);

Background/Summary

TECHNICAL FIELD

[0001] The present disclosure relates to a battery system, and more particularly to, a cooling assembly for the battery system.

BACKGROUND

[0002] Battery systems are used in a variety of applications as a means of power supply. For example, battery systems are being increasingly implemented in stationary and mobile machines, such as, passenger vehicles or construction machines, to supply operating power. In order to perform efficiently, battery modules of the such battery systems may have to be maintained and operated within predefined temperature limits to prevent overheating of the battery modules. Thus, all battery systems have a cooling system that supply a cooling fluid to maintain a temperature of the battery system within predefined temperature limits.

[0003] Battery systems vary in configuration based on the energy requirements of each application. For example, the battery system may have battery modules arranged in varying numbers of rows and columns. However, having a unique cooling system for each configuration increases a number of parts, inventory costs, and material costs for the cooling system. Moreover, such unique cooling systems may require longer lead time for manufacturing and assembly.

[0004] CN219801006U describes a battery liquid cooling structure and a battery pack, wherein the battery liquid cooling structure comprises at least one liquid cooling unit, the liquid cooling unit comprises a connecting pipe, a liquid inlet connector, a liquid outlet connector and at least two liquid cooling pipes for cooling a battery, the lengths of the liquid cooling pipes extend along a first direction, all the liquid cooling pipes are arranged at intervals along a second direction, the first direction and the second direction form an included angle, two adjacent liquid cooling pipes are at least communicated in parallel through two connecting pipes arranged at intervals, the liquid cooling pipes positioned at two sides of the second direction are respectively communicated with the liquid inlet connector and the liquid outlet connector, the connecting pipes on the liquid inlet connector and the liquid cooling pipes communicated with the liquid inlet connector are arranged at intervals along a set direction, and the connecting pipes on the liquid outlet connector and the liquid cooling pipes communicated with the liquid outlet connector are arranged at intervals along the set direction, and the set direction and the second direction form an included angle. The battery liquid cooling structure has low manufacturing cost, is convenient to assemble, and has high temperature uniformity for cooling the battery.

SUMMARY OF THE DISCLOSURE

[0005] In an aspect of the present disclosure, a cooling assembly for a battery system is provided. The battery system includes at least one string of battery modules. The cooling assembly includes an inlet system. The inlet system includes an inlet manifold. The inlet system also includes an inlet connecting tube extending along a first central axis and coupled to the inlet manifold. The inlet system further includes a first inlet connecting member coupled to the inlet connecting tube and extending along the first central axis. The inlet connecting tube is disposed between the inlet manifold and the first inlet connecting member. The first inlet connecting member defines a first surface and at least one first inlet fluid port defined in the first surface. The inlet system includes a second inlet connecting member coupled to the first inlet connecting member at the first surface of the first inlet connecting member. The second inlet connecting member extends along a second central axis that is offset from and parallel to the first central axis. The second inlet connecting member defines at least one second inlet fluid port in fluid communication with the at least one first inlet fluid port of the first inlet connecting member. The cooling assembly also includes an outlet system in fluid communication with the inlet system. The outlet system includes an outlet manifold. The outlet system also includes a first outlet connecting member extending along a third central axis and coupled to the outlet manifold. The first outlet connecting member defines at least one first outlet fluid port. The outlet system further includes an outlet connecting tube coupled to

the first outlet connecting member and extending along the third central axis. The first outlet connecting member is disposed between the outlet manifold and the outlet connecting tube. The outlet system includes a second outlet connecting member coupled to the outlet connecting tube and extending along the third central axis. The outlet connecting tube is disposed between the first outlet connecting member and the second outlet connecting member. The second outlet connecting member defines at least one second outlet fluid port.

[0006] In another aspect of the present disclosure, a battery system is provided. The battery system includes at least one string of battery modules. The battery system also includes a cooling assembly to direct cooling fluid towards the at least one string of battery module. The cooling assembly includes an inlet system. The inlet system includes an inlet manifold. The inlet system also includes an inlet connecting tube extending along a first central axis and coupled to the inlet manifold. The inlet system further includes a first inlet connecting member coupled to the inlet connecting tube and extending along the first central axis. The inlet connecting tube is disposed between the inlet manifold and the first inlet connecting member. The first inlet connecting member defines a first surface and at least one first inlet fluid port defined in the first surface. The inlet system includes a second inlet connecting member coupled to the first inlet connecting member at the first surface of the first inlet connecting member. The second inlet connecting member extends along a second central axis that is offset from and parallel to the first central axis. The second inlet connecting member defines at least one second inlet fluid port in fluid communication with the at least one first inlet fluid port of the first inlet connecting member. The cooling assembly also includes an outlet system in fluid communication with the inlet system. The outlet system includes an outlet manifold. The outlet system also includes a first outlet connecting member extending along a third central axis and coupled to the outlet manifold. The first outlet connecting member defines at least one first outlet fluid port. The outlet system further includes an outlet connecting tube coupled to the first outlet connecting member and extending along the third central axis. The first outlet connecting member is disposed between the outlet manifold and the outlet connecting tube. The outlet system includes a second outlet connecting member coupled to the outlet connecting tube and extending along the third central axis. The outlet connecting tube is disposed between the first outlet connecting member and the second outlet connecting member. The second outlet connecting member defines at least one second outlet fluid port.

