

## **METHOD FOR INSPECTING WELDING QUALITY**

### **TECHNICAL FIELD**

**[0001]** The present disclosure relates to a method for inspecting a welding quality.

### **BACKGROUND**

**[0002]** In general battery modules, secondary batteries are used in power sources of electric vehicles and hybrid vehicles, which are being proposed to solve environmental problems such as air pollution from existing gasoline or diesel vehicles, as it recently become possible to miniaturize and lightweight electronic equipment due to the development of the advanced electronics industry

**[0003]** Types of these secondary batteries include lithium-ion batteries, lithium polymer batteries, nickel-cadmium batteries, nickel-hydrogen batteries, and nickel-zinc batteries, and unit secondary batteries with a certain voltage, that is, battery cells, are square, cylindrical, or pouch-shaped depending on the shape thereof, but, pouch-type battery cells that are used is thinner and lighter than square or cylindrical cells, may be manufactured in various shapes and forms, have excellent efficiency and heat dissipation per volume area, and are easy to be stacked in multiple layers are gradually increasing.

**[0004]** FIG. 1 is a view illustrating a general battery module.

FIG. 2 is a view illustrating a state, in which front and rear covers are removed in FIG. 1.

**[0005]** As illustrated in FIGS. 1 and 2, a general battery module 1 includes a cell stack 2, in which a plurality of battery cells are stacked in a leftward/rightward direction, end plates 3 that are disposed on opposite side surface of the cell stack 2 in the leftward/rightward direction, and a clamp 4 that connects the pair of end plates 3. The clamp 4 is a structure for forming a surface-pressure by restraining expansion of battery cells, and may be overlap-welded to the end plates 3.

**[0006]** Furthermore, the plurality of battery cells have a lead tab 5 on at least one side in a forward/rearward direction. The lead tabs 5 of the plurality of battery cells are electrically connected to each other by a bus bar 6. To achieve this, the lead tabs 5 may be welded to the bus bar 6.

**[0007]** As described above, when the battery cells are formed, several welding processes are performed. FIG. 3 is an enlarged view illustrating portion "A" of FIG. 2. FIG. 4 is an enlarged view illustrating portion "B" of FIG. 2. When welding is performed, welding beads are formed at an overlapping portion of the lead tab 5 and the bus bar 6 and a portion of the clamp 4 and the end plate 3. However, it is impossible to determine a quantitative quality of the welding only by inspecting the welding beads by naked eyes.

**[0008]** Furthermore, in recent years, laser welding has been

mainly used for welding of battery modules. Conventionally, a quality of laser welding is inspected through a destructive inspection, such as a tensile strength test, after a specimen is manufactured to recognize the quality of the laser welding. According to the method, a full investigation is impossible.

**[0009]** Accordingly, a method for quantitatively diagnosing a quality while allowing a full investigation is necessary.

#### **SUMMARY**

**[0010]** The present disclosure has been made to solve the above-mentioned problems occurring in the prior art while advantages achieved by the prior art are maintained intact.

**[0011]** An aspect of the present disclosure provides a method for inspecting a quality of welding, by which a welding quality may be quantitatively diagnosed while a full investigation is possible.

**[0012]** The technical problems to be solved by the present disclosure are not limited to the aforementioned problems, and any other technical problems not mentioned herein will be clearly understood from the following description by those skilled in the art to which the present disclosure pertains.

**[0013]** According to an aspect of the present disclosure, a method for inspecting a welding quality includes a nondestructive testing method of inspecting a welding quality of a welding object by measuring a penetration depth of the welding object during a

welding process, the welding object includes an upper plate, and a lower plate welded to a lower side of the upper plate, and the penetration depth measured through the nondestructive testing method is a depth, by which the lower plate is recessed due to the welding process.

**[0014]** In another example, the nondestructive testing method may include a penetration depth measuring operation of measuring the penetration depth, and a quality determining operation of determining whether the measured penetration depth corresponds to a reference penetration depth range.

**[0015]** In another example, the reference penetration depth range may be determined based on a material of the upper plate and a thickness of the upper plate.

**[0016]** In another example, the penetration depth measuring operation may include a displacement measuring process of measuring a displacement of a welded portion of the welding object by projecting a laser beam for measurement toward the welded portion during the welding process, and a penetration depth determining process of determining the penetration depth based on the displacement measured in the displacement measuring process.

**[0017]** In another example, the method may further include a destructive inspection method of manufacturing a specimen of the welding object, and then inspecting a welding quality of the specimen by generating a displacement at a portion of the

specimen, and a validity of the nondestructive testing method is determined by comparing the welding quality of the welding object, which is determined through the nondestructive testing method, and the welding quality of the specimen, which is determined through the destructive inspection method.

