

PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Composite Reinforced Plastics Pipe

5 We, UNITED AIRCRAFT CORPORATION, a Corporation organized and existing under the laws of the State of Delaware, United States of America, of 400 Main Street, East Hartford, Connecticut, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

10 This invention relates to a composite reinforced plastics pipe capable of withstanding both internal and external pressure loads.

15 According to the invention, there is provided a composite reinforced plastics pipe capable of withstanding internal and external pressure loads, comprising a unitary annular wall structure, said wall structure being formed by a plurality of winding turns of a continuous filamentary band extending around the longitudinal axis of the pipe and along the length thereof, the band consisting essentially of a multiplicity of continuous generally parallel filaments, at least two further pluralities of said turns each spaced radially of said first mentioned plurality of turns, adjacent radially spaced turns being separated by particulate material, and a cured synthetic plastics resin matrix binding together the components of the wall structure, the volume of the particulate material in the zones between said adjacent turns being such that substantially all of the compressive loads between said adjacent turns are withstood by the particulate material.

35 Features and advantages of the invention will be apparent from the following description of embodiments thereof, given by way of example only, in conjunction with the accompanying drawings, in which:—

40 Figure 1 is a schematic representation of

the formation of the composite reinforced pipe according to this invention, and

Figures 2, 3 and 4 are enlarged views of sections through the various embodiments of composite pipe according to this invention.

Referring to the drawings, the composite reinforced plastics pipe includes a unitary annular wall structure formed by a first plurality of contiguous or non-contiguous winding turns of a continuous filamentary band 2 extending around the longitudinal axis of the pipe and along the length thereof, the band consisting essentially of a multiplicity of continuous generally parallel filaments 7, at least two further pluralities of such turns each spaced radially of the first mentioned plurality of turns, adjacent radially spaced turns being separated by particulate material 4, and a cured synthetic plastics resin matrix binding together the components of the wall structure, the volume of the particulate material in the zones or layers between adjacent turns being such that substantially all the compressive loads between the adjacent turns are withstood by the particulate material.

The relative thickness of each filamentary turn and the particulate material in an adjacent zone should be carefully adjusted since too thin a particulate zone will require excessive amounts of filamentary material in the finished pipe and too thick a zone will create internal shear stresses which will cause cracks at the interfaces between the filaments and the particles upon deformation of the pipe. It has been found that the ratio of thickness of the particulate zones to the filamentary turns, T_p/T_f , should preferably be within the range of from 2:1 to 50:1 and preferably at about 6:1.

It should be noted that the ratio of the T_p/T_f need not be constant across the wall

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of the pipe. Since the shear stresses are not uniformly distributed across the wall, it is possible to maximize the properties of the pipe by employing low T_p/T_i values in the regions of stress concentration and higher values of T_p/T_i in low stress areas.

For example, the shear stresses produced by the "D" loads (see ASTM C-76-63T) concentrate within the wall adjacent to the internal and external surfaces thereof. The T_p/T_i value in these regions can be selected in the lower portion of the range whereas in the central portion of the wall where there is little shear stress, the T_p/T_i value can be selected in the upper portion of the range.

Preferably the pipe would be designed such that the structure, after curing of the synthetic plastics resin binder, contains sufficient filamentary material to withstand the internal pressure loads and sufficient particulate material between the filamentary turns to withstand the compressive and "D" loads. However, due to the above limitations on the relative thicknesses of the respective turns and zones, in some applications when extremely high external loading pressures are encountered, it may be necessary to incorporate amounts of filamentary material in excess of that required to withstand the internal pressures.

Due to its high strength, chemical and physical properties and commercial availability, fiberglass is the preferred filamentary material. However, other high strength filaments such as metallic wires or filaments and other materials such as filamentary silica could be employed.

The preferred particulate material is sand. However, many other materials may be used such as particulate silica, small hollow spheres of various materials for example graphite. If, for example, a light weight conduit is desired, vermiculite or small hollow spheres of various materials such as glass or phenolic resin would be preferred materials.

Any suitable synthetic plastics resin binder may be used, epoxy and polyester binders being particularly desirable.

Referring now to Figure 1, a schematic representation of a method of fabricating pipe according to this invention is shown. Since the apparatus forms no part of this invention, only the elements necessary for an understanding of this invention are shown, a complete description of a suitable machine appearing in U.S. Patent No. 3,228,616.