[0007] Other features and aspects of this disclosure will be apparent from the following description and the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a diagrammatic representation of a battery system having a cooling assembly, according to an example of the present disclosure;

[0009] FIG. **2** is a schematic perspective view of an inlet system of the cooling assembly of FIG. **1**, according to an example of the present disclosure;

[0010] FIG. **3** is a schematic perspective views of an inlet connecting tube and a first inlet connecting member of the inlet system of FIG. **2**;

[0011] FIG. **4** is a schematic perspective view of a second inlet connecting member of the inlet system of FIG. **2**;

[0012] FIG. **5** is a schematic sectional view illustrating a coupling of the second inlet connecting member of FIG. **4** with fluid lines in the battery system of FIG. **1**;

[0013] FIGS. **6**A to **6**C illustrate different configurations for the inlet system based on a number of strings of battery modules associated with the battery system of FIG. **1**;

[0014] FIG. **7** is a schematic perspective view of an outlet system of the cooling assembly of FIG.

1, according to an example of the present disclosure;
[0015] FIG. **8** is a schematic sectional view illustrating a first outlet connecting member of the outlet system of FIG. **7** with fluid lines in the battery system of FIG. **1**; and
[0016] FIGS. **9**A to **9**C illustrate different configurations for the outlet system based on a number of strings of battery modules associated with the battery system of FIG. **1**.

DETAILED DESCRIPTION

[0017] Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.
[0018] Referring to FIG. **1**, a diagrammatic representation of an exemplary battery system **100** is illustrated. In some examples, the battery system **100** may be used in energy storage systems. In an example, the battery system **100** may supply electrical power to a moving machine, such as a work/construction machine, or a stationary machine.
[0019] The battery system **100** includes one or more strings **102** of battery modules **104**. In the illustrated example of FIG. **1**, the battery system **100** includes the single string **102** of battery modules **104**. The single string **102** of battery modules **104** includes two rows of battery modules **104** disposed adjacent to each other along a horizontal axis A**1**. Furthermore, each row of the battery modules **104** includes eleven battery modules **104** herein that are stacked along a vertical axis A**2** of the battery system **100**. The battery modules **104** are electrically coupled together in a stacked relationship to provide a desired amount of power output and voltage output. It should be noted that the configuration of the battery system **100** as explained herein is exemplary in nature, and the battery system **100** may include two strings of battery modules, three strings of battery modules, four strings of battery modules, and so on, based on application requirements.
[0020] Each battery module **104** may include a number of rechargeable lithium-ion batteries to store electric power and distribute the stored electric power at a desired voltage and a desired amperage for desired applications. In other examples, each battery module **104** may include a number of rechargeable lead-acid batteries, nickel metal hydride (NiMH) batteries, and the like that converts chemical energy to electrical energy.
[0021] The battery system **100** includes a cooling assembly **106** to direct cooling fluid towards the one or more strings **102** of battery modules **104**. The cooling fluid may include water, a combination of water and one or more chemicals, or any other type of cooling fluid. The cooling assembly **106** may be coupled to a thermal management system (not shown) of the battery system **100** to maintain a temperature of the battery system **100** within desired operating limits. The thermal management system may include, for example, a pump, a fluid vessel, valves, a controller, and the like. The cooling fluid enters the cooling assembly **106** via an inlet system **200** of the cooling assembly **106** and flows through the battery modules **104** to maintain the temperature of the battery system **100** within desired operating limits. Further, the cooling fluid, at a higher temperature, exits the cooling assembly **106** via an outlet system **700** of the cooling assembly **106**.
[0022] As shown in FIG. **1**, the inlet system **200** is disposed proximal to a bottom end **108** of the battery system **100** and the outlet system **700** is disposed proximal to a top end **110** of the battery system **100**. As such, the cooling fluid flows upwards while flowing through the battery modules **104** of the battery system **100** before exiting the cooling assembly **106** via the outlet system **700**. However, in other examples, the inlet system **200** may be disposed proximal to the top end **110** of the battery system **100** and the outlet system **700** may be disposed proximal to the bottom end **108** of the battery system **100**.
[0023] Referring to FIG. **2**, the inlet system **200** includes an inlet manifold **202**. The inlet manifold **202** is an interface between the thermal management system and the cooling assembly **106**. The cooling fluid enters the cooling assembly **106** via the inlet manifold **202**. The inlet manifold **202** includes a tubular member **204** and a bracket **206** to couple the inlet manifold **202** with the battery system **100** (see FIG. **1**). A plurality of first fasteners **208** couple the inlet manifold **202** with the battery system **100**. The first fasteners **208** may include bolts, pins, screws, and the like. In an

