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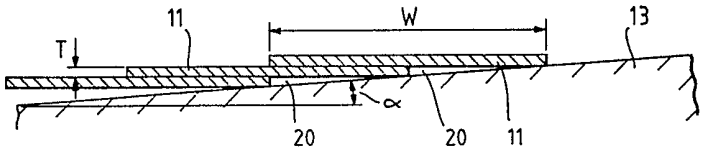
(54) Manufacture of composite material components

(57) In a method of manufacturing a component of frusto-conical form a tape (11) comprising epoxy resin impregnated carbon filaments is wound on to a mandrel (13) which is of frusto-conical form. The tape (11) is wound so that each successive revolution of wound tape overlaps the preceding revolution of wound tape by approximately 50% of the tape width. The tape width (W) is defined by the expression $W=\frac{nt}{\tan\alpha}$ where t is the tape thickness, α is the cone angle in degrees of the mandrel (13), and n is the number of tape layers or tapes wound in one pass of winding.

Fig. 3.



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The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

Fig. 1.

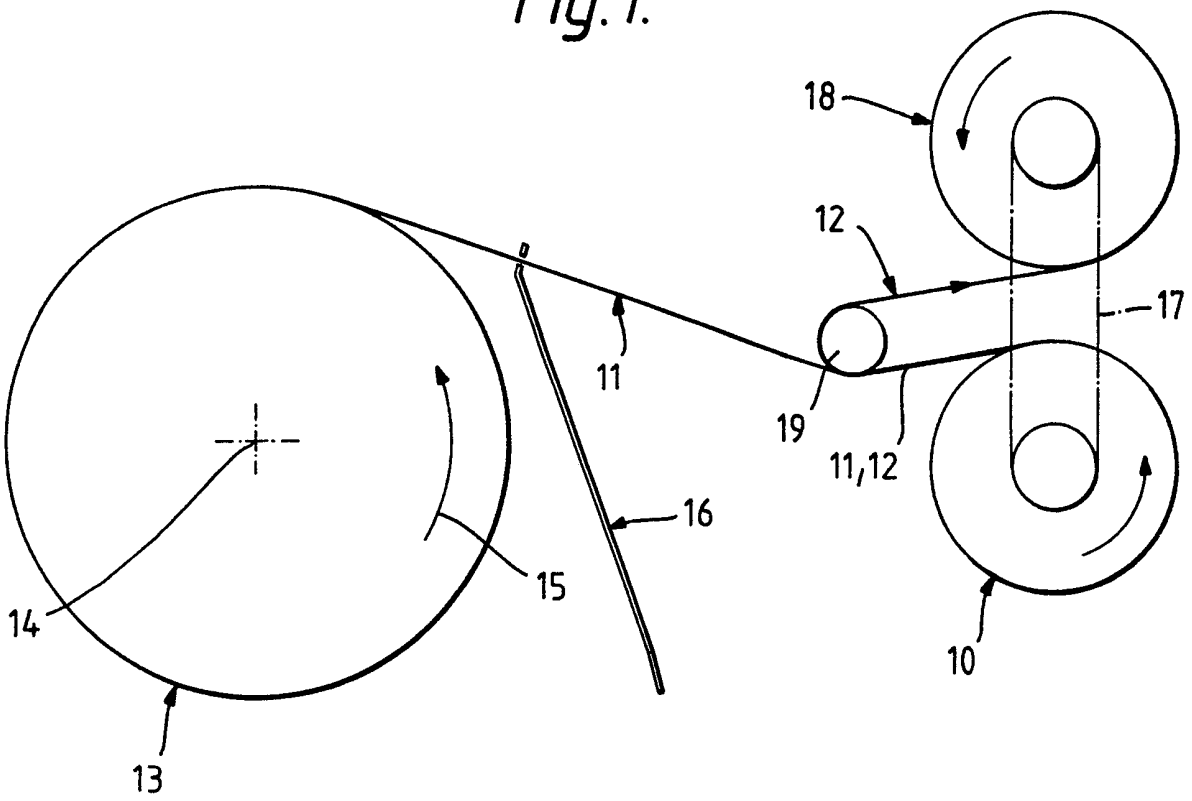


Fig. 2.

