



G00002



166166

An orthosis and method of manufacturing the same

THIS INVENTION relates to an orthosis and a method of manufacturing the same. More particularly, the present invention relates to the method of manufacturing an orthosis from a composite structure.

Traditional orthoses are usually manufactured from aluminium alloy and steel and are relatively heavy. As a result, a great deal of the orthosis wearer's energy is used when manoeuvring the limb or limbs to which the orthosis is fitted. Additionally, the weight of the orthoses can cause high levels of stress on the orthosis wearer's skeletal structure.

The present invention seeks to provide a lightweight orthosis and method of manufacturing orthoses which can be applied to the entire range of orthoses or external bracing devices.

Another problem associated with traditional orthoses is that the materials from which they are made are particularly susceptible to corrosion in countries or areas of high humidity.

Whilst high strength carbon fibres and the like provide the required strength for an orthosis and the cost of such materials is relatively low, it has been found that long continuous carbon fibres are susceptible to breaking under the tensile stresses imposed when post-forming an orthosis and are also susceptible to excessive buckling in areas of the orthoses subject to compression. It is therefore an object of the present invention to provide a lightweight orthosis and method of manufacturing such an

orthosis using a composite structure which does not suffer from the above-mentioned problems.

Accordingly, one aspect of the present invention provides a method of manufacturing an orthosis having a structure comprising a number of strips for fitting in substantially parallel alignment along a limb and a number of bands for fitting at least partially around the limb, the method comprising the steps of: providing lengths of continuous fibres oriented substantially parallel to one another; cutting the lengths to form discontinuous lengths of fibres; placing a plurality of such discontinuous lengths adjacent one another, there being a gap between adjacent discontinuous lengths to form a first layer; laminating a further layer of discontinuous lengths to the first layer to form a composite structure from which a strip or band can be cut; applying resin to the composite structure; curing the composite structure; and cutting the strips or bands from the composite structure.

Another aspect of the present invention provides an orthosis comprising a structure for fitting to a limb, the structure including a number of joints to allow the limb and structure to move together in substantially normal limb movement, the structure comprising a number of strips for fitting in substantially parallel alignment along the limb and a number of bands for fitting at least partially around the limb, wherein the strips and bands are manufactured from a composite structure comprising a plurality of layers of lengths of discontinuous fibres cut from a length of continuous fibre, the lengths in each layer being adjacent one another and separated by a gap.

A further aspect of the present invention provides a test rig for applying pressure to an orthosis, which test

rig comprises: means to secure the ends of the test rig; and means to apply pressure to one of the ends of the orthosis, the pressure application means comprising a loading pin and a receiving plate, one of the loading pin or receiving plate being attached to the means to secure one of the ends of the orthosis and the other of the loading pin or the receiving plate being attachable to a load cell, the tip of the loading pin being substantially hemispherical and receivable in a substantially hemispherical indent in the receiving plate so that pressure can be applied to the orthosis at various angles.

In order that the present invention may be more readily understood, embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a perspective view of an orthosis embodying the present invention;

FIGS. 2(a) to (d) are schematic representations showing the formation of a composite structure for use in the present invention;

FIG. 3 is a perspective view of one end of a strip or band for an orthosis manufactured in accordance with one embodiment of the present invention;

FIG. 4 is a schematic view of a post-forming apparatus for use with a method embodying the present invention;

FIG. 5 is a side view of a part of a strip manufactured in accordance with one embodiment of the present invention connected to a part of a band

manufactured in accordance with one embodiment of the present invention;

FIG. 6 is a cross-section taken through the strip and band of Figure 5 along line VI-VI;

FIG. 7 is a perspective view of an orthosis manufactured in accordance with one embodiment of the present invention secured in a test rig;

FIG. 8 is a detailed view of a lower part of the test rig shown in Figure 7; and

FIG. 9 is a detailed view of an upper part of the test rig shown in Figure 7.