example, the inlet manifold **202** may be made of a metallic material, such as, cast iron.
[0024] The inlet system **200** also includes an inlet connecting tube **210** extending along a first central axis X**1** and coupled to the inlet manifold **202**. The inlet connecting tube **210** is a tube that is in fluid communication with the tubular member **204** of the inlet manifold **202** to receive the cooling fluid therefrom.
[0025] The inlet system **200** further includes a first inlet connecting member **211** coupled to the inlet connecting tube **210** and extending along the first central axis X**1**. The first inlet connecting member **211** is in fluid communication with the inlet connecting tube **210** to receive the cooling fluid from the inlet connecting tube **210**. The tubular member **204** of the inlet manifold **202**, the inlet connecting tube **210**, and the first inlet connecting member **211** are co-axial with each other and in fluid communication with each other. The inlet connecting tube **210** is disposed between the inlet manifold **202** and the first inlet connecting member **211**. The first inlet connecting member **211** defines a first length L**1** along the first central axis X**1**.
[0026] Further, the first inlet connecting member **211** is coupled with the inlet connecting tube **210** via a loose fit. In an example, a radial seal (not shown herein), such as an O-ring, may be disposed on an outer surface of the inlet connecting tube **210**. Further, a portion of the inlet connecting tube **210** may be received within the first inlet connecting member **211**, such that the radial seal is disposed between an inner surface of the first inlet connecting member **211** and the outer surface of the inlet connecting tube **210**. The first inlet connecting member **211** has a rectangular shape. In an example, the first inlet connecting member **211** may be made of a metallic material, such as, aluminum.
[0027] Referring now to FIG. **3**, the first inlet connecting member **211** defines a first surface **212**. The first inlet connecting member **211** also defines a surface **218** (shown in FIG. **2**) opposite the first surface **212**.
[0028] Further, the first inlet connecting member **211** defines one or more first inlet fluid ports **214** defined in the first surface **212**. In the illustrated example of FIG. **3**, the first inlet connecting member **211** defines two first inlet fluid ports **214**. The first inlet fluid ports **214** extend in a direction that is orthogonal to the first central axis X**1**. The first surface **212** defines one or more circular grooves **220** that surround the one or more first inlet fluid ports **214**. Specifically, the first surface **212** defines two circular grooves **220** that surround a corresponding first inlet fluid port **214**. Further, the first surface **212** also defines a number of first apertures **216**. The first surface **212** defines four first apertures **216** herein. The first apertures **216** are disposed proximate to the first inlet fluid ports **214**.
[0029] The inlet system **200** includes a second inlet connecting member **222** coupled to the first inlet connecting member **211** at the first surface **212** of the first inlet connecting member **211**. The inlet system **200** also includes a number of mechanical fasteners **224** to connect the first inlet connecting member **211** with the second inlet connecting member **222**. The mechanical fasteners **224** further connect the first inlet connecting member **211** with the second inlet connecting member **222** with the battery system **100** (see FIG. **1**). The mechanical fasteners **224** may include bolts, pin, screws, and the like.
[0030] Referring now to FIGS. **2** and **4**, the second inlet connecting member **222** extends along a second central axis X**2** that is offset from and parallel to the first central axis X**1**. The second inlet connecting member **222** has a rectangular shape. In an example, the second inlet connecting member **222** may be made of a metallic material, such as, steel. The second inlet connecting member **222** defines a second length L**2** along the second central axis X**2**. The second length L**2** of the second inlet connecting member **222** is greater than the first length L**1** of the first inlet connecting member **211**.
[0031] As shown in FIG. **4**, the second inlet connecting member **222** defines one or more second inlet fluid ports **226** in fluid communication with the one or more first inlet fluid ports **214** (see FIG. **3**) of the first inlet connecting member **211** (see FIGS. **2** and **3**). In the illustrated example of

FIG. **4**, the second inlet connecting member **222** defines two second inlet fluid ports **226**. The second inlet fluid ports **226** extend in a direction that is orthogonal to the second central axis X**2**. The second inlet connecting member **222** receives the cooling fluid via the second inlet fluid ports **226**.

[0032] Further, the second inlet connecting member **222** defines a second surface **228** in contact with the first surface **212** (see FIG. **3**) of the first inlet connecting member **211**. The second surface **228** defines the one or more second inlet fluid ports **226**. The second surface **228** further defines one or more circular grooves **230** that surround the one or more second inlet fluid ports **226**. Specifically, the second surface **228** defines two circular grooves **230** that surround a corresponding second inlet fluid port **226**.

