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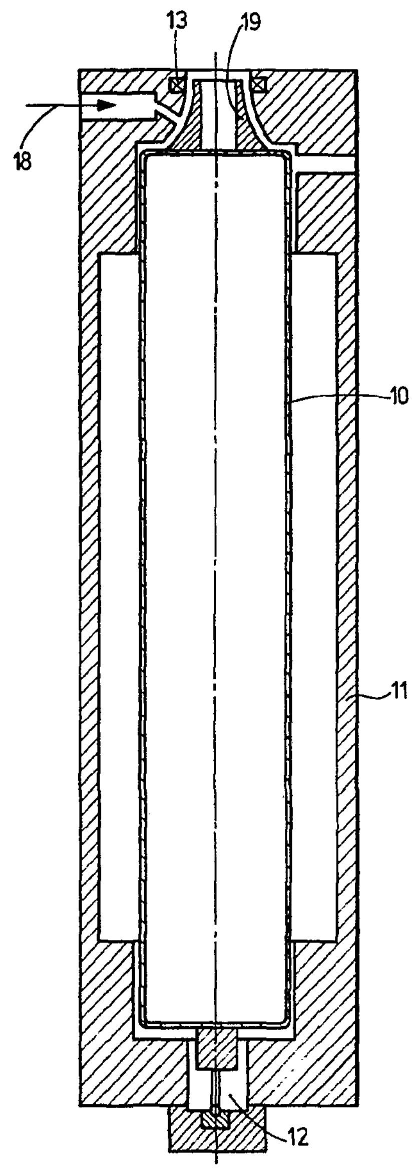
(54) Rotor

(57) In the field of hollow high speed rotors there is an increasing demand for progressively higher speeds of safe operation. High speed operation causes support bearings to be carefully designed if the rotor speed is to pass safely through its critical speed of operation where intense vibration is experienced. Also the rotational speed is limited by the peripheral velocity and strength of the outside surface portion of the rotor. The invention proposes that elemental boron, which has great tensile strength and lightness be used to provide a major part of a hollow rotor so that increased operating speeds can be attained. Such a rotor is usable to provide a high speed centrifuge drum.

Fig. 2



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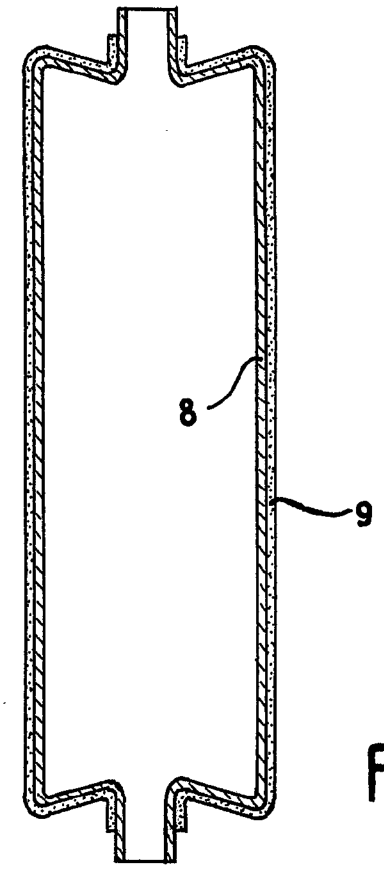

