

TITLE: Railway vehicle body and corresponding method

5 The present invention relates to a railway vehicle body, the body comprising an openwork body shell comprising longitudinal tubes, linking tubes intersecting the longitudinal tubes, and fittings connecting longitudinal tubes and linking tubes, the body further comprising claddings extending between the longitudinal tubes and the linking tubes.

10 The invention particularly applies to railway vehicles of the subway, regional rail, tram, and freight train types, among others.

“Body” refers to a structure defining an interior space within the body intended to receive occupants of the railway vehicle and/or equipment, and an exterior space outside the body. The body is supported by a base element that is connected to bogies of the railway vehicle. The base element defines a floor of the interior space.
15 The railway vehicle bodies are generally formed of beams and crossbars made of metal or metal alloy parts. To form the body, the beams and crossbars are, for instance, welded to one another.

However, metal bodies are heavy and increase the operating costs of the railway vehicle, and impact the ground-level equipment.

20 To reduce the railway vehicle’s weight, GB 972405 proposes forming elements of the body from a polymer material. This document describes a method for obtaining structural elements, such as side sills and crossbars, by pressing polymer material into moulds designed for that purpose.

Such a solution is not wholly satisfactory. This is because the size and shape
25 of the railway vehicle’s body are not easy to adapt from one vehicle to another in order to meet the vehicle’s gauge requirements and to adapt the number and shape of the windows and doors defined in the body.

The method as described in GB 972405 makes it difficult and expensive to form body elements of variable size and shape. For instance, it is necessary to
30 provide a specific mould for each size or shape variation of a body element.

One goal of the invention is therefore to have a body whose size and shape are easy to adapt, while being lightweight and easy to manufacture.

To that end, one object of the invention is a body of the aforementioned type, wherein the longitudinal tubes and the linking tubes comprise fusible yarns
35 assembled one to another by heating.

The body according to the invention may comprise one or more of the following features, taken alone or in any combination that is technically possible:

- the longitudinal tubes and linking tubes comprise non-fusible structural yarns, the structural yarns being distinct from the fusible yarns.
- the fusible yarns are thermoplastic polymer yarns, and the structural yarns comprise inorganic fibres belonging to at least one of the elements of the group constituted by glass fibres, carbon fibres, and basalt fibres.
- The fusible yarns are arranged into a plurality of woven and/or braided layers.
- At least one tube from among the longitudinal and linking tubes has a circular cross-section.
- The fitting comprises a first connective part for connecting a first tube from among the longitudinal tubes and the linking tubes, the first connective part forming a recess configured to receive a second tube from among the longitudinal tubes and the linking tubes.
- The second tube comprises at least one second connective part forming an complementary recess configured to receive the first connective part at the recess.
- The fitting comprises at least one interconnection between the longitudinal tubes and the linking tubes, the interconnection defining at least one pocket receiving an end of a longitudinal tube and at least one additional pocket receiving an end of a linking tube.
- The interconnection has a cladding fastening surface, onto which a cladding is mounted.
- The interconnection is formed by weaving a weft yarn along a first direction, and a warp yarn along a second direction.
- The interconnection is formed of yarns of at least two different materials.
- The claddings are connected to the longitudinal tubes and/or to the linking tubes by clipping elements.
- The fusible yarns are thermoplastic polymer yarns.
- The structural yarns comprise inorganic fibres belonging to at least one of the elements of the group constituted by glass fibres, carbon fibres, and basalt fibres.
- The structural yarns comprise organic polymer fibres.

A further object of the invention is a method of manufacturing a railway vehicle body, the method comprising a phase of assembly comprising:

- a step of providing longitudinal tubes and linking tubes made from fusible yarns assembled onto one another by heating,
- a step of connecting longitudinal tubes with linking tubes at the fittings to form an openwork body shell, and
- a step of fastening claddings between the longitudinal tubes and the linking tubes.

