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(56) Documents Cited:
GB 1156833 A **US 6281773 B1**
US 3176473 A **US 20070014946 A1**

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(54) Abstract Title: **Reworkable pressure vessel for a superconducting magnet**

(57) A pressure vessel or a method of making a pressure vessel, suitable for a superconducting magnet, comprises first and second parts made from fibre-reinforced thermoplastic which are able to be repeatedly bonded together and/or separated apart by the application of a thermal process. The thermal process can be used to open or close the vessel such that the vessel can be reworked if a fault in the vessel assembly is identified. This can provide savings in the processing time required and the levels of waste material generated during the production of such an assembly. The thermoplastic material may be polypropylene or polyethylene. The thermoplastic material may be suitable for recycling via granulation and moulding processes. The thermal process may be hot tool welding, infra-red welding, laser welding, spin welding, ultrasonic welding, vibration welding or resistance welding forms of fusion bonding. The same or a different thermal process may be used for the bonding and separation of the vessel parts.

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RE-WORKABLE PRESSURE VESSELS FOR SUPERCONDUCTING MAGNET ARRANGEMENTS.

This invention relates to re-workable pressure vessels for superconducting magnet arrangements, and to methods of making such vessels. It relates especially, though not exclusively, to pressure vessels utilised in magnetic resonance imaging (MRI) systems.

It is well known that, in order to fully test the superconducting magnets which are used in MRI systems, they need to be sealed, as for operation, in a cryostatic environment, within a pressure vessel, usually referred to as an outer vacuum chamber (OVC), which provides thermal isolation from room temperature.

Ideally, if the test is successful, the OVC and the cryogenic magnet assembly which it contains can be fitted into the MRI system for which it is intended. If, however, the test is unsuccessful, the chamber has to be opened in order to provide access to facilitate the repair or re-working of the magnets.

Where the OVC is made of metallic material, it is usual for the sealing to be effected by welding, and opening such an OVC requires the welds to be cut. Since this removes material from the vicinity of the welds, the original OVC cannot generally be re-used and, whilst some at least of the metallic material can be recycled, and does not therefore pose a significant disposal problem, as regards landfill for example, the operation as a whole is wasteful of material and rather costly. In this latter respect, it will be appreciated that the time and cost involved in the assembly of a metallic OVC is considerable, requiring several hours of skilled coded weld time.

It has thus been proposed to fabricate OVC enclosures from fibre-reinforced composite thermosetting plastics materials. However, OVCs so fabricated need, like their metallic counterparts, to be cut open when testing indicates that magnet repairs are called for, and the situation is thus little improved. Furthermore the OVC, having been cut open, cannot be re-used and the scrapped OVC has to be disposed of. Fibre-reinforced thermosetting plastics materials are generally non-recyclable, however, and it is becoming increasingly unacceptable, as well as expensive, to send such materials to landfill sites for disposal.

It will further be appreciated that, whether or not a magnet system contained in an OVC made of thermosetting plastics needs re-working after test, the problem of acceptably disposing of the OVC still arises at the end of the product's working life.

There are thus requirements for improved demountable pressure vessels for superconducting magnet arrangements and for improved methods of manufacturing, opening and re-closing such vessels, and it is an object of the present invention to address these requirements.

According to the invention from one aspect, there is provided a reworkable pressure vessel adapted to contain superconducting magnet arrangements; at least first and second separate parts of the vessel being fabricated from fibre-reinforced thermoplastic material; wherein said first and second parts comprise facing end surfaces adapted for fusion bonding together to form a union closing said vessel such that said vessel can be opened and re-closed by repeated application of fusion bonding to said union. Parts of such pressure vessels are thus readily secured together by

means of fusion bonding, which is a reversible process, thereby permitting the vessel to be opened so as to provide access to superconducting magnet components enclosed therein, and its subsequent re-closure, again by fusion bonding.

In some preferred embodiments, the fusion bonding processes used to open and/or re-close the vessel comprises a re-application of the same process used to effect the original bond. In other embodiments, different fusion bonding processes from that used for the original bond may be used for opening and/or re-closure.

It is preferred that the fusion bonding process used is chosen from a group of processes comprising: hot tool welding; infra-red welding; laser welding; spin welding; ultrasonic welding; vibration welding; and resistance welding.

It is preferred that the thermoplastics material comprises polypropylene or polyethylene.

In some preferred embodiments, at least an outer shell of the pressure vessel is formed entirely of said reinforced thermoplastics material.

The invention thus provides that pressure vessels opened to permit the repair of magnets that fail during testing can be re-sealed. Moreover, pressure vessels constructed of fibre reinforced thermoplastics materials can be recycled at the end of the product life using standard plastic recycling methods. One example of such a method comprises the removal of any metallic inserts followed by grinding of the remaining fibres and plastics material which is then shredded into small pieces and fed into a

granulator, ultimately producing small pellets that can be used as raw material in a standard extrusion/compression moulding apparatus.