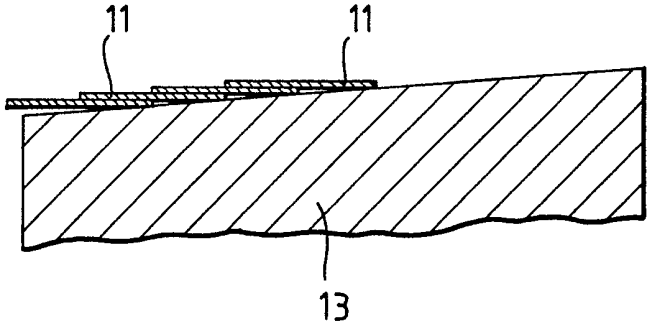


Fig. 3.

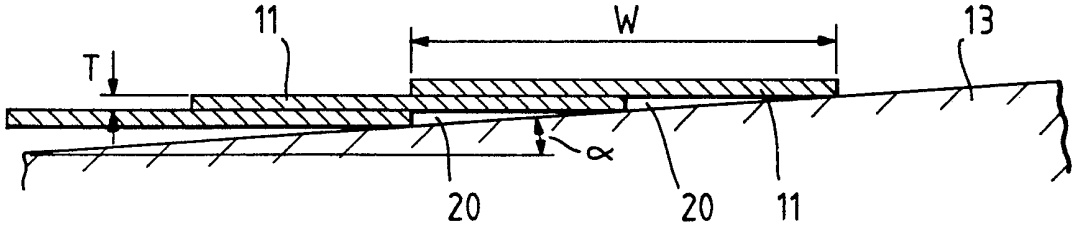


Fig. 4.

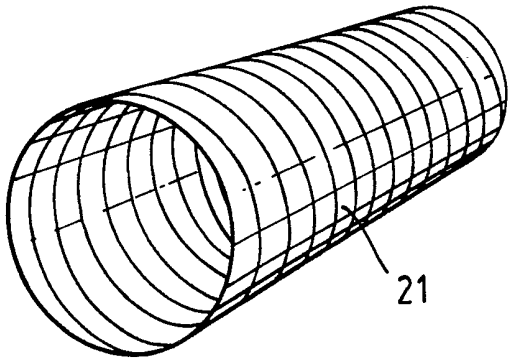
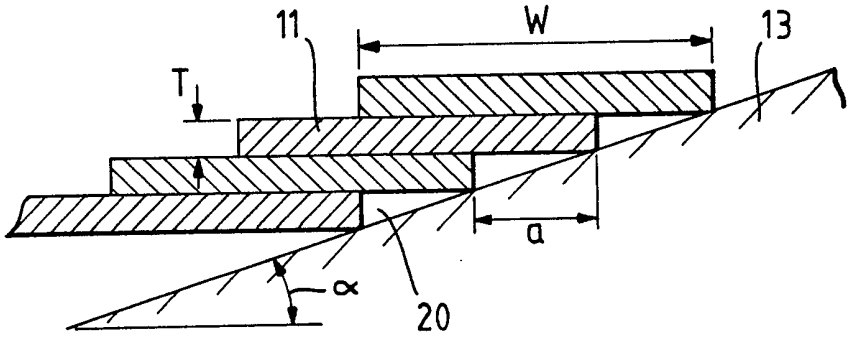


Fig. 5.



SPECIFICATION

Manufacture of composite material components

This invention relates to the manufacture of composite material components and has particular reference to the manufacture of composite material components comprising reinforcing filaments enclosed in a resin matrix material.

It is well known to manufacture composite material components by the technique of winding a tow of resin impregnated filaments on to a rotating mandrel of appropriate configuration. The filament tows may be dip impregnated with the resin immediately prior to winding or alternatively pre-impregnated with the resin some time prior to the winding operation. Winding using dip impregnation, sometimes called wet winding, is slow and the resin content of the resultant composite material is difficult to control. Moreover rotation of the wound component must continue after winding has been completed in order to ensure that there is no sagging of the resin prior to its gellation. Winding using pre-impregnated tows, sometimes called dry winding, is faster than wet winding. However the amount of resin in the tow has to be low in order to prevent tow tackiness thereby allowing the two to be supplied on a spool. This means that the tow is fairly inflexible and has to be wound under constant tension, and also that additional resin must be applied to the wound tows.

Both wet and dry winding additionally suffer from the problem of the creation of gaps or overlaps between successive wound layers when applied to frusto-conical mandrels and this leads in turn to the distortion or kinking of the filaments in the tow. Such distortion or kinking is highly undesirable in view of the prejudicial effect which it has upon the strength of the resultant composite material component.

