

### [54] EPICYCLIC WEAVING OF FIBER DISCS

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### Related U.S. Application Data

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[51] Int. Cl. ....D06c 3/08

[58] Field of Search .....28/15, 2, 1, 21; 139/34; 223/46; 242/1.2, 82; 19/159; 156/169, 172, 173, 175

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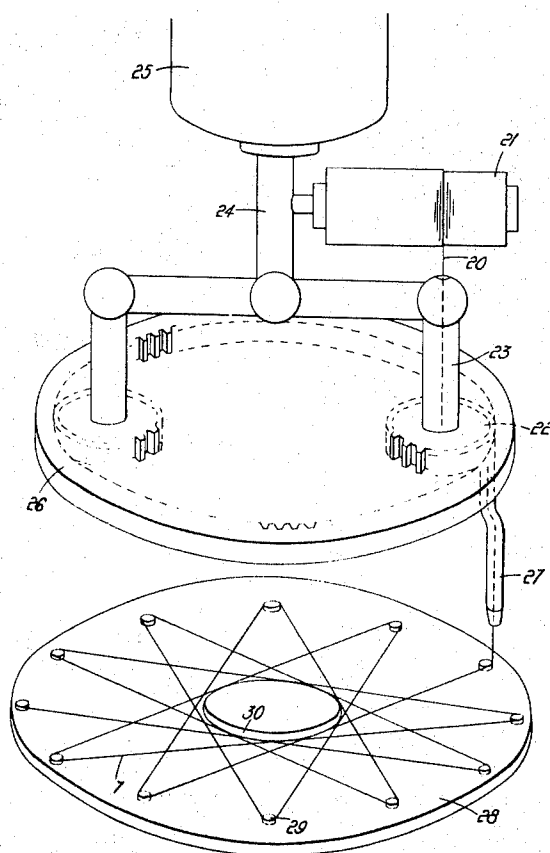
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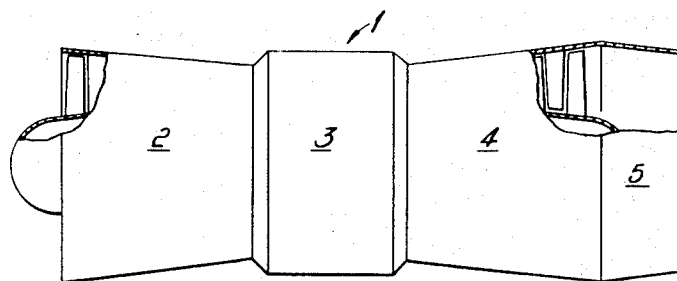
### [57] ABSTRACT

An apparatus for winding one or more fibers under tension onto a former is used for making a turbine or compressor rotor for a gas turbine engine. The apparatus includes an epicyclic system having an annulus wheel means and at least one planet wheel means which can be rolled about a circumference of the annulus wheel means to define an epicycloid path of travel. A guide means is operatively associated with one of the planet wheel means for guiding one or more fibers from a source of supply onto a former, and the guide means is arranged so that its end nearer the former follows a substantially epicycloid motion as dictated by the rolling of the planet wheel means about the circumference of the annulus wheel means.