Fig.1

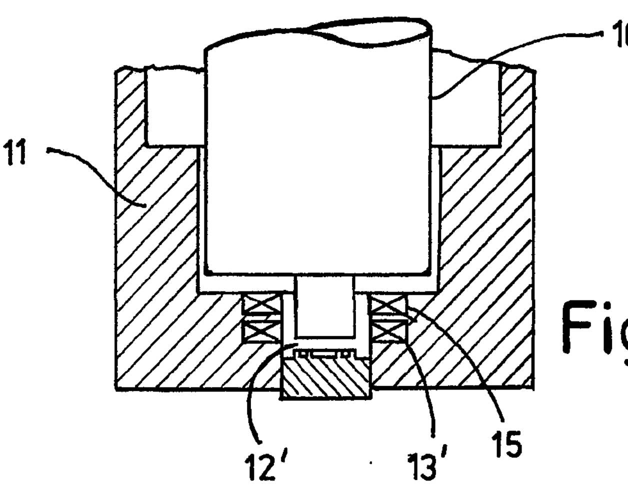

Fig.3

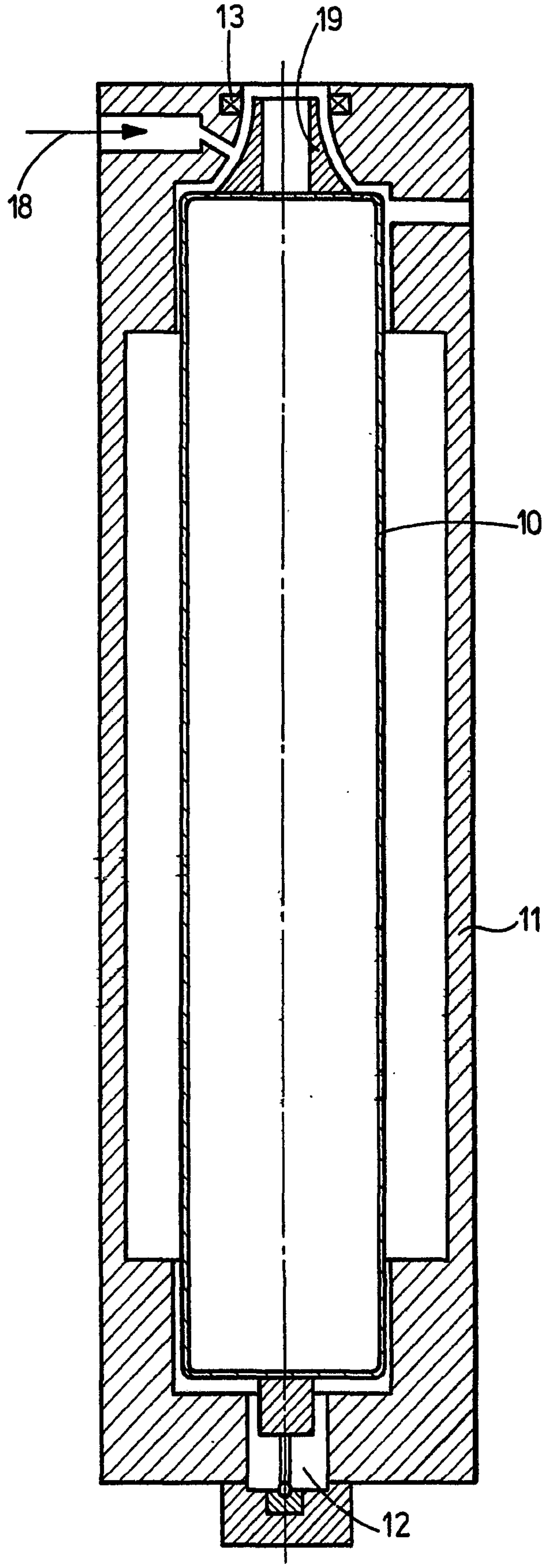

Fig. 2

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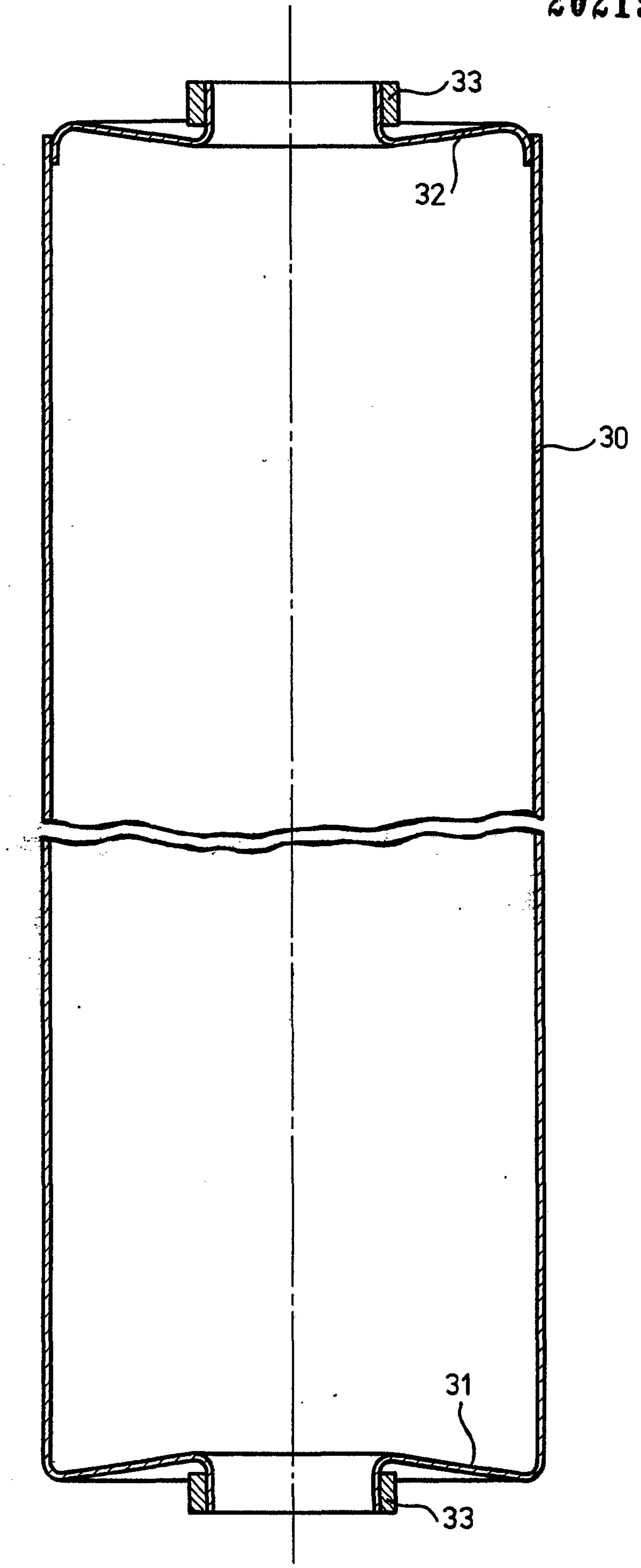
Fig. 4



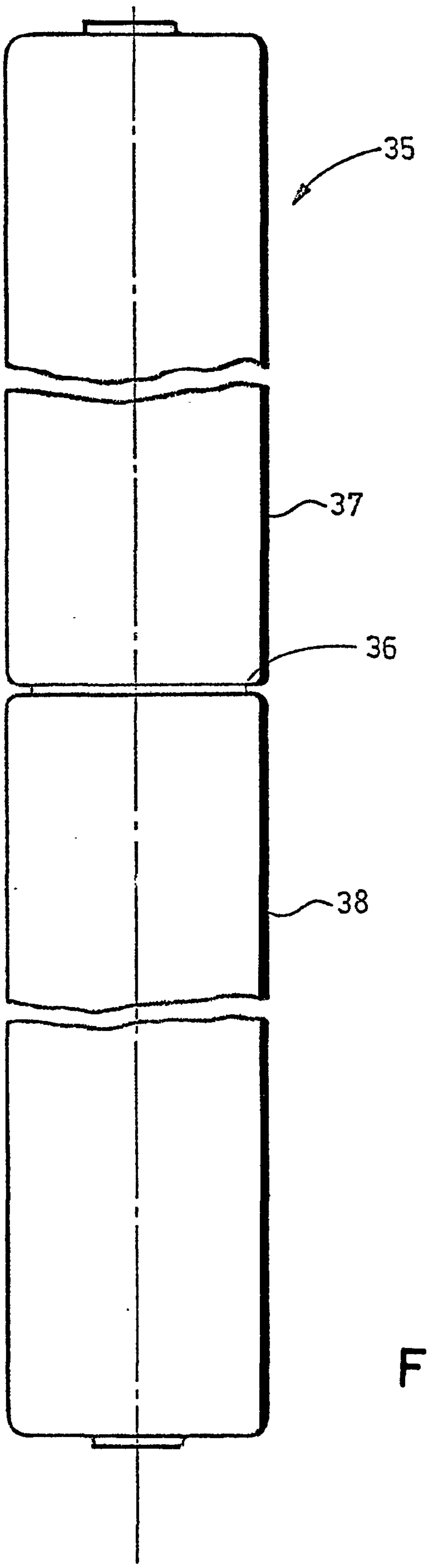


Fig. 5

SPECIFICATION

A rotor

The invention relates to rotor which is constructed as a hollow cylinder, and to such a rotor more particularly but not exclusively associated with a centrifuge drum operable at high rotational speeds.