It is an object of the present invention to provide a method of winding resin preimpregnated filamentary material on to a frusto-conical mandrel in which any such distortion or kinking of the filaments is substantially avoided.

According to the present invention, a method of manufacturing a component of generally frusto-conical form which comprises a composite material includes the step of winding a tape comprising reinforcing filaments impregnated with the matrix material of said composite material on to a body having a surface which is of generally frusto-conical form so that each successive revolution of wound tape at least partially overlaps the preceeding revolution of wound tape, said tape width being defined by the expression $W = \frac{nt}{\tan\alpha}$ where W is the tape width, t is the wound tape thickness, α is the cone angle in degrees of the surface upon which the tape is wound, and n is the number of tape layers wound in one pass of winding.

The invention will now be described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a schematic side view of apparatus suitable for carrying out the method of manufacture of the present invention.

Figure 2 is a view on section line A-A of Figure 1.

Figure 3 is a view of an enlarged portion of Figure 2.

Figure 4 is a view of a component manufactured in accordance with the present invention.

With reference to Figure 1, a spool 10 carries a tape 11 which comprises continuous filaments of carbon which have been pre-impregnated with an uncured epoxy resin. The tape 11 has a backing film 12 attached to it so that the layers of tape 11 carried by the spool 10 do not stick to each other.

The tape 11 is drawn off the spool 10 by a frusto-conical mandrel 13 which is driven about an axis 14 in the direction indicated by the arrow 15. A tape guide 16 determines the placement of the tape 11 upon the mandrel. The spool 10 is thus caused to rotate in the direction indicated by the arrow 17 as the tape 11 is wound on to the rotating mandrel 13. A slipping clutch (not shown) associated with the tape spool 10 ensures that the tape 11 is maintained in tension.

The spool 10 is connected by a drive belt 17 to a further spool 18 which collects the backing film from the tape 11. Thus as the tape 11 with its backing film 12 is drawn off the spool 10, they pass over a roller 19 where the tape 11 and film 12 are separated. The tape 11 is then wound on to the mandrel 13 and the backing film 12 wound on to the further spool 18.

The spools 10 and 18 and the tape guide 16 are traversed along a path generally parallel with the axis 14 of rotation of the mandrel 13 at such a rate that the tape 11 is wound on to the mandrel 14 in the manner shown in Figure 2 so that there is overlapping of successive wound revolutions of the tape 11. More specifically the tape 11 is wound on to the mandrel 13 in such a manner that each successive wound revolution overlaps the preceeding wound revolution by approximately 50% of the tape width and a double layer of tape is wound onto the mandrel 13 in one pass. This can be seen more easily if reference is made to Figure 3.

Figure 3 also illustrates the other limiting feature of the present invention, that is the relationship between tape width W, tape thickness t and the cone angle α in degrees of the frusto-conical mandrel 14. Thus the tape width W must equal $\frac{2t}{\tan\alpha}$. This relationship ensures that the gap 20 below each wound

revolution of the tape 11 is acceptably small. In practice, each tape 11 portion which bridges a gap 20, partially collapses into that gap so that the number of wound fibres 11 which are unsupported is minimal. The overlapping of the tape 11 ensures that on a frusto-conical surface such as that of the mandrel 14, there is substantially no tape distortion so that there is no deformation or kinking of the filaments which made up the tape 11. This in turn ensures that the full strength of the filaments will be utilised in any composite material component which is manufactured in accordance with the method of the present invention.

In the embodiment described with reference to Figures 2 and 3, two layers of tape 11 are wound on to the mandrel 14 in one pass. It is possible however to wind more than two layers in one pass as can be seen in Figure 5 where 3 layers of tape 11 have been wound in one pass. For the three layer arrangement, $\tan \alpha = \frac{a}{t}$ where α and t are as previously designated and a is that portion of the tape 11 width which is unsupported. Thus $a = \frac{t}{\tan\alpha}$ and the width of tape, W = 3a so that $W = \frac{3t}{\tan\alpha}$. The tape overlap is therefore $\frac{1}{3}$x tape width.

In general terms therefore for n layers of tape 11, wound in one pass $W = \frac{nt}{\tan\alpha}$ so that the tape 11 overlap is $\frac{1}{n}$x tape width. Thus as n increases the tape width W must increase proportionally.

It will be seen therefore that the method of the present invention provides a method of filament winding on to a frusto-conical surface which avoids the distortion which would occur if a tape were to be wound thereon with edge to edge contact instead of overlapping. It also avoids the problem of the creation of large gaps within the wound material which would occur if there was no control over tape 11 overlap and tape 11 dimensions.