According to the invention from another aspect, there is provided a method of manufacturing a pressure vessel that can subsequently be opened and re-closed, and which is adapted to contain superconducting magnet arrangements, the method comprising the steps of:

fabricating first and second separate parts of the vessel from fibre-reinforced thermoplastics material; said first and second parts comprising facing end surfaces adapted to abut in fitting relationship;

fusion bonding said abutting end surfaces together to form a union closing said vessel; and

repeatedly applying thermal bonding to said union to open and re-close said vessel.

In order that the present invention may be clearly understood and readily carried into effect, one embodiment thereof will now be described.

In accordance with one example of the invention from one aspect, a reworkable pressure vessel formed with or containing internal fitments associated with the retention and operation of a superconducting magnet arrangement, and thus constituting an OVC, comprises two identical housing parts, both made entirely of fibre-reinforced thermoplastics material. Essentially, the two parts each form a half of the OVC, and they are formed with identical end surfaces designed to accurately match one another, and to be placed into abutting relationship when the OVC is to be closed.

Upon closure, these end surfaces are fusion bonded together to form a union closing the OVC, which can then be submitted to tests in the usual way to determine, inter alia, the functional and operational status of the magnet assembly housed therein.

The thermal bonding process used to form the union is reversible and thus, in accordance with a principal feature of the invention, the OVC can be opened and re-closed by repeated application of fusion bonding to the union. Such pressure vessels are thus readily opened, so as to provide access to the superconducting magnet components enclosed therein for repair or reconfiguration, and subsequently re-closed, again by the application of fusion bonding without loss or damage to the existing vessel components.

The fusion bonding process comprises an application of heat to the two abutting surfaces to be united, and a suitably timed application of pressure by means of opposing forces. These operations are well known to those skilled in the art, and are readily applied to the present context.

Typical fusion bonding processes usable in embodiments of the invention include: hot tool welding; infra-red welding; laser welding; spin welding; ultrasonic welding; vibration welding; and resistance welding. In this connection, it will be appreciated that the process used at any stage, and in any given embodiment of the invention, may be dictated by factors such as the dimensions of the OVC, by operational requirements or simply by process availability and/or by the degree of familiarity of available personnel with certain processes.

Indeed, in some embodiments, the fusion bonding process used to open and/or re-close the vessel may comprise a re-application of the same process used to effect the original bond. In other embodiments, however, different fusion bonding processes from that used for the original bond may be used for opening and/or re-closure.

It is preferred that the thermoplastics material comprises polypropylene or polyethylene. The fibre reinforcement preferably comprises multidirectional fibre matting in order to cope with the forces which a pressure vessel adapted to contain a superconducting magnet is subjected to.

The two halves of the OVC described above are preferably formed entirely of said reinforced thermoplastics material. If operational or other requirements so dictate, however, the OVC may contain, or be partially formed of, metallic or other materials.

As previously mentioned, pressure vessels constructed of fibre reinforced thermoplastics materials can be recycled at the end of the product life using standard plastic recycling methods.

The invention further provides a method of manufacturing a pressure vessel that can subsequently be opened and re-closed, and which is adapted to contain superconducting magnet arrangements. In one embodiment, the method requires fabricating, from fibre-reinforced thermoplastics material, first and second separate parts of the vessel, the parts having respective facing end surfaces; bringing the end surfaces into abutting relationship; fusion bonding the abutting end surfaces together

to form a union closing the vessel; and repeated applications of fusion bonding to the union to open and re-close the vessel.

While polypropylene and polyethylene have been suggested as suitable thermoplastic materials, other thermoplastic materials may be employed, according to the required mechanical strength and thermal properties of the vessel. Similarly, the fibre reinforcement will typically comprise glass fibres, but may alternatively or in addition comprise carbon fibres, aramid fibres or any other fibrous material considered to have suitable thermal and mechanical properties.

It has been proposed, in WO 2003/031860 A1, to construct a laminated pressure vessel, such as a water storage tank, from a cylindrical portion and two somewhat hemispherical end caps; each portion comprising an inner layer of non fibre-reinforced thermoplastics material and an outer layer of fibre-reinforced thermoplastics material. The portions are jointed together by thermal bonding but, although access to the interior of the tank is needed in some embodiments, no consideration is given to opening the joints and re-closing them. Rather, access is provided through an opening in one of the end caps. However, the described vessel is very specific to water containment including bafflers and internal features designed specifically for holding water. The body of the tank is formed by filament winding. The present invention prefers the use of fibre matting, rather than wound continuous filaments.

CLAIMS:

1. A reworkable pressure vessel adapted to contain superconducting magnet arrangement; at least first and second separate parts of the vessel being fabricated from fibre-reinforced thermoplastics material; wherein said first and second parts comprise facing end surfaces adapted for fusion bonding together to form a union closing said vessel such that said vessel can be opened and re-closed by repeated application of fusion bonding to said union.