High-speed rotors operated in the course of advancing technology with constantly increasing speeds, are used in various technical fields, for example in turbines and in centrifuges for separating gaseous or liquid media.

The rotors are generally designed for operation in a subcritical range in order to avoid difficult problems of dynamic characteristics and those related to the bearing system. This means that the rotor length is adapted to the materials in use in dependence on the diameter and the maximum permissible speed so that the natural frequency remains above the rotational frequency of the rotor.

Assuming identical rotor velocity and neglecting any constants depending on the material the length of subcritical rotors can be increased in the same ratio as the rotor diameter.

"Multi-deck" rotors operating at supercritical speeds have been developed in order to achieve an increase of speed for long rotors. To this end the rotors are subdivided into individual portions by so-called tubular corrugations and are coupled to each other by the tubular corrugation in an exceptionally soft flexible manner, Accordingly, the bearing forces can be minimised when passing through the critical speeds. This technique however is used only with rotors having a homogeneous structure, for example steel rotors. Carbon fibre reinforced plastics whose tensile strength is greater than that of steel, cannot be used in conjunction with this technique for high-speed long rotors.

The prior art also discloses bearing techniques by means of which rotors can be operated in the supercritical speed. However, this calls for special and very expensive bearings and more powerful driving units owing to the substantial deflections which occur when passing through the critical natural frequencies.

The limits of rotor speed for a given rotor geometry are defined by materials. The so-called tearing length, i.e. the ratio of ultimate tensile strength to density, defines the circumferential velocity of hollow rotor members.

Suitable materials for this relationship include glass fibre-epoxy resin laminates, high-tensile steel, Kevlarepoxy resin laminates, carbon fibre-epoxy resin laminates and the like. The tearing length of materials used in such laminates is substantially improved because of their greatly reduced density but this cannot be fully utilized due to the need for bonding to a matrix compound which is necessary for the rotor.

It is the object of the invention to provide rotors of the kind described hereinbefore which can also be used for very long rotors with a higher circumferential rotor velocity.

According to one aspect of the invention there is provided a rotor constructed as hollow member wherein at least a major part of the rotor is formed, or formed substantially, of elemental boron.

Boron, a non-metallic element, can be produced in amorphous and crystalline form. In its crystalline form it is the hardest material next to diamond and its significance in recent years has constantly increased in the abrasives industry. It has long been possible to convert the hard, brittle and not easily meltable element as a filament into a high-tensile and relatively elastic form. A fine substrate filament of tungsten in a thickness of 10—12 μm is vapour-coated with boron by means of gas phase separation to yield a filament thickness of 100—130 μm.

Filaments produced by this method have exceptionally high tensile values. However, like all other filaments or fibres this high-tensile boron filament can also be used only when bonded to a matrix compound and thus loses a substantial proportion of its original specific tensile strength. Boron filaments combined by an aluminium matrix into strips for components used in air frames and space travel have become known.

Preferably and by contrast to the known fibre matrix bond, a rotor is produced as a complete moulding from boron.

In a rotor of this kind it is possible to achieve tensile values for the shaped part of the hollow member comparable to the tensile values of boron filaments so that the permissible maximum speeds can be doubled compared with those of an identical rotor constructed of steel.

For reasons of economy, only the shell, which is particularly highly stressed in rotation, need be constructed of boron. It is also possible to construct the entire rotor with the end covers of boron in which case the components can be separate or the covers and the shell can be integrally formed.

Preferably the end covers can be directly constructed with contours for mounting driving and/or bearing elements.

Preferably radially minor regions of the covers of the rotor are constructed for receiving bearing parts and driving elements. Advantageously, support rings of boron or some other material can be provided on the interior of the cover or around annular shoulders which are integrally formed for receiving and mounting driving or bearing elements on the cover.