**[0018]** In another example, the destructive inspection method may include a manufacturing operation of manufacturing a reference specimen upper plate and a reference specimen lower plate having a reference size, and an overlap welding operation of overlap-welding the reference specimen upper plate and the reference specimen lower plate.

**[0019]** In another example, the destructive inspection method may further include a displacement generating operation of generating an upward displacement in the overlap-welded reference specimen upper plate, and a peel strength measuring operation of measuring a peel strength when the reference specimen upper plate is destructed.

**[0020]** In another example, the destructive inspection method may further include a specimen quality determining operation of determining whether the peel strength measured in the peel strength measuring operation is a reference peel strength or higher.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0021]** The above and other objects, features and advantages of

the present disclosure will be more apparent from the following detailed description taken in conjunction with the accompanying drawings:

**[0022]** FIG. 1 is a view illustrating a general battery module;

**[0023]** FIG. 2 is a view illustrating a state, in which front and rear covers are removed in FIG. 1;

**[0024]** FIG. 3 is an enlarged view illustrating portion "A" of FIG. 2;

**[0025]** FIG. 4 is an enlarged view illustrating portion "B" of FIG. 2;

**[0026]** FIG. 5 is a view conceptually illustrating a cross-section of a welded portion of a welding object;

**[0027]** FIG. 6 is a flowchart illustrating a sequence of a nondestructive testing method; and

**[0028]** FIG. 7 is a flowchart illustrating a sequence of a destructive inspection method.

#### **DETAILED DESCRIPTION**

**[0029]** Hereinafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. In adding reference numerals to the components of the drawings, it is noted that the same components are denoted by the same reference numerals even when they are drawn in different drawings. Furthermore, in describing the embodiments of the present disclosure, when it is determined that a detailed description of

related known configurations and functions may hinder understanding of the embodiments of the present disclosure, a detailed description thereof will be omitted.

**[0030]** A method for inspecting a welding quality according to an embodiment of the present disclosure may be a welding quality inspecting method for inspecting a quality of welding, which is applied to a battery module. Then, the welding may be laser welding, but the present disclosure is not limited thereto.

**[0031]** Hereinafter, an object that is welded will be defined as a welding object for convenience of description. As an example, the welding object may be an overlapping portion of a lead tab and a bus bar. Alternatively, the welding object may be an overlapping portion of a clamp and an end plate. FIG. 5 is a view conceptually illustrating a cross-section of a welded portion of a welding object. The welding object may include an upper plate 10 and a lower plate 20. The lower plate 20 may be a plate that is welded to a lower side of the upper plate 10. The upper plate 10 may be a portion that is directly exposed to a laser beam. Furthermore, the lower plate 20 is not directly exposed to the laser beam, but may mean a portion that is melt due to heat input by the laser beam.

**[0032]** Here, an upward/downward direction is referred for convenience of description and is determined relative to a viewing direction, and the upward/downward direction may not necessarily mean a vertical direction.

**[0033]** As an example, the upper plate 10 may be a portion of the clamp 4 (FIG. 2), and the lower plate 20 may be a portion of the end plate 3 (FIG. 2). As another example, the upper plate 10 may be a portion of the lead tab 5, and the lower plate 20 may be a portion of the bus bar 6.

**[0034]** As an example, the upper plate 10 may be formed of an aluminum material. Then, a thickness of the upper plate 10 may be  $0.4T$ . As another example, a material of the upper plate 10 is copper. Then, a thickness of the upper plate 10 may be  $0.2T$ . A material of the lower plate 20 may be copper. A thickness of the lower plate 20 may be  $0.8T$  or more.

**[0035]** The method for inspecting a welding quality may include a nondestructive testing method. The nondestructive testing method may mean a method for inspecting a welding quality of a welding object by measuring a penetration depth of the welding object without destructing the welding object during a welding process. The penetration depth may mean a depth, by which the lower plate 20 is recessed due to the welding process.

**[0036]** When welding is performed, heat input by a laser beam occurs, and as in FIG. 5, the lower plate 20 is melted and recessed. The penetration depth may mean a depth, by which the lower plate 20 is recessed in this process.

**[0037]** The penetration depth may be an element having a correlation with a welding output that determines a quality of welding. As an example, as compared with a general case, the

penetration depth decreases while the welding is not properly performed when the welding output becomes weak. Furthermore, in contrast, as compared with a general case, the welding depth increases while the welding becomes excessive when the welding output becomes strong.

**[0038]** The welding output is an important element for determining a quality of welding as described above, and it also may be valid to determine the quality of welding by measuring the penetration depth that has a correlation with the welding output. This may be understood as providing a quantitative quality determining reference unlike determining a quality of the welding based on the number of pores formed on an external appearance conventionally.