[0033] The second inlet connecting member **222** includes one or more sealing members **232** at least partially received within the one or more circular grooves **230** of the second surface **228** of the second inlet connecting member **222**. Specifically, the second inlet connecting member **222** includes two sealing members **232**, each of which is disposed within a corresponding circular groove **230**. Further, a portion of the sealing members **232** is also received within the corresponding circular groove **220** (see FIG. **3**) in the first inlet connecting member **211**. The sealing member **232** is sandwiched between the second inlet connecting member **222** and the first inlet connecting member **211**. In an example, the sealing member **232** may include a press and place seal having an annular shape.

[0034] Further, the second surface **228** also defines a number of second apertures **234**. The second surface **228** defines four second apertures **234** herein. The second apertures **234** are disposed proximate to the second inlet fluid ports **226**. The second apertures **234** are in alignment with corresponding first apertures **216** (see FIG. **3**) in the first inlet connecting member **211** to receive the mechanical fasteners **224** (see FIG. **2**) to connect the first inlet connecting member **211** with the second inlet connecting member **222**.

[0035] Further, the second inlet connecting member **222** defines one or more third inlet fluid ports **236**. The one or more third inlet fluid ports **236** is defined in a surface **238** of the second inlet connecting member **222** that is orthogonal to the second surface **228** of the second inlet connecting member **222**. The second inlet connecting member **222** is in fluid communication with the one or more strings **102** (see FIG. **1**) of battery modules **104** (see FIG. **1**) via the one or more third inlet fluid ports **236**. In the illustrated example of FIG. **4**, the second inlet connecting member **222** defines two third inlet fluid ports **236**. The third inlet fluid ports **236** extend in a direction that is orthogonal to the second central axis X**2**. Moreover, the third inlet fluid ports **236** and the second inlet fluid ports **226** extend orthogonal to each other. The third inlet fluid ports **236** direct the cooling fluid towards the battery modules **104**.

[0036] Referring now to FIG. **5**, each third inlet fluid port **236** is coupled to a corresponding fluid line **112** in the battery system **100** via a corresponding first sealing element **240**. The first sealing element **240** may be made of a polymer, such as, plastic and may have a rubber over molding. In an example, the first sealing element **240** may be manufactured by an injection molding process.

[0037] Referring now to FIGS. **6**A to **6**C, the inlet system **200** may include more than one inlet connecting tube **210**, more than one first inlet connecting member **211**, and more than one second inlet connecting member **222**. As shown in FIGS. **6**A to **6**C, the inlet connecting tube **210** includes a number of inlet connecting tubes **210**. Further, the first inlet connecting member **211** includes a number of first inlet connecting members **211**. Furthermore, the second inlet connecting member **222** includes a number of second inlet connecting members **222**. A total number of each of the number of inlet connecting tubes **210**, the number of first inlet connecting members **211**, and the number of second inlet connecting members **222** is based on a total number of strings of battery modules **104** (see FIG. **1**) associated with the battery system **100** (see FIG. **1**). However, the inlet system **200** will include only the single-common inlet manifold **202** irrespective of the total number of strings of battery modules **104**.