2. A vessel according to claim 1, wherein the thermoplastics material comprises polypropylene or polyethylene.

3. A vessel according to claim 1 or claim 2, wherein the fusion bonding process used to form said union is chosen from the group comprising: hot tool welding; infra-red welding; laser welding; spin welding; ultrasonic welding; vibration welding; and resistance welding.

4. A vessel according to claim 3, wherein the same fusion bonding process used to form said union is utilised for one at least of said repeated applications.

5. A vessel according to any preceding claim, wherein at least an outer shell of the pressure vessel is formed entirely of said reinforced thermoplastics material.

6. A reworkable pressure vessel substantially as herein described and adapted to contain superconducting magnet arrangements.

7. A method of manufacturing a pressure vessel that can subsequently be opened and re-closed, and which is adapted to contain superconducting magnet arrangements, the method comprising the steps of:

fabricating first and second separate parts of the vessel from fibre-reinforced thermoplastics material; said first and second parts comprising facing end surfaces adapted to abut in fitting relationship;

fusion bonding said abutting end surfaces together to form a union closing said vessel; and

repeatedly applying thermal bonding to said union to open and re-close said vessel.

8. A method according to claim 7, wherein the fusion bonding process used to open and/or re-close the vessel comprises a re-application of the same process used to effect the original bond.

9. A method according to claim 7, wherein a different fusion bonding process from that used for the original bond is used for opening and/or re-closure of the vessel.

10. A method according to any of claims 7 to 9, further comprising recycling the material of the vessel to produce pellets that can be used as raw material in a standard extrusion/compression moulding apparatus.

11. A method according to claim 10 wherein the step of recycling comprises the steps of removing any metallic inserts; grinding of the remaining fibres and plastics material, thereby shredding them into small pieces; and feeding said small pieces into a granulator.

Amendments to the Claims have been filed as follows

1. A reworkable pressure vessel for containing a superconducting magnet arrangement; at least first and second separate parts of the vessel being fabricated from fibre-reinforced thermoplastics material; wherein said first and second parts comprise facing end surfaces adapted for fusion bonding together to form a union closing said vessel such that said vessel can be opened and re-closed by repeated application of fusion bonding to said union.

2. A vessel according to claim 1, wherein the thermoplastics material comprises polypropylene or polyethylene.

3. A vessel according to claim 1 or claim 2, wherein the fusion bonding process used to form said union is chosen from the group comprising: hot tool welding; infra-red welding; laser welding; spin welding; ultrasonic welding; vibration welding; and resistance welding.

4. A vessel according to claim 3, wherein the same fusion bonding process used to form said union is utilised for one at least of said repeated applications.

5. A vessel according to any preceding claim, wherein at least an outer shell of the pressure vessel is formed entirely of said reinforced thermoplastics material.

6. A reworkable pressure vessel substantially as herein described and adapted to contain superconducting magnet arrangements.

7. A method of manufacturing a pressure vessel for containing a superconducting magnet arrangement, which pressure vessel can subsequently be opened and re-closed, the method comprising the steps of:

fabricating first and second separate parts of the vessel from fibre-reinforced thermoplastics material; said first and second parts comprising facing end surfaces adapted to abut in fitting relationship;

fusion bonding said abutting end surfaces together to form a union closing said vessel; and

repeatedly applying thermal bonding to said union to open and re-close said vessel.

8. A method according to claim 7, wherein the fusion bonding process used to open and/or re-close the vessel comprises a re-application of the same process used to effect the original bond.

9. A method according to claim 7, wherein a different fusion bonding process from that used for the original bond is used for opening and/or re-closure of the vessel.

10. A method according to any of claims 7 to 9, further comprising recycling the material of the vessel to produce pellets that can be used as raw material in a standard extrusion/compression moulding apparatus.

11. A method according to claim 10 wherein the step of recycling comprises the steps of removing any metallic inserts; grinding of the remaining fibres and plastics material, thereby shredding them into small pieces; and feeding said small pieces into a granulator.

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Application No: GB0724573.1 **Examiner:** Mr John Watt

Claims searched: 1 - 11 **Date of search:** 9 April 2008

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	US 2007/0014946 A1 (HUANG ET AL) see figs.1 - 9 and paragraphs [0021] and [0035].
A	-	GB 1156833 A (SIEMENS) see figs.1 - 3 and page 2, lines 68 - 109.
A	-	US 3176473 A (ANDONIAN) see figs.1 - 3 and col.1, lines 8 - 56.
A	-	US 6281773 B1 (YOUNG) see figs.1 - 5 and col.6, lines 14 - 18.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

F17C; G01R; H01F

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, TXTE

International Classification:

Subclass	Subgroup	Valid From
F17C	b0013/00	01/01/2006
G01R	0033/3815	01/01/2006
H01F	0006/04	01/01/2006