The method according to the invention may comprise one or more of the following features, taken alone or in any combination that is technically possible:

- the method comprises an initial phase of producing longitudinal tubes and linking tubes, comprising:
 - + a step of assembling the fusible yarns,
 - + a step of heating the fusible yarns,
 - + a step of cutting the tubes to the right length.
- the fitting comprises a first connective part for connecting a first tube from among the longitudinal tubes and the linking tubes, the first connective part forming a recess configured to receive a second tube from among the longitudinal tubes and the linking tubes, during the step of connecting, the recess receives a second tube from among the longitudinal tubes and the linking tubes.

The invention will be better understood upon reading the following description, given only as an example, and with reference to the attached drawings, in which:

Figure 1 is a schematic depiction in perspective view of the body shell of a body according to the invention;

Figure 2 is a schematic depiction in perspective view of a tube comprising a connective part;

Figure 3 is a schematic depiction in perspective view of a fitting between two tubes;

Figure 4 is a schematic depiction in perspective view of part of the body;

Figure 5 is a schematic depiction in perspective view of an interconnection between tubes; and

Figure 6 is a flowchart of a method for manufacturing a body.

In the remainder of the description, the phrase "substantially equal to" generally refers to being equal within 10%, and preferably within 5%. Furthermore, the phrase "substantially perpendicular to" refers to a relationship of perpendicularity generally within 10 degrees, and preferably within 5 degrees.

Figure 1 depicts a railway vehicle 1 comprising a chassis 2 and a body 4.

The railway vehicle 1 has a longitudinal direction L, also called the direction of travel. The railway vehicle 1 is in this case configured to move along a longitudinal direction L, for instance on rails that are not depicted. A vertical direction V is also defined, substantially perpendicular to the longitudinal direction L, and a transverse direction T substantially perpendicular to the longitudinal direction L and the vertical direction V.

In the description, the terms “on”, “under”, “above”, “below”, “higher”, and “lower” are defined relative to a direction of elevation of the railway vehicle 1, which is the vertical direction when the railway vehicle 1 is travelling on horizontal rails (not depicted).

The chassis 2 comprises (not depicted) bogies comprising wheels disposed on rails. The chassis 2 is configured to support the body 4 disposed below the chassis 2.

The body 4 of the railway vehicle 1 defines an interior space 6 within the body 4 and an exterior space 8 outside the body 4. The interior space 6 within the body 4 forms, for instance, a passenger compartment, in which passengers, who are not depicted, are present. In one complement or variant, the interior space 6 receives equipment.

The body 4 comprises an openwork body shell 14 and claddings 16 fastened onto the openwork body shell 14. The claddings 16 are visible in Figures 3 and 4 and are described below.

The openwork body shell 14 is a structure comprising, for instance, end arches 20, longitudinal tubes 24, linking tubes 26, and fittings 27.

The end arches 20 are disposed at a front end and a rear end of the body 4, along the longitudinal direction L.

Each end arch 20 forms an upside-down “U” profile. Each end arch 20 comprises, for instance, two vertical risers 28, a central crossbar 30 that is substantially horizontal, and two angular elements 32. The angular elements 32 each connect an upper end of the respective vertical riser 28 to the central crossbar 30. The vertical risers 28 and the central crossbar 30 are, for instance, profiles with a rectangular cross-section.

The longitudinal tubes 24 and the linking tubes 26 are disposed, for instance, at the side walls and on a roof of the body 4.

The longitudinal tubes 24 extend in the longitudinal direction L. In the example of Figure 1, the longitudinal tubes 24 are not curved, meaning that the longitudinal tubes 24 extend parallel to the longitudinal direction L.

The linking tubes 26 are, for instance, disposed substantially perpendicular to the longitudinal tubes 24. In other words, the linking tubes 26 intersect the longitudinal tubes 24.

The linking tubes 26 form in their transverse cross-section an upside-down “U” profile, meaning that they form arches between the end arches 20 of the front end and the rear end along the longitudinal direction L. The linking tubes 26 comprise curved segments 34 and straight segments 36. Each linking tube 26 comprises, for instance, on a first side wall of the body 4, a straight segment 36, followed by three curved segments 34 at the roof, and on a second side wall of the body 4 opposite the first side wall, a straight segment 36.