[0038] As shown in FIG. **6**A, when the battery system **100** (see FIG. **1**) includes two strings of battery modules **104** (see FIG. **1**), the inlet system **200** includes two inlet connecting tubes **210**, two first inlet connecting members **211**, and two second inlet connecting members **222**. The two inlet connecting tubes **210** may be of same length or varying lengths based on design and dimensions of the battery system **100**. Further, as shown in FIG. **6**B, when the battery system **100** (see FIG. **1**) includes three strings of battery modules **104** (see FIG. **1**), the inlet system **200** includes three inlet connecting tubes **210**, three first inlet connecting members **211**, and three second inlet connecting members **222**. The three inlet connecting tubes **210** may be of same length or varying lengths based on design and dimensions of the battery system **100**. Furthermore, as shown in FIG. **6**C, when the battery system **100** (see FIG. **1**) includes four strings of battery modules **104** (see FIG. **1**), the inlet system **200** includes two four inlet connecting tubes **210**, four first inlet connecting members **211**, and four second inlet connecting members **222**. The four inlet connecting tubes **210** may be of same length or varying lengths based on design and dimensions of the battery system **100**.
[0039] Referring now to FIG. **7**, the cooling assembly **106** also includes the outlet system **700** in fluid communication with the inlet system **200**. The outlet system **700** includes an outlet manifold **702**. The cooling fluid at a higher temperature exits the cooling assembly **106** via the outlet manifold **702**. The outlet manifold **702** includes a tubular member **704** and a bracket **706** that couples the outlet manifold **702** with the battery system **100** (see FIG. **1**). A plurality of second fasteners **707** couple the outlet manifold **702** with the battery system **100**. The second fasteners **707** may include bolts, pins, screws, and the like. In an example, the outlet manifold **702** may be made of a metallic material, such as, cast iron.
[0040] Referring to FIGS. **7** and **8**, the outlet system **700** also includes a first outlet connecting member **708** extending along a third central axis X**3** and coupled to the outlet manifold **702**. The first outlet connecting member **708** is in fluid communication with the tubular member **704** of the outlet manifold **702** to receive the cooling fluid from the outlet manifold **702**. In an example, the first outlet connecting member **708** may be made of a metallic material, such as, aluminum. The first outlet connecting member **708** includes a first bracket **710**, a first tube member **712** integral with the first bracket **710**, and a second bracket **714** integral with the first tube member **712**. The first and second brackets **710**, **714** are identical in shape and dimensions.
[0041] Further, the first outlet connecting member **708** defines one or more first outlet fluid ports **716**, **718**. In the illustrated example of FIGS. **7** and **8**, the first outlet connecting member **708** includes two first outlet fluid ports **716**, **718**. The one or more first outlet fluid ports **716**, **718** is defined in the first bracket **710** and/or the second bracket **714**. Specifically, the first outlet fluid port **716** is defined in the first bracket **710** and the first outlet fluid port **718** is defined in the second bracket **714**. The first outlet fluid ports **716**, **718** extend orthogonal to the third central axis X**3**. The cooling fluid, that has a higher temperature after flowing through the battery modules **104** (see FIG. **1**), is received within the first outlet connecting member **708** via the first outlet fluid ports **716**, **718**. Further, the first outlet connecting member **708** directs the cooling fluid towards the outlet manifold **702**.
[0042] As shown in FIG. **7**, the outlet system **700** further includes an outlet connecting tube **720** coupled to the first outlet connecting member **708** and extending along the third central axis X**3**. The first outlet connecting member **708** is disposed between the outlet manifold **702** and the outlet connecting tube **720**. The outlet connecting tube **720** is in fluid communication with the first outlet connecting member **708**. The outlet connecting tube **720** is embodied as a tube herein. In an example, the outlet connecting tube **720** may be made of a metallic material, such as, aluminum. Further, the first outlet connecting member **708** is coupled with the outlet connecting tube **720** via a loose fit. In an example, a radial seal (not shown herein), such as an O-ring may be disposed on an outer surface of the outlet connecting tube **720**. Further, a portion of the outlet connecting tube **720** may be received within the first outlet connecting member **708** such that the radial seal is disposed between an inner surface of the first outlet connecting member **708** and the outer surface of the

outlet connecting tube **720**.
[0043] Referring to FIGS. **7** and **8**, the outlet system **700** includes a second outlet connecting member **722** coupled to the outlet connecting tube **720** and extending along the third central axis X**3**. The outlet connecting tube **720** is disposed between the first outlet connecting member **708** and the second outlet connecting member **722**. As such, the tubular member **704** of the outlet manifold **702**, the first outlet connecting member **708**, the outlet connecting tube **720**, and the second outlet connecting member **722** are co-axial with each other and in fluid communication with each other. The second outlet connecting member **722** is similar in design and dimensions to the first outlet connecting member **708**. In an example, the second outlet connecting member **722** may be made of a metallic material, such as, aluminum.
[0044] The second outlet connecting member **722** includes a third bracket **724**, a second tube member **726** integral with the third bracket **724**, and a fourth bracket **728** integral with the second tube member **726**. The third and fourth brackets **724**, **728** are identical in shape and dimensions.
[0045] The second outlet connecting member **722** defines one or more second outlet fluid ports **730**, **732**. In the illustrated example of FIGS. **7** and **8**, the second outlet connecting member **722** includes two second outlet fluid ports **730**, **732**. The one or more second outlet fluid ports **730**, **732** is defined in the third bracket **724** and/or the fourth bracket **728**. Specifically, the second outlet fluid port **730** is defined in the third bracket **724** and the second outlet fluid port **732** is defined in the fourth bracket **728**. The second outlet fluid ports **730**, **732** extend orthogonal to the third central axis X**3**. The cooling fluid, that has a higher temperature after flowing through the battery modules **104** (see FIG. **1**), is received within the second outlet connecting member **722** via the second outlet fluid ports **730**, **732**. Further, the second outlet connecting member **722** directs the cooling fluid towards the outlet manifold **702**, via the first outlet connecting member **708** and the outlet connecting tube **720**.
[0046] The second outlet connecting member **722** is coupled with the outlet connecting tube **720** via a loose fit. In an example, a radial seal (not shown herein), such as an O-ring may be disposed on the outer surface of the outlet connecting tube **720**. Further, a portion of the outlet connecting tube **720** may be received within the second outlet connecting member **722** such that the radial seal is disposed between an inner surface of the second outlet connecting member **722** and the outer surface of the outlet connecting tube **720**.
[0047] Referring now to FIG. **8**, each of the first and second outlet fluid ports **716**, **718**, **730**, **732** is coupled to the corresponding fluid line **112** in the battery system **100** via a corresponding second sealing element **734**. The second sealing element **734** may be made of a polymer, such as, plastic and may have a rubber over molding. In an example, the second sealing element **734** may be manufactured by an injection molding process.
[0048] Referring now to FIGS. **2** and **7**, each of the first inlet connecting member **211**, the second inlet connecting member **222**, the first outlet connecting member **708**, and the second outlet connecting member **722** is manufactured by a casting process. Alternatively, each of the first inlet connecting member **211**, the second inlet connecting member **222**, the first outlet connecting member **708**, and the second outlet connecting member **722** may be manufactured by any other technique, without any limitations.
[0049] Referring to FIGS. **9**A to **9**C, the outlet system **700** may include more than one first outlet connecting member **708**, more than one outlet connecting tube **720**, and more than one second outlet connecting member **722**. As shown in FIGS. **9**A to C, the first outlet connecting member **708** includes a number of first outlet connecting members **708**. Further, the outlet connecting tube **720** includes a number of outlet connecting tubes **720**. Furthermore, the second outlet connecting member **722** includes a number of second outlet connecting member **722**. A total number of each of the plurality of first outlet connecting members **708**, the plurality of outlet connecting tube **720**, and the plurality of second outlet connecting member **722** is based on a total number of strings of battery modules **104** (see FIG. **1**) associated with the battery system **100** (see FIG. **1**). However, the

