TANK WITH REINFORCED CORRUGATED MEMBRANE

Technical field of the invention

The present invention relates to a fluidtight tank. In particular, the present invention relates to a fluidtight and thermally insulated tank intended for transporting liquefied natural gas (LNG) by ship.

Prior art

Document FR 2 781 557 describes a tank incorporated into the structure of a ship, for transporting LNG. The walls of the tank comprise, in succession from the inside of the tank outward, a primary fluidtight barrier, a primary thermally insulating barrier, a secondary fluidtight barrier and a secondary thermally insulating barrier. The primary fluidtight barrier is a membrane produced using corrugated metal sheets made of stainless steel. More specifically, each sheet has a series of corrugations running parallel to the axis of the ship and another series of corrugations perpendicular to the axis of the ship.

During operation, mechanical stresses are generated in the membrane. These stresses have a number of origins: thermal contraction when the tank is cooled, the effect of the beam of the ship, the hydrostatic pressure due to filling, and dynamic pressure due to the shifting of the cargo, particularly as a result of the swell.

The corrugations provided in the metal sheets of the membrane are intended to allow the membrane to deform in order to limit the stresses generated by thermal contraction and the effect of the beam of the ship.

It has been found that the dynamic pressure could cause plastic deformation of the corrugations. Now, over time, such deformations can lead to impaired flexibility of the sheets and reduce the fluidtightness of the membrane, particularly at the joints between sheets.

In order to increase the ability of the membrane to withstand pressure and to limit plastic deformation, document FR 2 861 060 proposes the provision of reinforcing ribs on the corrugations.

However, it may be beneficial to improve the ability of the membrane to withstand pressure still further.

Summary of the invention

One problem that the present invention sets out to address is that of providing a tank which does not have at least some of the aforementioned disadvantages of the prior art. In particular, one object of the invention is to improve the ability of the membrane to withstand pressure, so as to avoid or limit plastic deformation thereof.

The solution proposed by the invention is a fluidtight tank, of which at least one wall comprises a fluidtight membrane intended to be in contact with product contained in the tank, and a support adjacent to the membrane, in which tank the membrane comprises at least one sheet having at least one corrugation, characterized in that it comprises a reinforcing element inserted under the corrugation between the membrane and the support.

It has been found that such a reinforcing element is able to limit the stresses generated in the membrane.

Of course, the membrane may comprise several sheets, the sheet may have several corrugations and a reinforcing element may be positioned under one or several corrugations of one or several sheets. The support may for example by a thermally insulating layer and, more specifically, a plywood panel of a thermally insulating layer.

According to one embodiment, the reinforcing element has an internal passage which allows gas to flow between the corrugation and the support, passing through the reinforcing element.

According to one embodiment, an external passage allows gas to circulate between the corrugation and the support, bypassing the reinforcing element.

Advantageously, the reinforcing element is made of a material chosen from: plywood, polyethylene, polycarbonate, glass fiber reinforced polycarbonate, polyether imide and expanded polystyrene.

According to one embodiment, the reinforcing element comprises an outer envelope the shape of which corresponds substantially to the shape of the corrugation.

For preference, the reinforcing element comprises at least one reinforcing web inside said envelope.

Advantageously, when the tank contains no product, the minimum distance between the reinforcing element and the corrugation is comprised between 0% and 5% of the height of the corrugation.

For preference, the sheet has a first series of mutually parallel corrugations and a second series of

mutually parallel corrugations which run transverse to the corrugations of the first series, the reinforcing element being inserted under a corrugation of the first series. Of course, several reinforcing elements may be inserted under several corrugations of the first series.

According to one embodiment, the reinforcing element has a length that corresponds to the distance between two corrugations of the second series. As an alternative, this length may be shorter or longer.

Advantageously, the reinforcing element is inserted under the corrugation such that it can slide with respect to the membrane and to the support. In this case, the manufacture of the tank does not entail a step of attaching the reinforcing element.