Typically, in the example of Figure 1, an arch of a linking tube 26 is a single part, meaning the curved parts 34 and the non-curved parts 36 forming an arch constitute a linking tube 26 made of a single piece.

As is particularly visible in Figures 2 and 3, the longitudinal tubes 24 and the linking tubes 26 are tubular elements having circular cross-sections. The circular cross-sections have an outer radius R. The dimension of radius R of the tube 24, 26 may, for instance, be selected based on a dimension of the tube 24, 26 to be inserted. The radius R is, for instance, comprised between 2 cm and 5 cm.

The circular cross-sections are bounded by tube walls. Each tube wall has a thickness P. The thickness P of the tube 24, 26 depends on a diameter of the fusible yarn used, multiplied by the number of yarns. The thickness P is, for instance, between 0.1 mm (for example, the diameter of a thin yarn, and only one) and 50 mm (for instance, the diameter of a thick yarn and/or multiple yarns used). In one particular embodiment, the thickness P is between 3 mm and 5 mm.

The longitudinal tubes 24 and the linking tubes 26 are formed from fusible yarns intended to be bound to one another, and from structural yarns intended to be interwoven between the fusible yarns.

The fusible yarns are distinct from the structural yarns. More specifically, the longitudinal tubes 24 and the linking tubes 26 are formed by braiding or binding the fusible yarns and structural yarns, then by linking the fusible yarns to one another and to the structural yarns.

The fusible yarns of the longitudinal tubes 24 and of the linking tubes 26 are arranged into a plurality of braided layers nested within one another.

“Fusible yarns” means yarns that can be softened by heating. The fusible yarns are configured to be assembled onto one another by heating, e.g. by means of an oven or hot air gun.

The fusible yarns typically comprise a fuse resin. The fusible yarns are for instance formed of a thermoplastic polymer, such as polyamide (PA), polyamide-imide (PAI), a polyolefin such as a polyethylene (PE) or a polypropylene (PP), polyester, or a blend thereof.

“Structural yarns” means yarns whose melting point is greater than the melting point of the fusible yarns, particularly at least 10% higher than the melting point of the fusible yarns.

The structural yarns are, for instance, organic polymer yarns with a higher glass transition temperature than those of the inorganic (carbon, glass, basalt, etc.) or fusible yarns.

The longitudinal tubes 24 and the linking tubes 26 are assembled one to another by heating and/or transverse pricking at the link of the tube yarns by a structural and/or fusible yarn at the fittings 27.

Each fitting 27 thereby connects a longitudinal tube 24 with a linking tube 26.

According to a first embodiment of the fitting 27, depicted in particular in Figures 2 and 3, each fitting 27 comprises a first connective part 38 and a second connective part 40.

As is particularly visible in Figure 2, the first part 38 of the fitting 27 forms a recess 42. The recess 42 has a notch shape that opens up laterally relative to a direction of extension of the longitudinal tube 24. The recess 42 has a maximum depth PM and a length LA in a direction of extension of the longitudinal tube 24. The maximum depth PM of the recess 42 is, for instance, 0.8 to 1.2 times the radius R. The length LA is, for instance, 1 to 3 times the radius R.

The first connective part 38 of the longitudinal tube 24 receives the linking tube 26 in the recess 42. The longitudinal tube 24 and the linking tube 26 are connected directly, with no intermediary element between the longitudinal tube 24 and the linking tube 26 at the fitting 27, by partial fusion between the tubes 24, 26. For instance, the longitudinal tube 24 is disposed perpendicularly to the linking tube 26.

Additionally, as depicted in Figure 3, the second part 40 of the linking tube 26 forms a recess that is complementary to the recess 42 that receives the first connective part 38 at the recess 42. In other words, the second part 40 forms a recess with the same shape and dimensions as the recess 42 of the first connective part 38.