outlet system **700** will include only the single-common outlet manifold **702** irrespective of the total number of strings of battery modules **104**.

[0050] As shown in FIG. **9**A, when the battery system **100** (see FIG. **1**) includes two strings of battery modules **104** (see FIG. **1**), the outlet system **700** includes two first outlet connecting members **708**, three outlet connecting tubes **720**, and two second outlet connecting members **722**. Further, as shown in FIG. **9**B, when the battery system **100** (see FIG. **1**) includes three strings of battery modules **104** (see FIG. **1**), the outlet system **700** includes three first outlet connecting members **708**, five outlet connecting tubes **720**, and three second outlet connecting members **722**. Furthermore, as shown in FIG. **9**C, when the battery system **100** (see FIG. **1**) includes four strings of battery modules **104** (see FIG. **1**), the outlet system **700** includes four first outlet connecting members **708**, seven outlet connecting tubes **720**, and four second outlet connecting members **722**.

[0051] It is to be understood that individual features shown or described for one embodiment may be combined with individual features shown or described for another embodiment. The above described implementation does not in any way limit the scope of the present disclosure. Therefore, it is to be understood although some features are shown or described to illustrate the use of the present disclosure in the context of functional segments, such features may be omitted from the scope of the present disclosure without departing from the spirit of the present disclosure as defined in the appended claims.

Industrial Applicability

[0052] The present disclosure relates to the cooling assembly **106** for the battery system **100**. The cooling assembly **106** described herein has a simple design and may be assembled in a time-efficient manner. The cooling assembly **106** may be used with battery systems of different capacities. The cooling assembly **106** may be scalable based on a configuration, and more specifically, based on the total number of strings of battery modules **104** associated with the battery system **100**. The scalable design of the cooling assembly **106** may reduce a number of parts, material costs, and inventory costs associated with the cooling assembly **106**. Specifically, the cooling assembly **106** may be assembled using the same parts, in multiples, for different configurations or different battery system capacity. Furthermore, the cooling assembly **106** includes the single inlet manifold **202** and the single outlet manifold **702** that allows the cooling fluid to enter and exit the cooling assembly **106**, respectively.

[0053] The first inlet connecting member **211** is coupled with the inlet connecting tube **210** via the radial seal, which may prevent leakage of the cooling fluid through an interface of the first inlet connecting member **211** and the inlet connecting tube **210**. Further, the radial seal may also simplify an assembly process of the first inlet connecting member **211** with the inlet connecting tube **210**. Moreover, each third inlet fluid port **236** of the second inlet connecting member **222** is coupled to the corresponding fluid line **112** in the battery system **100** via the corresponding first sealing element **240**. The first sealing elements **240** may prevent leakage of the cooling fluid through an interface of the third inlet fluid port **236** and the corresponding fluid line **112**, and may also simplify an assembly process of the second inlet connecting member **222** with the corresponding fluid line **112**. The second inlet connecting member **222** also includes the sealing members **232** that seal the second inlet connecting member **222** with the first inlet connecting member **211**, thereby preventing any leakage of the cooling fluid through an interface of the second inlet connecting member **222** and the first inlet connecting member **211**.