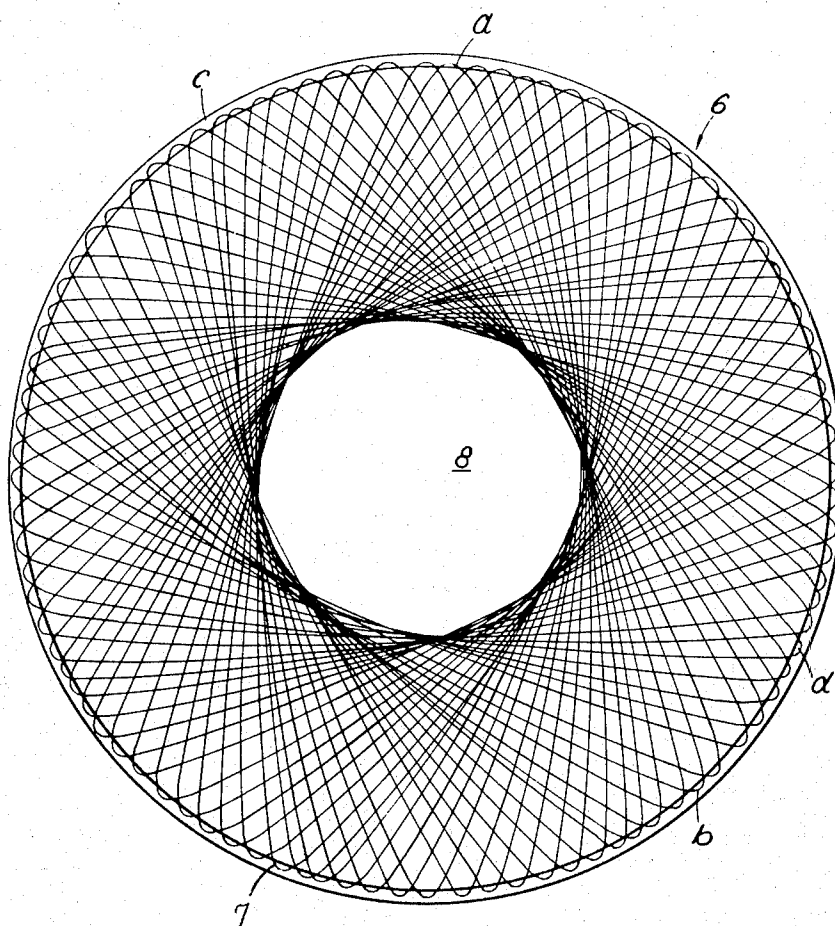
**5 Claims, 6 Drawing Figures**



*Fig. 1*



*Fig. 2*



*Fig. 3*

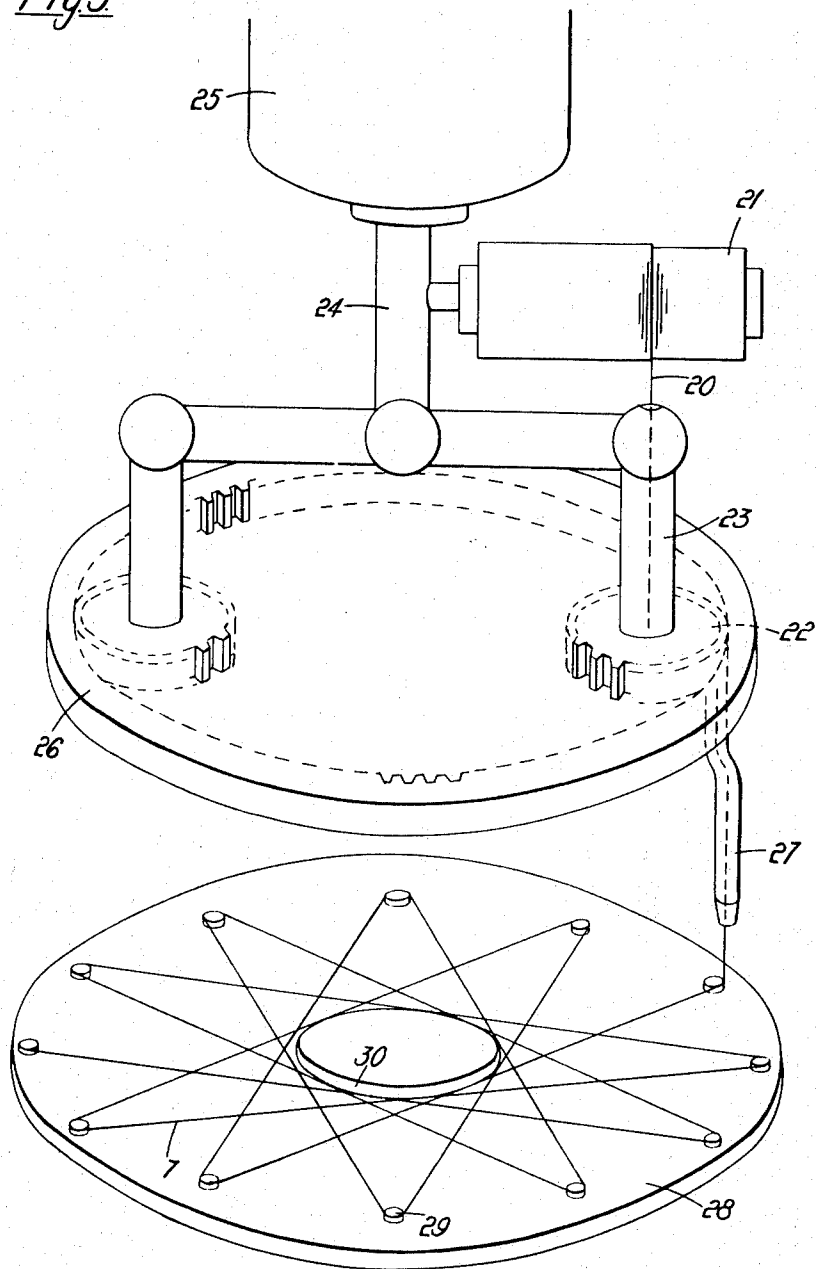


Fig. 4

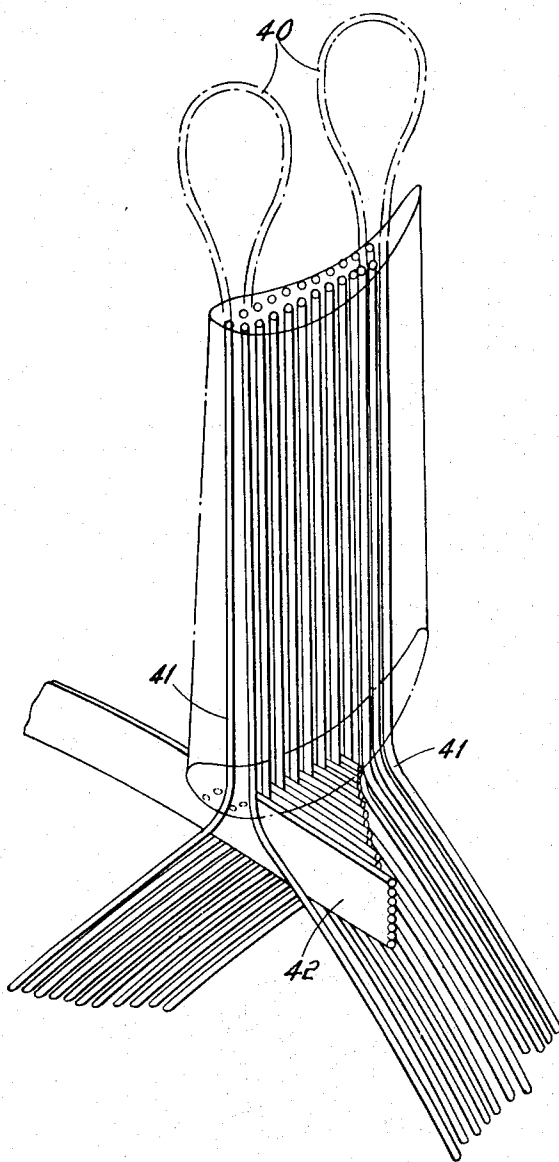


Fig. 6

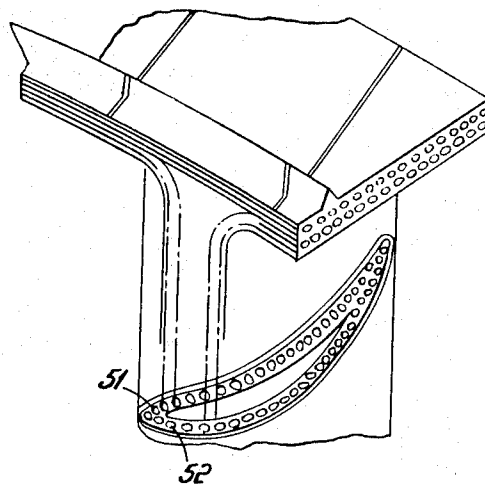
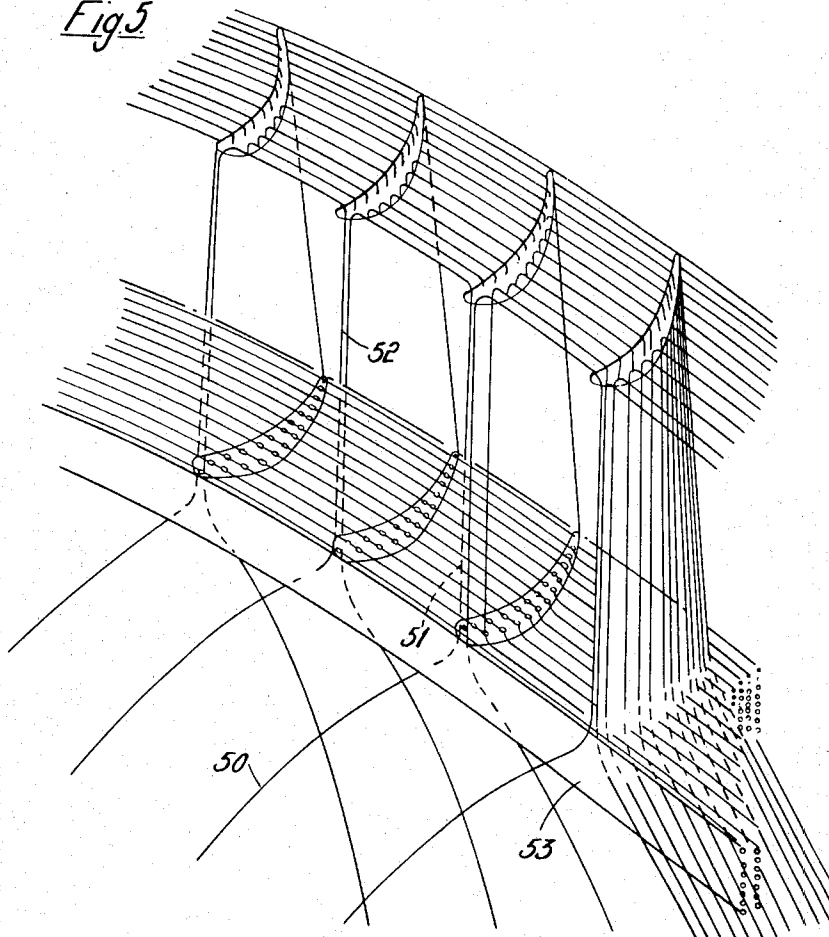


Fig. 5



## EPICYCLIC WEAVING OF FIBER DISCS

This is a division of application Ser. No. 735,411 filed June 7, 1968, now U.S. Pat. No. 3,682,460 issued Jan. 4, 1972.

The present invention relates to turbine and compressor rotors for gas turbine engines and includes a method of making such rotors both separately and with integral blades thereon.

Although the following descriptions and accompanying drawings relate to various methods and products, the primary objective of this application is to describe and claim an apparatus for producing certain products in accordance with the methods which are described below.

According to one aspect of the present invention a turbine or compressor rotor for a gas turbine engine comprises a single continuous fiber or a continuous bundle of fibers woven between points on the circumference of the rotor said points lying on opposite sides of the center of the rotor and the fiber or bundle of fibers passing adjacent to the circumference of an aperture at the center of the rotor between said points. The rotor rim may have increased thickness in order to anchor the fibers and to provide means for attaching blades to the rotor.