In an alternative form, the reinforcing element is fixed to the membrane or to the support. That makes it possible to ensure that the reinforcing element remains positioned at the desired location.

According to one embodiment, the membrane has an undercut, the reinforcing element being clipped to or wedged in the undercut.

According to one embodiment, at least two reinforcing elements are positioned respectively under two adjacent corrugations of the membrane, one of said two reinforcing elements forming an end stop for the other of said two reinforcing elements. Thus, one reinforcing element is held captive by the other and thus kept in position.

Advantageously, the reinforcing element has at least one weak point able to deform or break if subjected to a stress above a determined threshold.

That makes it possible, through controlled plastic deformations of the membrane, to determine the pressures experienced by the membrane and to identify potential risks of damage to the underlying support.

For preference, away from the corrugation, the membrane is in contact with the support.

The invention also provides a floating construction comprising a tank according to the above invention. This may be a ship or some other type of floating installation.

Brief description of the figures

The invention will be better understood, and other objects, details, features and advantages thereof will become more clearly apparent, during the course of the following description of one particular embodiment of the invention which has been given solely by way of nonlimiting example with reference to the accompanying drawings. In these drawings:

- figure 1 is a perspective view of a corrugated sheet of a tank according to one embodiment of the invention;
- figure 2 is a perspective view in cross section of a corrugation of the corrugated sheet of figure 1, and of a reinforcing element according to a first alternative form;
- figures 3 to 9 depict, in perspective, various alternative forms of the reinforcing element;
- figures 10 and 11 depict, in cross section, other alternative forms of the reinforcing element;

- figure 12 is a view of the sheet of figure 1 from above, at the location of a corrugation intersection, and a view in perspective and partial cross section of a reinforcing element fixed by clipping under a corrugation;
- figure 13 depicts a reinforcing element intended to be positioned under several corrugations at the same time; and
- figure 14 is an exploded perspective view of two reinforcing elements collaborating with one another.

Detailed description of one embodiment of the invention

A tank according to one embodiment of the invention may have a multilayer structure similar to the tanks of documents FR 2 781 557 and FR 2 861 060, which documents were cited in the introductory part. In particular, the tank has a primary fluidtight membrane made with corrugated metal sheets which rest on a plywood panel of a primary thermally insulating layer. As the general aspects of this multilayer structure are known, the description hereinbelow relates to the special features of the tank according to one embodiment of the invention.

The sheet 1 depicted in figure 1 is a corrugated sheet made of stainless steel, of rectangular overall shape. The primary fluidtight membrane of the tank is produced by welding several sheets of this type edge to edge.

As figure 1 shows, the sheet 1 comprises three large corrugations 2 running along the length of the sheet 1, and nine small corrugations 3 running across the width of the sheet 1. The corrugations are said to be large 2 and small 3 because the height of the large

corrugations 2 is greater than that of the small corrugations 3.

As an alternative, the sheet 1 could have a different number of large corrugations 2 and/or of small corrugations 3. Likewise as an alternative, the corrugations of the sheet 1 could have reinforcing ribs as described in FR 2 861 060. The corrugations of the sheet 1 could also have other configurations, for example as in documents FR 2 735 847 or KR-10-2005-0050170.

Figure 2 shows that the sheet 1 rests on the plywood 4 of the underlying thermally insulating layer. As an alternative, the sheet 1 could rest on some other type of support. It may also be seen from this figure that a reinforcing element 5 is positioned under the large corrugation 2, between the sheet 1 and the plywood 4. In the context of this description, "under" means that the reinforcing element 5 is covered by the corrugation, but does not necessarily mean that it lies lower down. Specifically, on the vertical walls of the tank, the reinforcing element 5 is in horizontal alignment with the corrugation covering it.

In the example of figure 2, the length of the reinforcing element 5 corresponds to the distance between two small corrugations 3.

Several reinforcing elements 5 may be positioned, each under a large corrugation 2 between two small corrugations 3. The number and distribution of the reinforcing elements 5 may be determined according to the way in which the anticipated stresses are distributed in the membrane of the tank during operation.