**[0039]** In detail, the nondestructive testing method may include a penetration depth measuring operation and a quality determining operation. FIG. 6 is a flowchart illustrating a sequence of a nondestructive testing method. The penetration depth measuring operation may be an operation of measuring a penetration depth. The quality determining operation may be an operation of determining whether the penetration depth corresponds to a reference penetration depth range.

[Table 1]

|                |                   |                                                    |
|----------------|-------------------|----------------------------------------------------|
| Upper plate 10 | Lower plate 20    | Reference penetration depth range                  |
| Al (0.4T)      | Cu (0.8T or more) | 80% to 120% of upper plate 10 (0.32 mm to 0.48 mm) |

|           |  |                                                                |
|-----------|--|----------------------------------------------------------------|
| Cu (0.2T) |  | 80% to 200% of thickness of upper plate 10 (0.16 mm to 0.4 mm) |
|-----------|--|----------------------------------------------------------------|

**[0040]** Table 1 is a table representing an example of the reference penetration depth range. As represented in Table 1, the reference penetration depth may be determined based on the material of the upper plate 10 and the thickness of the upper plate 10. As an example, as represented in Table 1, when the material of the upper plate 10 is aluminum and the thickness thereof is 0.4T, the reference penetration depth may be determined 80% to 120% of the thickness of the upper plate 10, that, is 0.32 mm to 0.48 mm. As another example, when the material of the upper plate 10 is copper and the thickness thereof is 0.2T, the reference penetration depth range is 80% to 200% of the thickness of the upper plate 10, that is, 0.16 mm to 0.4 mm. However, this is a simple example, and may be a value that may be changed by an ordinary person if necessary.

**[0041]** Meanwhile, the penetration depth measuring operation may include a displacement measuring process and a penetration depth determining process. The displacement measuring process may be a process of measuring a displacement of the welding portion of the welding object by projecting a laser beam toward the welding portion during the welding process. The laser beam for measurement may be a laser beam of a low output as compared with a laser beam used for welding.

**[0042]** As an example, a welding device for welding the welding object may include a laser beam oscillating device for measurement

and a sensor device. When the laser beam oscillating device for measurement oscillates a laser beam for measurement toward the welded portion, the sensor device may recognize a displacement of the welded portion by measuring the laser beam reflected by the welded portion. This process is a process that may be performed during the welding process, and thus the process may be performed all the welding objects, on which the welding is performed. Accordingly, according to the present disclosure, as a destructive inspection is performed, a full investigation may be possible unlike a conventional inspection method, in which a full investigation is difficult.

**[0043]** The penetration depth determining process may include a penetration depth determining process of determining a penetration depth based on the displacement measured in the displacement measuring process. The penetration depth may be understood as a value, excluding the thickness of the upper plate 10, Accordingly, when the displacement of the welded portion is measured, the penetration depth may be determined.

**[0044]** Meanwhile, to use the determined reference penetration depth range, a validity of the reference penetration depth range has to be ensured. To ensure the validity of the reference penetration depth range, a process of comparing data that are obtained through the destructive inspection process may be necessary. Hereinafter, the related contents will be described in detail.

**[0045]** The method for inspecting a welding quality may further include a destructive inspection method of inspecting the welding quality of the specimen by generating a displacement at a portion of the specimen after the specimen of the welding object is manufactured. FIG. 7 is a flowchart illustrating a sequence of a destructive inspection method.

**[0046]** Because the method for inspecting a welding quality further includes the destructive inspection method, the validity of the nondestructive testing method may be determined by comparing a welding quality of the welding object, which is determined in the nondestructive testing method, and a welding quality of the specimen, which is determined in the destructive inspection method. This process may be regarded as a process of determining the reference penetration depth range based on the welding quality of the specimen, which is determined in the destructive inspection method.

**[0047]** The destructive inspection method may include a manufacturing operation and an overlap welding operation. The manufacturing operation may be an operation of manufacturing the reference specimen upper plate 10 and the reference specimen lower plate 20, which have a reference size. The reference size may be 45 mm × 45 mm. The overlap welding operation may be an operation of overlap-welding the reference specimen upper plate 10 and the reference specimen lower plate 20. Then, a bead length of the overlap-welded welded portion may be 30 mm.

**[0048]** The destructive inspection method may further include a displacement generating operation and a peel strength measuring operation. The displacement generating operation may be an operation of generating an upward displacement in the reference specimen upper plate 10. The generation of the displacement may be understood as a process for measuring a peel strength. The peel strength measuring operation may be an operation of measuring a peel strength when the specimen upper plate 10 is destructed.