A continuous fiber is meant to include a fiber in which two ends have been joined by an overlapping joint in which the length of overlap is at least 10 fiber diameters.

According to another aspect of the present invention method of making a turbine or compressor rotor for a gas turbine engine, comprises the steps of weaving a single continuous fiber or a continuous bundle of fibers on to a former in a plurality of passes between points on the circumference of the former, and on opposite sides of the center thereof, the fiber or bundle of fibers passing adjacent to the circumference of an aperture at the center of the rotor between each two points. The fiber may be anchored at the rim of the former by providing additional material to thicken the rim.

The fibers are preferably held in tension throughout the weaving process and are also preferably coated with either a synthetic resin material or a metallic material.

Furthermore the fibers may be given an additional coating during the weaving process, which coating serves to hold the fiber in place.

In the application of the invention to a compressor rotor which operates at relatively low temperature the coating on the fiber may be a thermosetting resin, for example epoxy, polyimide, polyquinoxaline, polythiazole, polybenzimidazole resins or a ladder polymer.

In the application of the invention to turbine rotors which operate at relatively high temperatures the fiber may be coated with a metal or a metal alloy, for example nickel, chromium, niobium, tantalum or an alloy of nickel and chromium.

The fiber itself may be carbon, boron or silica.

In the case of metal coated fibers the fibers may be coated with metal during an electrolytic process or alternatively the metal may be sprayed on in molten state, or vapor deposited.

The above described method lends itself to continuous production of fibrous rotors and in one method of carrying out the invention the fibers are fed to a point

on the circumference of a planet wheel of an epicyclic gear. On rotation of the planet wheel around the periphery of the annulus gear the point on the circumference to which the fiber is fed performs an epicycloid motion. During this motion the fibers may be wound around pegs disposed on the circumference of the former or alternatively the former may comprise a disc which has been previously etched with grooves of a substantially epicycloid shape.

The whole of the woven disc may be filled with a filler material, for example a foamed ceramic in order to provide axial support for the fiber.

The method may be extended to the production of a rotor with integral blades by superimposing on the weaving motion a radial movement every time the fiber reaches the circumference of the former. The resulting radially extending fiber portions form a reinforcing spine in a rotor blade.

In an alternative construction the integral blade and disc may be formed with an integral shroud joining the blade tips by causing the weaving mechanism to move radially from the disc circumference outwards to form a flank of one blade and to then move circumferentially to the next blade and finally to move radially inwards to the circumference of the disc before performing the next pass across the disc.

The invention also includes a gas turbine engine provided with rotor discs woven as described above.

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

FIG. 1 illustrates diagrammatically a gas turbine engine to which the invention may be applied,

FIG. 2 shows a disc made by the method according to the present invention,

FIG. 3 illustrates diagrammatically one type of machine for making discs according to the present invention,

FIG. 4 shows how a blade may be formed integrally with the disc,

FIG. 5 illustrates how an integral disc and blade may be provided with an integral shroud at the blade tip, and

FIG. 6 illustrates a finished blade with an integral shroud woven according to the present invention.

Referring now to FIG. 1 there is shown a gas turbine engine 1 having compressor means 2, combustion equipment 3, turbine means 4 and a final nozzle 5 in flow series. Both the compressor means 2 and the turbine means 4 of the gas turbine engine comprise rotor discs 6 on which are mounted a plurality of aerofoil shaped blades. One such rotor disc 6 is illustrated in FIG. 2 and comprises a plurality of fiber portions, 7 of a single continuous fiber or continuous bundle of fibers, which are woven in tension between successive points on the circumference of the disc, the fiber portions passing adjacent to the circumference of a central aperture 8 of the disc. In the particular weave shown in FIG. 2 the successive points on the circumference on the disc lie on opposite sides of the center of the disc, for example a fiber portion starting at the circumference at point *a* extends across the disc adjacent to the center apertures to a point *b* on the circumference on the opposite side of the center and then extends back across the disc adjacent to the central aperture to a point *c* on

the circumference on the opposite side of the center. From there the fiber extends to point *d*, and in this manner the weave is continued until the whole disc is formed.