As an alternative, the length of the reinforcing element 5 may be shorter than the distance between two small corrugations 3 or, if the geometry of the intersection between corrugations so permits, longer than this distance. As another alternative, reinforcing elements 5 may be provided under the small corrugations 3.

The reinforcing element 5 is put into position as depicted in figure 2, without being fixed either to the sheet 1 or to the plywood 4. It can therefore slide if necessary under the large corrugation 2. The manufacture of the tank therefore does not entail a step of fixing the reinforcing elements 5. As an alternative, the reinforcing element 5 may be fixed to the membrane or to the plywood 4.

There are many suitable shapes for the reinforcing element 5. Figures 3 to 11 depict various shapes which may suit. The views in figures 3 to 9 are perspective views of a slice of reinforcing element 5, the length of which may exceed the length depicted. The views in figures 10 and 11 are views in cross section. In these various figures, the same reference symbols are used to denote elements that are similar.

The reinforcing element 5 of figure 3 has a solid section. Its two lateral faces 6 are curved and of a shape that corresponds to that of the corrugation 2. However, the lateral faces 6 do not extend as far as the top of the corrugation 2 and the reinforcing element 5 has a flat top face 7. Gas can circulate between the top of the corrugation 2 and the upper face 7.

The reinforcing element 5 of figure 4 has an envelope 7 the exterior shape of which corresponds to the shape of

the corrugation 2. A circular passage 9 allows gas to pass through the reinforcing element 5. In the alternative form of figure 5, the passage 9 has a shape corresponding to the exterior shape of the envelope 7, in order to offer a larger passage area.

The reinforcing element 5 of figure 6 also has an envelope 7 the exterior shape of which corresponds to the shape of the corrugation 2, and a passage 9. To improve the mechanical strength of the reinforcing element 5, internal webs 10 cross the passage 9. Figures 7 to 9 depict alternative configurations of the webs 10.

The reinforcing elements in figures 3 to 9 can be produced for example in one of the following materials: polyethylene, polycarbonate, glass fiber reinforced polycarbonate, polyether imide and expanded polystyrene. They may be manufactured using any appropriate technique (injection molding, molding, extrusion, machining, etc.).

The reinforcing elements 5 of figures 10 and 11 have a solid cross section. Their lateral faces 6 each have two flat bands. As was the case of the reinforcing element in figure 3, gas can pass between the upper face 7 and the top of the corrugation. The reinforcing elements 5 in figures 10 and 11 may, for example, be made of plywood, by machining.

The reinforcing element 5 of figure 11 has a lug 22 fixed to its lower face 23. The lug 22 can be used to fix the reinforcing element 5 to the plywood 4, for example at the joint between two sheets of plywood.

Figure 12 shows, on the left, the geometry of the corrugations at an intersection between a large

corrugation 2 and a small corrugation 3. It may be seen that in this region the membrane has an undercut 20. The right-hand part of figure 12 shows that the reinforcing element 5 positioned under a large corrugation 2 has, at its end, tabs 21 which allow the reinforcing element 5 to be fixed to the membrane, by clipping into the undercut 20. As an alternative, the tabs 21 could be wedged into position.

Figure 13 is a perspective depiction of a reinforcing element 5 which is intended to be positioned under several large corrugations 2 and small corrugations 3 at the same time. Its shape corresponds to that of the corrugations, including at the intersections. Internal passages 9 are provided both in the parts situated under the small corrugations 3 and under the large corrugations 2.

Figure 14 depicts two reinforcing elements 5, one intended to be positioned under a large corrugation 2 and the other under a small corrugation 3, intersecting where the corrugations intersect. At this point, the reinforcing elements 5 each have a cutout 24 allowing them to be positioned relative to one another. As can be seen in this figure, the reinforcing elements 5 are of rectangular cross section.