**[0049]** Conventionally, the destructive inspection method is performed by measuring a tensile strength. According to the tensile strength measuring scheme, the specimen is exposed to a complex force of a tensile force and a shear force, and thus, the inspection result may become inaccurate.

**[0050]** According to the present disclosure, the destructive inspection is performed by measuring not the tensile strength but the peel strength, and thus, the specimen may be exposed to a single force whereby a more reliable inspection result may be obtained.

**[0051]** The destructive inspection method may further include a specimen quality determining operation. The specimen quality determining operation may be an operation of determining whether the peel strength measured in the peel strength measuring operation is a reference peel strength or more.

**[0052]** The reference peel strength that is a peel strength corresponding a normal range for the material of the upper plate

10 is determined in advance by experiments. As an example, when the material of the upper plate 10 is aluminum and the thickness thereof is  $0.4T$ , the peel strength that is determined to be normal may be 1.3 kgf/mm. As another example, the material of the upper plate 10 is copper and the thickness thereof is  $0.2T$ , the peel strength that is determined to be normal may be 3.0 kgf/mm.

**[0053]** The reference penetration depth range may be determined by the specimens having a peel strength that is determined to be normal. As an example, when the material of the upper plate 10 is aluminum and the thickness thereof is  $0.4T$ , the penetration depth may be 0.32 mm to 0.48 mm when the peel strength is 1.3 kgf/mm or more. Accordingly, the reference penetration depth range may be determined to be 0.32 mm to 0.48 mm.

**[0054]** According to the present disclosure, because the quality of welding may be determined by performing the nondestructive testing based on the reference penetration depth range acquired according to the destructive inspection method, the welding quality may be quantitatively diagnosed while the full investigation is possible.

**[0055]** According to the present disclosure, because a welding quality may be determined based on a penetration depth of a heat input object measured during a welding process, a quantitative quality determination reference may be provided while a full investigation is possible.

**[0056]** Although the present disclosure has been described with

reference to the limited embodiments and the drawings in the above description, the above description is simply an exemplary description of the technical spirits of the present disclosure, and an ordinary person in the art, to which the present disclosure pertains, may make various corrections and modifications without departing from the essential characteristics of the present disclosure. Therefore, the embodiments disclosed in the present disclosure are not for limiting the technical spirits of the present disclosure but for describing them, and the scope of the technical spirits of the present disclosure is not limited by the embodiments. The protection scope of the present disclosure should be construed by the following claims, and all the technical spirits in the equivalent range should be construed as being included in the scope of the present disclosure.

**WHAT IS CLAIMED IS:**

1. A method for inspecting a welding quality, the method comprising:

a nondestructive testing method of inspecting a welding quality of a welding object by measuring a penetration depth of the welding object during a welding process,

wherein the welding object includes an upper plate, and a lower plate welded to a lower side of the upper plate, and

wherein the penetration depth measured through the nondestructive testing method is a depth, by which the lower plate is recessed due to the welding process.

2. The method of claim 1, wherein the nondestructive testing method includes:

a penetration depth measuring operation of measuring the penetration depth; and

a quality determining operation of determining whether the measured penetration depth corresponds to a reference penetration depth range.

3. The method of claim 2, wherein the reference penetration depth range is determined based on a material of the upper plate and a thickness of the upper plate.

4. The method of claim 2 or claim 3, wherein the penetration depth measuring operation includes:

a displacement measuring process of measuring a displacement of a welded portion of the welding object by projecting a laser beam for measurement toward the welded portion during the welding process; and

a penetration depth determining process of determining the penetration depth based on the displacement measured in the displacement measuring process.

5. The method of any one of claims 1 to 4, further comprising:

a destructive inspection method of manufacturing a specimen of the welding object, and then inspecting a welding quality of the specimen by generating a displacement at a portion of the specimen, and

a validity of the nondestructive testing method is determined by comparing the welding quality of the welding object, which is determined through the nondestructive testing method, and the welding quality of the specimen, which is determined through the destructive inspection method.

6. The method of claim 5, wherein the destructive inspection method includes:

a manufacturing operation of manufacturing a reference specimen upper plate and a reference specimen lower plate having a reference size; and

an overlap welding operation of overlap-welding the reference specimen upper plate and the reference specimen lower plate.

7. The method of claim 6, wherein the destructive inspection method further includes:

a displacement generating operation of generating an upward displacement in the overlap-welded reference specimen upper plate; and

a peel strength measuring operation of measuring a peel strength when the reference specimen upper plate is destructed.

8. The method of claim 7, wherein the destructive inspection method further includes:

a specimen quality determining operation of determining whether the peel strength measured in the peel strength measuring operation is a reference peel strength or higher.