When winding has been completed, the whole mandrel 13 assembly carrying the wound tape 11 is heat treated in the usual manner in order to cure the epoxy resin with which the tape was impregnated. This results in the thermal expansion of the mandrel 13 which in turn provides a further reduction in the size of any gaps which may be present in the wound tapes 11. The completed composite material component 21, which can be seen in Figure 4, is then removed from the mandrel 13.

Although the present invention has been described with reference to the manufacture of a composite material article comprising reinforcing filaments of carbon enclosed in a matrix of an epoxy resin, alternative materials could be used if so desired. Thus the filaments could be of glass or other suitable material and other thermosetting polymers, such as polyimides, could be used if so desired. Indeed the method of the present invention could be utilised with filaments impregnated with a thermoplastic polymer such as a polysulphone. In such circumstances it would of course be unecessary to cure the polymer. However a heat treatment step could well be desirable in order to drive off any solvent which may have to be used in the application of the polymer to the filaments and of course to provide consolidation of the wound filaments through thermal expansion of the mandrel 13.

The method of the present invention has been described with reference to the manufacture of a composite material component which is of generally constant thickness. It may be desirable in certain circumstances however to provide variable thickness. This may be readily achieved by suitable control over the translation of the translatable assembly comprising the spools 10 and 18 and the tape guide 16.

In the embodiment of the method of the present invention described above, the mandrel 13 is caused to rotate and the assembly comprising the spools 10 and 18 and the tape guide 16 caused to translate along a path generally parallel with the axis of rotation 14 of the mandrel 13. It will be appreciated however that other modes of movement of the constituent pieces of the apparatus used in the method of the present invention could be utilised in achieving the same manner of relative movement between the mandrel 13 and the tape 11. It will also be appreciated that the method of the present invention may be used with dip impregnated filaments as opposed to filaments which are pre-impregnated with a resin matrix material. In such circumstances it would of course be unecessary to utilise the backing film 12.

Although the present invention has been described with reference to tape which is made up of unidirectional filaments, it will be appreciated that alternative tape configurations such as those formed from woven or knitted filaments could be used if so desired.

CLAIMS

1. A method of manufacturing a component of generally frusto-conical form including the step of winding a tape comprising reinforcing filaments impregnated with the matrix material of said composite material on to a body having a surface which is of generally frusto-conical form so that each successive revolution of wound tape at least partially overlaps the preceeding revolution of wound tape, said tape width being defined by the expression $W = \frac{nt}{\tan\alpha}$ where W is the tape width, t is the wound tape thickness α is the cone angle in degrees of the surface upon which the tape is wound, and n is the number of

tape layers wound in one pass of winding.

2. A method of manufacturing a component of generally frusto-conical form as claimed in claim 1 wherein said matrix material is a polymer.

3. A method of manufacturing a component of generally frusto-conical form as claimed in claim 2 wherein said polymer is a thermosetting resin.

4. A method of manufacturing a component of generally frusto-conical form as claimed in claim 3 wherein said thermosetting resin is an epoxy resin.

5. A method of manufacturing a component of generally frusto-conical form as claimed in any one preceding claim wherein said tape is wound on to said body by the rotation of said body.

6. A method of manufacturing a component of generally frusto-conical form as claimed in any one preceding claim wherein said body is a mandrel.

7. A method of manufacturing a component of generally frusto-conical form as claimed in any one preceding claim wherein said filaments are of carbon.

8. A method of manufacturing a component of generally frusto-conical form as claimed in any one preceding claim wherein said filaments are continuous.

9. A method of manufacturing a component of generally frusto-conical form substantially as hereinbefore described with reference to the accompanying drawings.

10. A component of generally frusto-conical form manufactured in accordance with the method of any one preceding claim.

Amendments to the claims have been filed, and have the following effect:-

(b) New or textually amended claims have been filed as follows:-

New Claims 9, 10 and 11

9. A method of manufacturing a component of generally frusto-conical form as claimed in any one preceding claim wherein each successive wound revolution of tape overlaps the preceding wound revolution of tape by approximately 50% of the tape width.

10. A method of manufacturing a component of generally frusto-conical form substantially as hereinbefore described with reference to the accompanying drawings.

11. A component of generally frusto-conical form manufactured in accordance with the method of any one preceding claim.

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