By suitably choosing the number of points *a*, *b*, *c*, *d* etc it can be arranged for the weave to start and finish at the same point on the circumference of the disc.

FIG. 3 illustrates diagrammatically one way in which the disc may be made. The fiber 20 is fed from a reel 21 to a point on the circumference of a planet wheel 22 of an epicyclic gear. The planet wheel 22 is attached by means of arms 23 to the driven shaft 24 of an electric motor 25 and on rotation of the shaft 24, the planet wheel 22 is driven round the internal periphery of an annulus gear 26 so that the point on the circumference of the planet wheel 22 to which the fiber is fed performs an epicycloid motion. From the planet wheel 22 the fiber is fed through a tube 27 to a former 28 on which are mounted a plurality of pegs 29 around which the fiber is wound. The former 28 is a flat disc having a central circular projecting boss 30 and a plurality of pegs 29 mounted around the periphery. By winding the fiber around the pegs 29 a continuous tension may be applied to the fiber portions 7 of the disc and the fiber portions will in this case be substantially straight between the pegs 29, and will also be substantially tangential to the central boss 30. The pegs 29 and the former 28 are initially coated with a releasing agent to aid removal of the finished rotor.

It may be desirable that the fiber portions 7 are curved, so that on rotation of the discs the resultant stress in the fiber portions is more nearly pure tension. This may be achieved by using the epicyclic gear to etch a continuous groove in the desired pattern on to a former and to subsequently feed the fibers under tension into the groove in the former.

The fibers are coated with either a thermosetting resin or a metal alloy, depending on the temperature of operation of the disc. The fiber on the reel 21 may have been pre-coated. In order to anchor the fiber portions in position during the winding process the fibers are continuously coated as they are woven. In the case of resin coated fibers for lower temperature operation the coating may be applied in the form of very viscous liquid and the disc may be heated when complete to cure the resin. When the fiber is to be coated with a metal or alloy, for high temperature operation, the whole weaving process may take place in a vat of electrolyte so that the fiber is individually coated and at the same time continuous electrolytic deposition anchors the fiber portions which have been positioned on the former. Alternatively the disc may be wound and electrolytically plated when finished.

In order to complete the disc as shown in FIG. 2 a plurality of circumferentially wound fibers are provided at the outer periphery of the disc to thicken the disc to provide material for withstanding the hoop stresses produced in the disc during rotation thereof and to anchor the fibers. In the case of electrolytically coated metal fibers this additional material at the periphery may be provided purely by electrolytic deposition.

The method described above produces an open weave in the disc, and this may in itself be sufficiently strong to withstand the stresses produced in operation.

However, it may be necessary to fill in the disc, apart from the central aperture, and this may be done with a lightweight material, for example, a foamed ceramic in the case of high temperature discs, or resin injection in the case of lower temperature discs.

Filling in the weave by these methods would in any case provide the disc with greater axial stiffness and prevent flutter of the fiber portions within the disc.

A plurality of aerofoil shaped blades are attached to the disc at its outer periphery in order to complete the rotor assembly. The blades may of course be made of conventional materials or may be made of fiber reinforced resins or metals. In the case of a fiber reinforced resin disc the blades may be bonded on with a resin bond, and in the case of a disc made from metal coated fibers with a strengthened periphery the blades may be welded to the periphery.

The blades may, if desired, be made integral with the disc in various ways as shown in FIGS. 4 to 6.

In FIG. 4 one method is illustrated wherein during the continuous winding of the disc, an additional radial movement is superimposed on the weaving motion everytime a point on the circumference of the disc is reached thus forming a radial loop 40, the radii of the loops being arranged to suit the diameters of the fibers to avoid stress concentrations.