In one variant, the linking tube 26 comprises the second connective part 40 and the longitudinal tube 24 comprises the first connective part 38.

According to a second embodiment of the fitting 27, depicted in particular in Figures 4 and 5, the fitting 27 comprises an interconnection 44 attached both between two segments of the longitudinal tube 24 and between two segments 36 of the linking tube 26.

5 The interconnection 44 is, for instance, a composite element formed of two different types of yarns, particularly fusible yarns and structural yarns as described above. The structural yarns form, for instance, a woven network, as represented by the hatching 46 in Figure 5.

10 The interconnection 44 is, for instance, formed by weaving a weft yarn along a first direction, and a warp yarn along a second direction. The first and second direction form, for instance, a substantially perpendicular angle between them.

The interconnection 44 comprises, for instance, the same materials as the tubes 24, 26 or a different material, based on the mechanical strength requirements or other important needs. For instance, the tube 24, 26 and the interconnection are
15 made of a composite material.

The interconnection 44 connects longitudinal tubes 24 and linking tubes 26.

The interconnection 44 comprises a flat base 48 and at least two pockets, for instance for pockets 52 protruding from the flat base 48.

20 The base 48 has a rectangular parallelepiped shape. The pockets 52 protrude from a first face of the base 48. A second face of the base 48, opposite the first face, defines a cladding fastening surface 54.

Each pocket 52 defines a cavity for receiving a tube segment 24, 26, here having a circular cross-section. The cavity has a shape complementary to the end of a segment of longitudinal tube 24 or linking tube 26.

25 Two pockets 52 from among the four pockets 52 each receive one end of a segment of longitudinal tube 24 and two other pockets 52 each receive one end of a segment of linking tube 26.

In the example in Figure 4, each pocket 52 is disposed perpendicular relative to two adjacent pockets 52.

30 Typically, the body 4 comprises one or more fittings 27 according to the first embodiment and one or more fittings 27 according to the second embodiment.

The cladding 16 is a plate, for instance one formed of a metallic material, such as aluminium or steel. Typically, the body 4 comprises a plurality of claddings 16 obstructing the openings defined in the openwork body shell 14 between the tubes
35 24, 26.

The claddings 16 are connected to the openwork body shell 14. More specifically, the cladding 16 is fastened to the fastening surface 54 of the interconnection 44, such as by gluing or riveting.

5 The claddings 16 are also connected to the longitudinal tubes 24 or to the linking tubes 26 by clipping elements 56 (for instance, visible in Figure 3). The clipping elements 56 are, for instance, fastened by gluing onto the claddings 16 and clipped onto the longitudinal tubes 24 or linking tubes 26.

10 The cladding 16 is, for instance, an exterior cladding forming an outer surface of the body 4 relative to the interior space 6 inside the body 4. In one variant or in complement, at least one cladding 16 is an interior cladding delimiting the interior space 6 within the body 4.

A method 100 for manufacturing the body 4 of a railway vehicle 1 will now be described, with reference to Figure 6.

15 The method 100 comprises an initial phase 110 of producing longitudinal tubes 24 and linking tubes 26, followed by a phase of assembling 120 the body 4.

The phase of production 110 comprises a step 130 of assembling fusible yarns and structural yarns, a step 140 of heating the fusible yarns and a step 150 of cutting the longitudinal tubes 24 and linking tubes 26.

20 During the step of assembling 130, the structural yarns and the fusible yarns are advantageously woven and braided to form the framework of the longitudinal tubes 24 and linking tubes 26. For instance, the structural yarns are woven together by combining a weft yarn along a first direction with a warp yarn along a second direction. At the end of the step of assembling 130, the structural yarns and the fusible yarns have an assembled network with a tubular shape.

25 The step of assembling 130 is, for instance, implemented by a weaving and/or braiding machine designed for that purpose.