[0054] Further, the first outlet connecting member **708** is coupled with the outlet connecting tube **720** via the radial seal, which may prevent leakage of the cooling fluid through an interface of the first outlet connecting member **708** and the outlet connecting tube **720**. The radial seal may also simplify an assembly process of the first outlet connecting member **708** with the outlet connecting tube **720**. Furthermore, the second outlet connecting member **722** is coupled with the outlet connecting tube **720** via the radial seal, which may prevent leakage of the cooling fluid through an interface of the second outlet connecting member **722** and the outlet connecting tube **720**. The

radial seal may also simplify an assembly process of the second outlet connecting member **722** with the outlet connecting tube **720**.
[0055] Moreover, each of the first and second outlet fluid ports **716**, **718**, **730**, **732** of the corresponding first and second outlet connecting members **708**, **722** is coupled to the corresponding fluid line **112** in the battery system **100** via the corresponding second sealing element **734**. The second sealing elements **734** may prevent leakage of the cooling fluid through an interface of the first and second outlet connecting members **708**, **722** and the corresponding fluid line **112**, and may also simplify an assembly process of the first and second outlet connecting members **708**, **722** with the corresponding fluid line **112**.
[0056] While aspects of the present disclosure have been particularly shown and described with reference to the embodiments above, it will be understood by those skilled in the art that various additional embodiments may be contemplated by the modification of the disclosed work machine, systems and methods without departing from the spirit and scope of the disclosure. Such embodiments should be understood to fall within the scope of the present disclosure as determined based upon the claims and any equivalents thereof.

Claims

1. A cooling assembly for a battery system, the battery system including at least one string of battery modules, the cooling assembly comprising: an inlet system including: an inlet manifold; an inlet connecting tube extending along a first central axis and coupled to the inlet manifold; a first inlet connecting member coupled to the inlet connecting tube and extending along the first central axis, wherein the inlet connecting tube is disposed between the inlet manifold and the first inlet connecting member, and wherein the first inlet connecting member defines a first surface and at least one first inlet fluid port defined in the first surface; and a second inlet connecting member coupled to the first inlet connecting member at the first surface of the first inlet connecting member, wherein the second inlet connecting member extends along a second central axis that is offset from and parallel to the first central axis, and wherein the second inlet connecting member defines at least one second inlet fluid port in fluid communication with the at least one first inlet fluid port of the first inlet connecting member; and an outlet system in fluid communication with the inlet system, the outlet system including: an outlet manifold; a first outlet connecting member extending along a third central axis and coupled to the outlet manifold, wherein the first outlet connecting member defines at least one first outlet fluid port; an outlet connecting tube coupled to the first outlet connecting member and extending along the third central axis, wherein the first outlet connecting member is disposed between the outlet manifold and the outlet connecting tube; and a second outlet connecting member coupled to the outlet connecting tube and extending along the third central axis, wherein the outlet connecting tube is disposed between the first outlet connecting member and the second outlet connecting member, and wherein the second outlet connecting member defines at least one second outlet fluid port.
2. The cooling assembly of claim 1, wherein the inlet system further includes a plurality of mechanical fasteners to connect the first inlet connecting member with the second inlet connecting member.
3. The cooling assembly of claim 1, wherein the second inlet connecting member defines a second surface in contact with the first surface of the first inlet connecting member, wherein the second surface defines the at least one second inlet fluid port, and wherein the second surface defines at least one circular groove that surrounds the at least one second inlet fluid port.
4. The cooling assembly of claim 3, wherein the second inlet connecting member includes at least one sealing member at least partially received within the at least one circular groove of the second surface of the second inlet connecting member.
5. The cooling assembly of claim 3, wherein the second inlet connecting member further defines at

least one third inlet fluid port, wherein the at least one third inlet fluid port is defined in a surface of the second inlet connecting member that is orthogonal to the second surface of the second inlet connecting member, and wherein the second inlet connecting member is in fluid communication with the at least one string of battery modules via the at least one third inlet fluid port.

6. The cooling assembly of claim 1, wherein the inlet connecting tube includes a plurality of inlet connecting tubes, wherein the first inlet connecting member includes a plurality of first inlet connecting members, wherein the second inlet connecting member includes a plurality of second inlet connecting members, and wherein a total number of each of the plurality of inlet connecting tubes, the plurality of first inlet connecting members, and the plurality of second inlet connecting members is based on a number of strings of battery modules associated with the battery system.

7. The cooling assembly of claim 1, wherein the first outlet connecting member includes a first bracket, a first tube member integral with the first bracket, and a second bracket integral with the first tube member, and wherein the at least one first outlet fluid port is defined in at least one of the first bracket and the second bracket.