A mandrel adapted for rotation, as shown by the arrow, has a band of fiberglass filaments 2 wet with synthetic plastics resin binder applied thereto. In an alternative embodiment, the synthetic plastics resin could be applied to the band 2 after it is on the mandrel by a suitable application such as brushing or spraying. Regardless of the specific means for applying the resin, sufficient

binder should be present to cause the amount of particulate material which is subsequently added to be held on the surface of the band until it is covered by a subsequent layer of filaments. The filaments are fed onto mandrel 1 from a movable carriage (not shown) which continually moves in passes back and forth from one end of the mandrel to the other as the mandrel rotates; the turns in each pass are contiguous to produce continuous annular layers of helically disposed filaments separated by layers of particulate material. The winding angle can be selected to meet specific requirements by workers in the art, preferably, however, the helically disposed filaments are wound in a very high angle helix which produces essentially a hoop winding. A hopper 3 travels with the movable carriage and distributes the particulate material 4 onto the fiberglass winding, the particles being held in place by the binder with which filaments 2 are wetted. The broken away section of Figure 1 illustrates the buildup of successive alternate layers of particles 4 and filament windings. The winding procedure is continued until the desired wall thickness is obtained. The outer layer may be either filamentary or particulate as desired. An outer particulate surface will, of course, produce a rougher finished surface, and may facilitate handling during the pipe laying operation. The entire structure is then cured and the mandrel is removed. Although it is preferable to remove the mandrel, a hollow mandrel could be employed and allowed to remain as the inner wall of the pipe. The end portion of the cylinder which may be irregular due to the end pattern formed by the reversal of the direction of the movable carriage can be cut off and the pipe is ready for use or the structure may be formed against flat stops, eliminating the final trim. Joint structures can be machined on the ends of the pipe if desired or a desired end configuration can be wound into the end portion if desired, for connecting the ends of a plurality of pipes together to form a pipeline.

Figure 2, a magnified view of a longitudinal section through a pipe wall, illustrating in greater detail the internal structure of the pipe. The internal wall 6 of the pipe 5 is shown as being a continuous layer of fiberglass filaments 7 surmounted by successive layers of particles 4 and further such layers 7, the entire structure being held together by the cured synthetic plastics resin binder. It is noted that each fiberglass layer 7 consists of two layers of filaments which results from band 2 being two filaments thick. In practice, it has been found that fiberglass bands from 5 to 6 monofilament diameters thick are easiest to handle and, accordingly, it is contemplated that the filament layers can be either one filament thick or many filaments thick.

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Figure 3 is a cross sectional view of another embodiment of this invention in which the T_1/T_2 ratio varies across the wall structure. In this embodiment the shear stress is concentrated near the surface 8, and, accordingly, the thickness of the particle layers in this region is smaller than in regions closer to the centre of the wall.

In another embodiment shown in Figure 4, the turns of each pass are non-contiguous and are separated by particulate material 4. Such a structure can be employed to reduce, in the case of embodiments 2 and 3, the likelihood of separation at the laminar interfaces between the continuous layers of filaments and particles. The structure of Figure 4 could be produced, for example, by applying the particles to the filament band prior to winding on the mandrel and then winding the particle coated band in an open pattern which requires two or more passes of the filament band to cover the entire winding surface.

It will be seen from the embodiments of Figures 2, 3 and 4 that the volume of particulate material in each zone or layer of particulate material provides particle-to-particle contact substantially through each zone or layer and particle-to-filamentary material contact at the interfaces of each layer of particulate material with adjacent layers of filamentary material so that substantially all the compressive loads between adjacent radially spaced turns of the pipe wall are withstood by the particulate material 4.

It is desirable to incorporate longitudinally disposed filaments into the wall structure to impart a resistance to bending moments, such filaments being in addition to the helically disposed filaments. The longitudinal filaments are preferably laid, under tension, on the outer surface of the pipe and held in place by an additional layer of hoop windings as illustrated by longitudinal filaments 9 and hoop filaments 10 in Figure 4.

It is also contemplated that various other materials such as non-permeable membranes, for example, of polyamide "H" film, rubber sheets or sheets of material known under the Trade Marks Mylar and Saran can be applied on the inner and outer surfaces of the pipe or within the wall structure without departing from the scope of the invention as defined by the appended claims.