30 During the step of heating 140, the fusible yarns are softened or melted by applying heat onto the fusible yarns. The heated fusible yarns are joined to one another and become attached to the structural yarns. At the end of the step 140, the longitudinal tubes 24 and the linking tubes 26 are formed.

35 During the step of cutting 150, after cooling the longitudinal tubes 24 and the linking tubes 26, the longitudinal tubes 24 and the linking tubes 26 are cut transversely. The required length of the longitudinal tubes 24 and the linking tubes 26, which for instance, depends on the desired size of the body 4, is chosen during the step of cutting 150.

The step of cutting 150 is, for instance, implemented by a cutting machine designed for that purpose. The step of cutting 150 is optional.

The phase of assembling 120 the body 4 comprises a step 160 of providing longitudinal tubes 24 and linking tubes 26, a step 170 of connecting the longitudinal tubes 24 with linking tubes 26, and a step 180 of fastening claddings 16.

During the step of providing 160 longitudinal tubes 24 and linking tubes 26, the tubes 24-26 are, for instance, delivered to an assembly site, for instance by truck or by a site's transport system. In some cases, the production site (phase 110) corresponds to the body 4 assembly site.

During the step of connecting 170, the longitudinal tubes 24 are connected with the linking tubes 26 at the fittings 27 to form the openwork body shell 14.

The first part 38 and the second part 40 of the fitting 27 are formed in the longitudinal tubes 24 and in the linking tubes 26. In particular, the recess is, for instance, formed by a mould adapted to create the recess 42 by heating the corresponding tube in the mould.

The first part 38 of the fitting 27 is inserted into the second part 40 of the fitting 27. The recess 42 receives, for instance, the complementary recess of the longitudinal tube 24 or linking tube 26. A connection between the longitudinal tube 24 and the linking tube 26 is advantageously established by heating the fitting 27, for instance using a hot air gun.

Additionally, during the step of connecting 170, the interconnection 44 is installed between the longitudinal tubes 24 and the linking tubes 26 to connect the longitudinal tubes 24 and the linking tubes 26. The pockets 52 of the interconnection 44 each receive a tube from among the longitudinal tubes 24 and the linking tubes 26, for instance so as to arrange the longitudinal tubes 24 and the linking tubes 26 perpendicular to one another.

At the end of the step of connecting 170, the openwork body shell 14 comprising the longitudinal tubes 24 and the linking tubes 26 has been formed.

During the step of fastening 180 claddings 16, the claddings 16 are fastened between the longitudinal tubes 24 and the linking tubes 26.

The claddings 16 are fastened to the fastening surface 54 of the interconnection 44, such as by gluing or riveting. The claddings 16 are furthermore connected to the longitudinal tubes 24 and/or to the linking tubes 26 by clipping elements 56. The clipping elements 56 are, for instance, fastened by gluing onto the claddings 16 and then clipped onto the longitudinal tubes 24 or linking tubes 26.

It is understood that the size and shape of the body 4 according to the invention is easily adaptable, because the structure of the body shell made of tubes is modular. The gauge of the railway vehicle 1 is therefore easily adaptable to the structural requirements of the rail network on which the vehicle is to travel. Furthermore, for instance the number and size of the windows and doors of the railway vehicle 1 is easily adaptable.

It is therefore not necessary to design for each vehicle, or even for each type of body, a specific mould for each shape or size variation of a body element.

The weight of the body 4 is lower, particularly owing to the use of composite materials. Typically, the weight is about 15% less. Consequently, the operating costs of the railway vehicle 1 are lower.

Furthermore, the manufacturing of the body 4 is easier and less expensive. In particular, for instance the weaving of the longitudinal tubes 24 and the linking tubes 26 makes it possible to easily modify the sizes and shapes of the longitudinal tubes 24 and the linking tubes 26 of the body 4.