The various shapes proposed hereinabove for the reinforcing element 5 allow the corrugations to deform in the event of thermal contraction and offer support for the corrugations in the event of deformation due to hydrostatic and dynamic pressures. To achieve this objective provision may be made for the minimum distance between the reinforcing element 5 and the corrugation under which it is located to be comprised between 0% and 5% of the height of the corrugation when

the tank is empty (and therefore when there is no thermal loading or hydrostatic or dynamic pressure).

The various shapes of reinforcing element 5 each have their own specific properties: cost and ease of manufacture, mechanical strength, quantity of material, etc. The most appropriate shape can be chosen to suit the application.

Numerical simulations have been carried out to check the effect of the reinforcing element 5 on the stresses generated in the membrane, as compared with a membrane that has no reinforcing element. These simulations showed that:

- in the case of thermal loading (contraction of the membrane as a result of the cold), the presence of a reinforcing element 5 does not introduce undesirable stresses into the membrane,
- in the event of thermal loading and uniform pressure loading (corresponding to the hydrostatic pressure of the cargo), the presence of a reinforcing element 5 allows the stresses in the membrane to decrease, and
- in the event of thermal loading and asymmetric pressure loading (corresponding to the dynamic pressure of the cargo), the presence of a reinforcing element 5 allows the stresses in the membrane to reduce.

Although the invention has been described in conjunction with one particular embodiment, it is quite obvious that it is not in any way restricted thereto and that it comprises all technical equivalents of the means described and combinations thereof where these fall within the scope of the invention.

CLAIMS

1. A fluidtight tank, of which at least one wall comprises a fluidtight membrane intended to be in contact with product contained in the tank, and a support adjacent to the membrane, in which tank the membrane comprises at least one sheet (1) having at least one corrugation (2, 3), characterized in that it comprises a reinforcing element (5) inserted under the corrugation between the membrane and the support.

2. The tank as claimed in claim 1, in which the reinforcing element has an internal passage (9) which allows gas to flow between the corrugation and the support, passing through the reinforcing element.

3. The tank as claimed in one of the preceding claims, in which an external passage allows gas to circulate between the corrugation and the support, bypassing the reinforcing element.

4. The tank as claimed in one of the preceding claims, in which the reinforcing element is made of a material chosen from: plywood, polyethylene, polycarbonate, glass fiber reinforced polycarbonate, polyether imide and expanded polystyrene.

5. The tank as claimed in one of the preceding claims, in which the reinforcing element comprises an outer envelope (7) the shape of which corresponds substantially to the shape of the corrugation.

6. The tank as claimed in claim 5, in which the reinforcing element comprises at least one reinforcing web (10) inside said envelope.

7. The tank as claimed in one of the preceding claims, in which, when the tank contains no product, the minimum distance between the reinforcing element and the corrugation is comprised between 0% and 5% of the height of the corrugation.

8. The tank as claimed in one of the preceding claims, in which the sheet has a first series of mutually parallel corrugations (2) and a second series of mutually parallel corrugations (3) which run transverse to the corrugations of the first series, the reinforcing element (5) being inserted under a corrugation (2) of the first series.

9. The tank as claimed in claim 8, in which the reinforcing element has a length that corresponds to the distance between two corrugations of the second series.

10. The tank as claimed in one of the preceding claims, in which the reinforcing element is inserted under the corrugation such that it can slide with respect to the membrane and to the support.

11. The tank as claimed in one of claims 1 to 9, in which the reinforcing element is fixed to the membrane or to the support.

12. The tank as claimed in claim 11, in which the membrane has an undercut (20), the reinforcing element being clipped to or wedged in the undercut.

13. The tank as claimed in one of the preceding claims, in which at least two reinforcing elements are positioned respectively under two adjacent corrugations of the membrane, one of said two reinforcing elements

forming an end stop for the other of said two reinforcing elements.

14. The tank as claimed in one of the preceding claims, in which the reinforcing element has at least one weak point able to deform or break if subjected to a stress above a determined threshold.

15. The tank as claimed in one of the preceding claims, in which away from the corrugation, the membrane is in contact with the support.

16. A floating construction comprising a tank as claimed in one of the preceding claims.