Referring to Figure 1, an orthosis manufactured in accordance with one embodiment of the present invention takes the form of a leg orthosis or leg brace. The orthosis has three basic elements: a foot receiving portion; a lower portion for fitting to the lower leg; and an upper portion for fitting to the upper leg. The foot receiving portion comprises a shoe 1 adapted to receive and secure a foot. A pair of strips 2,3 or uprights are attached by rivets to the shoe at the heel area of the shoe and project upwardly therefrom so as to be located on either side of the lower leg of a person wearing the orthosis and form the lower portion of the orthosis. The uprights 2,3 are bridged by a band 4 which is located so as to fit around the rear of the wearer's calf. The ends of the band 4 are attached to respective uprights 2,3 by connectors 5,6.

The uprights 2,3 each terminate in a lockable knee joint 7,8. A second pair of uprights 9,10 extend upwardly

from the knee joints 7,8. Approximately halfway up the second pair of uprights 9,10, a second band 11 bridges the uprights so as to be located approximately halfway up the rear of the wearer's thigh. The second pair of uprights 9,10 terminate in a third band 12 which again bridges the uprights 9,10 and is located at the top of the rear of the wearer's thigh. Both sets of bands 11,12 are attached to the uprights 9,10 by respective connectors 5,6.

The method of making the orthosis shown in Figure 1 involves the use of discontinuous lengths of fibres as the basic composite material rather than using continuous fibres. Referring to Figure 1, the composite components of the orthosis comprise both pairs of uprights 2,3 and 9,10 and the bands 4,11,12. The shoe 1 is preferably manufactured from polypropylene, the connectors 5,6 and the knee joints 7,8 are formed from stainless steel, aluminium alloy or another suitable metal or metal alloy.

The construction of the uprights 2,3 and 9,10 and the bands 4,11,12 is most important since these components will be undergoing some of the greatest stresses which long carbon fibre structures tolerate.

Referring to Figures 2(a) to (d), in accordance with a preferred embodiment of the invention, lengths of continuous carbon fibre are provided which are cut into a first set of rectangular pieces 13a of approximately 100mm in length. These rectangular pieces 13a are placed end to end with a small gap ΔL therebetween, approximately 25mm, so as to provide a layer of discontinuous lengths of carbon fibre as shown in Figure 2(a). All the fibres in the discontinuous fibre lengths are unidirectional. Preferably, the lengths of carbon fibre are pre-impregnated with polypropylene resin and are available in tape form.

Referring to Figure 2(b), a further length of continuous carbon fibre is cut into a second set of rectangular pieces 13b which are each laid on top of a respective one of the first set of rectangular pieces 13a. Referring to Figures 2(c) and 2(d), two further layers of rectangular pieces 13c, 13d, are laid down. In the examples shown in Figures 2(a) to 2(d), the resultant composite structure has four layers, there being five rectangular pieces in each layer. For the purpose of this description each of the four layers laminated one on top of the other is termed a composite panel 14. Thus, the composite structure shown in Figure 2(d) is made up of five panels 14.

Preferably, the direction of the fibres in each of the layers of the composite structure is different. Advantageously, at least one layer 15 has fibres which are oriented substantially parallel to a longitudinal axis of the strip or band which the composite structure is to be used to make, another layer 16 has fibres oriented at substantially 45° to the fibres of the first layer 15 and the fibres of a third layer 17 are oriented at substantially 90° to the fibres of the first layer 15, thus providing the necessary support in various directions. In particular, the layer 15 of fibres which are substantially parallel with a longitudinal axis of the strip or band provide longitudinal support whereas the fibres 16, 17 of the second and third layers provide lateral stiffness, torsion and stability.

Resin is then applied or the polypropylene pre-impregnated resin acts to produce a composite structure 18 from the layers of unidirectional discontinuous fibres. The composite structure 18 is then cured. The provision of the gap ΔL between panels 14, i.e. the discontinuous nature

of the composite structure 18 made from the adjacent panels 14, allows movement of fibres relative to one another in adjacent panels 14 without causing any distortion which would otherwise have resulted in the breaking of long continuous carbon fibres in tension or the buckling of long continuous carbon fibres in compression.

By being able to choose the orientation of the fibres in each layer 15,16,17 of a panel 14, the strength characteristics of each panel 14 can be tailored in accordance with the stresses likely to be imparted on that particular area of the strip or band.

Once the composite structure 18 comprising the various panels 14 is finished, the structure 18 is placed in an autoclave on a flat metallic plate or in a mould and cured.