The whole blade disc assembly may then be formed by assembling a plurality of discs and blade segments 41 in axial juxtaposition and interposing a plurality of layers 42 of circumferentially wound fibers at the outer periphery of the disc. The aerofoil shape for the blade may be finally produced by any of a plurality of methods, for example, forming a rough shape of removable expendable material around the fibers of the blade and coating their form with refractory metals or ceramics by spraying or vacuum deposition. In one method as above an electrically conducting wax former is made on which the fibers are positioned and the whole assembly is electroplated with a metal or metal alloy, and the wax is finally melted out leaving a hollow reinforced metal section in the required shape of the blade.

In the embodiment shown in FIG. 4 the ends of the loops may be cut and the individual fibers bent over to project circumferentially from either side of the blade and thus form a shroud on the blade tip.

Alternatively as more layers are wound onto the disc, the radially extending fibers may be cut short at different radial lengths to provide a tapering blade section.

An alternative method of making a blade with a shroud is shown in FIGS. 5 and 6. In these embodiments the fiber 50 which forms a woven disc is caused to move radially from the periphery of the disc to lie along one flank 51 of one blade and then to move circumferentially around the disc by one blade pitch and finally to move radially inwards towards the circumference of the disc to lie along one flank 52 of the next adjacent blade before traversing across the disc to the periphery on the opposite side of the disc. By this means a thin lamina section comprising a thin disc, having a plurality of portions of blade profile spaced around its circumference each having a shroud integral with the next adjacent blade profile section may be formed. These lamina sections may be built up with in-

terposed layers of circumferential fibers 53 at the disc rim into a complete blade disc assembly. Finally the whole blade disc assembly with its shroud may be resin plated or electro-plated to form the finished article as seen in FIG. 6.

The invention has been described referring to a single fiber element but it is clear that a plurality of fibers may be put together to form a bundle which itself is coated and the same processes would apply using the bundle of fibers.

The fibers to be used are ideally carboniferous fibers but again other fibers such as silica fibers or boron fibers with suitable coatings may be used.

The blades may be made hollow and suitable provision made for feeding cooling air from the disc to the blades.

In the case of separately made blades and rotors the blades may be made from fiber reinforced materials and may be made by any of the processes described in our co-pending U.S. application Ser. No. 685,434 filed Nov. 24, 1967 and now U.S. Pat. No. 3,532,438 issued Oct. 6, 1970, and British application Ser. No. 16874/67.

What we claim is:

1. Apparatus for winding one or more fibers under tension onto a former, comprising:  
an epicyclic system having (a) an annulus wheel means and (b) at least one planet wheel means which can be rolled about a circumference of said annulus wheel means to define an epicycloid path of travel for every point on each of said planet wheel means except for a point corresponding to the axis of rotation for the planet wheel means, driving means for rotating each of said planet wheel

means in its own center axis to thereby roll each planet wheel means about the circumference of said annulus wheel means, and

guide means operatively associated with one of said planet wheel means for guiding one or more fibers from a source of supply onto a former, said guide means being arranged so that its end nearer said former follows a substantially epicycloid motion dictated by the planet wheel means rolling about the circumference of said annulus wheel means, thereby causing said one or more fibers to be drawn under tension onto said former.

2. The apparatus of claim 1 wherein said annulus wheel means and said planet wheel means comprise gear members which maintain a meshing engagement during rotation of said planet wheel means by said driving means.

3. The apparatus of claim 1 wherein said epicyclic system includes two planet wheel means which are carried for rotation on opposite ends of an arm means so that the two planet wheel means contact diametrically opposite sides of said annulus wheel means during a rolling of the planet wheel means about the circumference of the annulus wheel means, and wherein said driving means is connected to said arm means for imparting rotation to the planet wheel means.

4. An apparatus according to claim 1 in which the former has a plurality of circumferentially arranged projections around which the fibers pass.

5. An apparatus according to claim 1 in which the former is provided with grooves for receiving said one or more fibers, the pattern of the grooves being substantially epicycloid.

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