8. The cooling assembly of claim 1, wherein the second outlet connecting member includes a third bracket, a second tube member integral with the third bracket, and a fourth bracket integral with the second tube member, and wherein the at least one second outlet fluid port is defined in at least one of the third bracket and the fourth bracket.

9. The cooling assembly of claim 1, wherein the first outlet connecting member includes a plurality of first outlet connecting members, wherein the outlet connecting tube includes a plurality of outlet connecting tubes, wherein the second outlet connecting member includes a plurality of second outlet connecting members, and wherein a total number of each of the plurality of first outlet connecting members, the plurality of outlet connecting tubes, and the plurality of second outlet connecting members is based on a number of strings of battery modules associated with the battery system.

10. The cooling assembly of claim 1, wherein each of the first inlet connecting member, the second inlet connecting member, the first outlet connecting member, and the second outlet connecting member is manufactured by a casting process.

11. A battery system comprising: at least one string of battery modules; and a cooling assembly to direct cooling fluid towards the at least one string of battery module, the cooling assembly including: an inlet system including: an inlet manifold; an inlet connecting tube extending along a first central axis and coupled to the inlet manifold; a first inlet connecting member coupled to the inlet connecting tube and extending along the first central axis, wherein the inlet connecting tube is disposed between the inlet manifold and the first inlet connecting member, and wherein the first inlet connecting member defines a first surface and at least one first inlet fluid port defined in the first surface; and a second inlet connecting member coupled to the first inlet connecting member at the first surface of the first inlet connecting member, wherein the second inlet connecting member extends along a second central axis that is offset from and parallel to the first central axis, and wherein the second inlet connecting member defines at least one second inlet fluid port in fluid communication with the at least one first inlet fluid port of the first inlet connecting member; and an outlet system in fluid communication with the inlet system, the outlet system including: an outlet manifold; a first outlet connecting member extending along a third second central axis and coupled to the outlet manifold, wherein the first outlet connecting member defines at least one first outlet fluid port; an outlet connecting tube coupled to the first outlet connecting member and extending along the third central axis, wherein the first outlet connecting member is disposed between the outlet manifold and the outlet connecting tube; and a second outlet connecting member coupled to the outlet connecting tube and extending along the third central axis, wherein the outlet connecting tube is disposed between the first outlet connecting member and the second outlet connecting member, and wherein the second outlet connecting member defines at least one second outlet fluid port.

12. The battery system of claim 11, wherein the inlet system further includes a plurality of mechanical fasteners to connect the first inlet connecting member with the second inlet connecting member.

13. The battery system of claim 11, wherein the second inlet connecting member defines a second surface in contact with the first surface of the first inlet connecting member, wherein the second surface defines the at least one second inlet fluid port, and wherein the second surface defines at least one circular groove that surrounds the at least one second inlet fluid port.

14. The battery system of claim 13, wherein the second inlet connecting member includes at least one sealing member at least partially received within the at least one circular groove of the second surface of the second inlet connecting member.

15. The battery system of claim 13, wherein the second inlet connecting member further defines at least one third inlet fluid port, wherein the at least one third inlet fluid port is defined in a surface of the second inlet connecting member that is orthogonal to the second surface of the second inlet connecting member, and wherein the second inlet connecting member is in fluid communication with the at least one string of battery modules via the at least one third inlet fluid port.

16. The battery system of claim 11, wherein the inlet connecting tube includes a plurality of inlet connecting tubes, wherein the first inlet connecting member includes a plurality of first inlet connecting members, wherein the second inlet connecting member includes a plurality of second inlet connecting members, and wherein a total number of each of the plurality of inlet connecting tubes, the plurality of first inlet connecting members, and the plurality of second inlet connecting members is based on a number of strings of battery modules associated with the battery system.

17. The battery system of claim 11, wherein the first outlet connecting member includes a first bracket, a first tube member integral with the first bracket, and a second bracket integral with the first tube member, and wherein the at least one first outlet fluid port is defined in at least one of the first bracket and the second bracket.

18. The battery system of claim 11, wherein the second outlet connecting member includes a third bracket, a second tube member integral with the third bracket, and a fourth bracket integral with the second tube member, and wherein the at least one second outlet fluid port is defined in at least one of the third bracket and the fourth bracket.

19. The battery system of claim 11, wherein the first outlet connecting member includes a plurality of first outlet connecting members, wherein the outlet connecting tube includes a plurality of outlet connecting tubes, wherein the second outlet connecting member includes a plurality of second outlet connecting members, and wherein a total number of each of the plurality of first outlet connecting members, the plurality of outlet connecting tubes, and the plurality of second outlet connecting members is based on a number of strings of battery modules associated with the battery system.

20. The battery system of claim 11, wherein each of the first inlet connecting member, the second inlet connecting member, the first outlet connecting member, and the second outlet connecting member is manufactured by a casting process.