Once cured, uprights 2,3 and 9,10 or bands 4,11,12 are cut from the structure 18 to the required width and length using a diamond edge coated plate saw.

For the purposes of construction of the orthosis, some of the ends of the uprights or bands are required to have an aperture. Referring to Figure 3, the outer surface of an end 19 of a strip or band requiring an aperture is abraded and a hole 20 drilled through the end. A pin 21 is placed through the hole 20 with both ends of the pin 21 protruding from the hole 20 as shown in Figure 3.

A single carbon fibre or a small number of carbon fibre threads 22 or the like are then impregnated with resin or adhesive and wound around the end 19 of the upright or band in order to strengthen it to prevent it from splitting as a result of the hole 20 having been

drilled through it. Once the adhesive or resin has hardened, the pin 21 can be removed from the hole 20 thereby resulting in a fully reinforced aperture at one end 19 of the upright or band.

The orthosis needs to be fitted to the intended wearer and once the appropriate measurements have been made, the various components of the orthosis such as the uprights 2,3 and 9,10 and bands 4,11,12 are post-formed into desired shapes. To do this, referring to Figure 4, a bed of upright plastics bars 23 is provided, the height of the plastics bars 23 with respect to one another is adjustable such that their relative heights define the intended shape of the upright or band. A rubber sheet 24 is laid over the bed of plastics bars 23 and then a thin flexible metal sheet 25 is laid over the rubber sheet 24. The upright 2,3 and 9,10 or band 4,11,12 is heated until malleable and then laid onto the metal sheet 25 on the bed of plastics bars 23. A second flexible metal sheet 26 is laid over the upright or band and a second rubber sheet 27 is laid over the flexible metal sheet 26 so that the malleable upright or band is sandwiched between a pair of flexible metal sheets 25,26 and a pair of rubber sheets 24,27. An array of pneumatic jacks 28 are located directly above the bed of plastics bars 23 and are actuatable to press down onto the sandwich construction. Since the upright or band is malleable, it adopts the shape prescribed by the plastics bars 23 on the bed. The rubber sheets 24,27 serve to distribute evenly the shaping pressure applied between the pneumatic jacks 28 and the plastics bars 23 and the metal sheets 25,26 serve to provide a smooth surface finish to the upright or band sandwiched therebetween.

The shaping pressure is applied by the pneumatic jacks 28 for a period of time until the strip or band has

cooled down and become rigid once again. The strip or band is then removed from the post-forming device.

The orthosis of Figure 1 is assembled starting from the knee joints 7,8. Each knee joint has a slot (not shown) in its upper and lower half for receiving an end of an upright. The ends of the uprights are abraded using fine sandpaper and wiped clean using acetone and then an adhesive used to bond the uprights and knee joints together, the uprights being seated in the recesses in the knee joints.

Similarly, the uprights and the bands are also abraded and adhered together using the connectors 5,6 as shown in Figure 5. Additionally, referring to Figure 6, the bands are provided with apertures at either end so that the connectors 5,6 can be rivetted to the bands.

The polypropylene shoe 1 is fixed to the ends of the uprights 3,4 using rivets.

Turning now to Figure 7, there is shown a test rig 30 for evaluating the performance of orthoses manufactured in accordance with the present invention.

The test rig 30 comprises a lower half 31 to receive the foot of the orthosis of Figure 1 and an upper half 32 adapted to receive the upper portion of the orthosis of Figure 1.

The lower uprights 3,4 of the orthosis are received by the lower half 31 of the test rig 30 in slots provided in a pair of steel bars 33 (see Figure 8). The steel bars 33 are pivotably mounted to horizontal bars 34 which are held in a frame 35 for securing to a platform or the like.

The other uprights 9,10 are held at their free end by a further pair of substantially vertical steel bars 36 which are bridged by a steel beam or plate 37. The upper surface of the steel beam 37 is formed with a dome-shaped indent 38 (see Figure 9). A load cell 39 is provided on the upper half of the test rig 30. A loading block 40 having a loading pin 41 projecting therefrom is attached to the load cell 39. The free end 42 (see Figure 9) of the loading pin 41 is hemispherical and adapted to engage in the dome-shaped indent 38 on the upper surface of the steel beam 37. The load cell 39 can be adjusted such that it applies pressure to the steel beam at various angles. It should be appreciated that both static and cyclic loading techniques are used to evaluate the performance of the orthosis.