CLAIMS

1. A railway vehicle (1) body (4), the body (4) comprising an openwork body shell (14) comprising longitudinal tubes (24), linking tubes (26) crossing the longitudinal tubes (24), and fittings (27) connecting longitudinal tubes (24) and linking tubes (26), the body (4) further comprising claddings (16) extending between the longitudinal tubes (24) and the linking tubes (26), characterized in that the longitudinal tubes (24) and the linking tubes (26) comprise fusible yarns assembled one to another by heating.
2. The railway vehicle (1) body (4) according to claim 1, wherein the longitudinal tubes (24) and linking tubes (26) comprise non-fusible structural yarns, the structural yarns being distinct from the fusible yarns.
3. The railway vehicle (1) body (4) according to claim 2, wherein the fusible yarns are thermoplastic polymer yarns, and wherein the structural yarns comprise inorganic fibres belonging to at least one of the elements of the group constituted by:
 - glass fibres;
 - carbon fibres; and
 - basalt fibres.
4. The railway vehicle (1) body (4) according to any one of the claims 1 to 3, wherein the fusible yarns are arranged into a plurality of woven and/or braided layers.
5. The railway vehicle (1) body (4) according to any one of the claims 1 to 4, wherein at least one tube from among the longitudinal tubes (24) and the linking tubes (26) has a circular cross-section.
6. The railway vehicle (1) body (4) according to any one of the claims 1 to 5, wherein the fitting (27) comprises a first connective part (38) for connecting a first tube from among the longitudinal tubes (24) and the linking tubes (26), the first connective part (38) forming a recess (42) configured to

receive a second tube from among the longitudinal tubes (24) and the linking tubes (26).

5 **7.** The railway vehicle (1) body (4) according to claim 6, wherein the second tube comprises at least one second connective part (40) forming a complementary recess configured to receive the first connective part (38) at the recess (42).

10 **8.** The railway vehicle (1) body (4) according to any one of the claims 1 to 7, wherein the fitting (27) comprises at least one interconnection (44) between the longitudinal tubes (24) and the linking tubes (26), the interconnection (44) defining at least one pocket (52) receiving an end of a longitudinal tube (24) and at least one additional pocket (52) receiving an end of a
15 linking tube (26).

9. The railway vehicle (1) body (4) according to claim 8, wherein the interconnection (44) has a cladding fastening surface (54), onto which a cladding (16) is installed.

20 **10.** The railway vehicle (1) body (4) according to claim 8 or 9, wherein the interconnection (44) is formed by weaving a weft yarn along a first direction, and a warp yarn along a second direction.

25 **11.** The railway vehicle (1) body (4) according to any one of the claims 8 to 10, wherein the interconnection (44) is formed from yarns of at least two different materials.

12. The railway vehicle (1) body (4) according to any one of the claims 1 to 11,
30 wherein the claddings (16) are connected to the longitudinal tubes (24) and/or to the linking tubes (26) by clipping elements (56).

13. A method (100) for manufacturing a railway vehicle (1) body (4), the method (100) comprising a phase of assembling (120) comprising:
35 - a step (160) of providing longitudinal tubes (24) and linking tubes (26) made from fusible yarns assembled one to another by heating,

- a step (170) of connecting longitudinal tubes (24) with linking tubes (26) at fittings (27) to form an openwork body shell (14), and
- a step (180) of fastening claddings (16) between the longitudinal tubes (24) and the linking tubes (26).

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14. The method (100) for manufacturing according to claim 13, the method (100) comprising an initial phase (110) of producing longitudinal tubes (24) and linking tubes (26) comprising:

- a step (130) of assembling the fusible yarns,
- a step (140) of heating the fusible yarns,
- a step (150) of cutting the tubes to the right length.

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15. The method for manufacturing according to claim 13 to 14, the fitting (27) comprising a first connective part (38) for connecting a first tube from among the longitudinal tubes (24) and the linking tubes (26), the first connective part (38) forming a recess (42) configured to receive a second tube from among the longitudinal tubes (24) and the linking tubes (26), wherein, during the step of connecting (170), the recess (42) receives a second tube from among the longitudinal tubes (24) and the linking tubes (26).

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