EXAMPLE

A composite reinforced plastic pipe, inner diameter 609.6 mm, outer diameter 647.7 mm was fabricated according to this invention. Each fiberglass layer was approximately 0.127 mm thick and composed of 2,850 individual monofilaments per cross-sectional cm, each filament being approximately 0.01295 mm in diameter. The particles used were sand particles having a mean size of about

0.762 mm and each particle layer was about 1.168 mm thick. The entire structure was bonded together by polyester resin which accounted for about 25% of the total weight. The finished pipe was capable of withstanding an internal pressure of 66 kg/cm² and an external "D" load of 1,674 kg.

The instant pipe is capable of withstanding external "D" loads about 1000% higher than a sandwich structure pipe fabricated from a concrete body sandwiched between inner and outer filament skins containing the same amount of fiberglass.

While this invention has been described with respect to specific examples thereof, it should not be construed as being limited thereto. Various modifications and substitutions will be obvious to workers in the art and can be made without departing from the scope of this invention as defined by the appended claims.

WHAT WE CLAIM IS:—

1. A composite reinforced plastics pipe capable of withstanding internal and external pressure loads, comprising a unitary annular wall structure, said wall structure being formed by a plurality of winding turns of a continuous filamentary band extending around the longitudinal axis of the pipe and along the length thereof, the band consisting essentially of a multiplicity of continuous generally parallel filaments, at least two further pluralities of said turns each spaced radially of said first mentioned plurality of turns, adjacent radially spaced turns being separated by particulate material, and a cured synthetic plastics resin matrix binding together the components of the wall structure, the volume of the particulate material in the zones between said adjacent turns being such that substantially all of the compressive loads between said adjacent turns are withstood by the particulate material.

2. A pipe according to claim 1, wherein the ratio of the thickness of a zone of particulate material to that of an adjacent turn of filamentary material is in the range 2:1 to 50:1.

3. A pipe according to claim 1 or claim 2, wherein the ratio of the thickness of a zone of particulate layer to the thickness of an adjacent turn varies across the wall thickness of the pipe.

4. A pipe according to claim 3, wherein said ratio is smaller in the sections of the wall in proximity to the inner and outer surfaces of the pipe wall, and larger in the section of the wall intermediate the first mentioned sections.

5. A pipe according to any one of the preceding claims, wherein said filamentary material is fibre-glass.

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In another embodiment shown in Figure 4, the turns of each pass are non-contiguous and are separated by particulate material 4. Such a structure can be employed to reduce, in the case of embodiments 2 and 3, the likelihood of separation at the laminar interfaces between the continuous layers of filaments and particles. The structure of Figure 4 could be produced, for example, by applying the particles to the filament band prior to winding on the mandrel and then winding the particle coated band in an open pattern which requires two or more passes of the filament band to cover the entire winding surface.

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3. A pipe according to claim 1 or claim 2, wherein the ratio of the thickness of a zone of particulate layer to the thickness of an adjacent turn varies across the wall thickness of the pipe.
4. A pipe according to claim 3, wherein said ratio is smaller in the sections of the wall in proximity to the inner and outer surfaces of the pipe wall, and larger in the section of the wall intermediate the first mentioned sections.
5. A pipe according to any one of the preceding claims, wherein said filamentary material is fiberglass.
6. A pipe according to any one of the



preceding claims, wherein said particulate material is sand.

- 5 7. A pipe according to any one of the preceding claims, wherein the turns of each of said pluralities of turns are contiguous to form a layer of filamentary material which is substantially continuous along the length of the pipe.

- 10 8. A pipe according to any one of claims 1 to 6, wherein the turns of each of said pluralities of turns are non-contiguous.

- 15 9. A pipe according to any one of the preceding claims, wherein the ends of the pipe define joint means whereby said pipe may be connected to other similar pipes.

10. A pipe according to any one of the preceding claims, and including longitudinally disposed filamentary material extending along the length of the pipe to provide resistance to bending loads applied to the pipe.

11. A composite reinforced plastics pipe, substantially as herein described with reference to Figure 1 taken together with any one of Figures 2 to 4 of the accompanying drawings.

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