The method of manufacturing the orthosis has been described above in relation to a leg orthosis. The method is, however, equally applicable to other orthoses and the invention is not limited to leg or knee orthoses.

CLAIMS:

1. A method of manufacturing an orthosis having a structure comprising a number of strips for fitting in substantially parallel alignment along a limb and a number of bands for fitting at least partially around the limb, the method comprising the steps of: providing lengths of continuous fibres oriented substantially parallel to one another; cutting the lengths to form discontinuous lengths of fibres; placing a plurality of such discontinuous lengths adjacent one another, there being a gap between adjacent discontinuous lengths to form a first layer; laminating a further layer of discontinuous lengths to the first layer to form a composite structure from which a strip or band can be cut; applying resin to the composite structure; curing the composite structure; and cutting the strips or bands from the composite structure.

2. A method according to Claim 1, wherein the lengths of continuous fibres comprise unidirectional continuous fibres.

3. A method according to Claim 1 or 2, wherein the composite structure is cured in an autoclave.

4. A method according to any preceding claim, wherein the composite structure is thermoplastic and the or each strip or band cut from the composite structure is heated until malleable, shaped to conform to the part of the limb to which the strip or band is to be fitted and then cooled in the desired shape.

5. A method according to Claim 4, wherein the strip or band is shaped by a plurality of jacks which apply pressure

to predetermined points on the strip or band to form the strip or band into the desired shape.

6. A method according to Claim 5, wherein the strip or band is sandwiched between flexible sheets.

7. A method according to Claim 6, wherein the strip or band is sandwiched between flexible metal sheets to achieve a smooth surface finish on the strip or band.

8. A method according to Claim 7, wherein the metal sheets and the strip or band are sandwiched between rubber sheets to distribute evenly the shaping pressure.

9. A method according to any preceding claim comprising the further step of orienting the layers of discontinuous lengths of fibre at predetermined angles to one another.

10. A method according to Claim 9, wherein each panel comprises a laminate of at least three layers of fibre, the fibres of a first layer being oriented substantially parallel with the longitudinal axis of the strip or band, the fibres of a second layer being oriented at substantially 45° to the fibres of the first layer, and the fibres of a third layer being oriented at substantially 90° to the fibres of the first layer, the fibres of the first layer providing longitudinal support, the fibres of the second and third layers providing lateral stiffness, torsion and stability.

11. A method according to any preceding claim, comprising the further step of forming an aperture in the strip or band and reinforcing the aperture by the steps of: inserting a pin in the aperture, both ends of the pin

protruding from the aperture; winding fibre around the strip or band in the area of the aperture; applying resin to the fibre; curing the resin and fibre; and removing the pin from the aperture.

12. A method according to any preceding claim, wherein a strip manufactured according to any preceding claim is securable to a band manufactured according to any preceding claim by a connector.

13. A method according to Claim 12, wherein the connector is bonded to the strip and the band.

14. A method according to Claim 12 or 13, wherein the connector is fixed to the band by fixing means passing through an aperture at one end of the band.

15. A method according to any one of Claims 12 to 14, wherein the connector has two ends and surrounds the strip, the ends of the connector being fixed to the band.

16. A method according to any preceding claim, wherein the fibre is carbon fibre.

17. A method according to any preceding claim, wherein the resin is polypropylene.

18. A method according to any preceding claim, wherein the fibre is pre-impregnated with the resin, the step of applying resin comprising the step of impregnating the fibre with the resin.

19. An orthosis comprising a structure for fitting to a limb, the structure including a number of joints to allow the limb and structure to move together in substantially

normal limb movement, the structure comprising a number of strips for fitting in substantially parallel alignment along the limb and a number of bands for fitting at least partially around the limb, wherein the strips and bands are manufactured from a composite structure comprising a plurality of layers of lengths of discontinuous fibres cut from a length of continuous fibre, the lengths in each layer being adjacent one another and separated by a gap.

20. A method of manufacturing an orthosis substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

21. An orthosis substantially as hereinbefore described with reference to and as shown in the accompanying drawings.