Stresses which can occur during rotation can be compensated by radial, circular symmetrical inclinations of the cover surface.

According to a further aspect of the invention there is provided a method for producing a rotor comprising the preparation of a substrate, the surface contour of which corresponds to the shape of the rotor and depositing elemental boron on the surface of the substrate by gas phase separation.

The rotor shell and end cover can be produced separately or intregrally. Contour shapes in the cover, for example for mounting bearing elements and discharge systems, can be directly formed therein.

The substrate member which represents an investment shape, can be subsequently destroyed.

By virtue of their homogeneous structure boron rotors can be produced directly with soft resilient corrugations in the shell part and therefore have the advantages of the multi-deck, supercritical construction which is a feature of steel rotors.

Examples of the invention will now be more particularly described with reference to the accompanying drawings, wherein;

Figure 1 illustrates in cross-section a manner in which a rotor can be manufactured, according to the invention,

Figure 2 is a sectional view showing an example of a rotor according to the invention,

Figure 3 is a sectional view illustrating a modified bearing assembly for supporting the rotor,

Figure 4 is a sectional view of another example of a rotor according to the invention, and

Figure 5 is a side view of yet another example of a rotor, according to the invention.

Referring to Figure1, the rotor constructed of boron is produced by depositing a boron film on a substrate by using one of the known methods, for example separation from the gaseous phase, as used for the production of boron fibres.

A sunstrate 8 of tungsten, ceramic or some other material formed as hollow member is coated on the exterior or interior with a boron film 9 and is subsequently wholly or partially removed so that the boron film substantially remains as a hollow member 9 which forms the rotor. If the coating is applied to both sides the substrate is retained quasi as ballast.

The construction of rotors can be adapted to varied requirements or applications.

Referring to Figure 2 a rotor 10 of elemental boron, produced as an integral unit and constructed as a centrifuge drum, is axially and radially supported in a lower cup needle bearing 12 and is concentrically guided in an upper magnetic bearing 13. Drive is applied by means of a gas jet 18 which is directed towards a turbine wheel 19 mounted co-axially on the upper end of the rotor.

Referring to Figure 3 there is shown as a modification a rotor 10′ which is closed at the bottom and is axially supported by a gas bearing 12′ and is radially supported by a magnetic bearing 13′. An electric motor 15 is provided for the drive.

Figure 4 shows as a further example a boron rotor 30 which is provided with an integral end cover 31 at one axial end and a separately constructed second end cover 32 at the opposite axial end. The inner cover extensions for receiving the bearing and driving components, not shown, are banded with rings 33 of boron or some other material in order to level the stresses.

Figure 5 shows a "two-deck" boron rotor 35. The tubular corrugation 36 which is co-formed in the course of gaseous phase separation provides individual tube parts 37, 38 with a high degree of flexure in the rotor middle when passing through the critical speed, accompanied by a relatively low bearing loading.

CLAIMS

1. A rotor constructed as hollow member wherein at least a major part of the rotor is formed or formed substantially or elemental boron.

2. A rotor according to Claim 1, wherein the rotor comprises a shell having a cover at each axial end.

3. A rotor according to Claim 1 or 2, wherein the rotor shell consists of elemental boron.

4. A rotor according to Claim 2, wherein the rotor shell and the end covers consist of elemental boron.

5. A rotor according to Claim 4, wherein the end covers are formed integrally with the rotor shell.

6. A rotor according to Claim 2 to 5, wherein radially inner regions of the covers of the rotors are constructed for receiving bearing parts and driving elements.

7. A rotor according to any one of Claims 2 to 6, wherein the radially inner regions of the end covers and transition regions between the rotor shell and the inner regions are constructed to yield optimum stresses.

8. A rotor according to Claim 4 or Claim 5, wherein the radially inner region of each integrally formed cover of the rotor, which region is provided to accommodate bearing and drive components, is banded with a boron ring for levelling the stresses.

9. A rotor according to any one of the preceding Claims, wherein the rotor is constructed with an uninterrupted tubular geometry.

10. A rotor according to any one of the Claims 1 to 8, wherein the rotor, constructed as centrifuge drum, comprises two or more co-axial tube parts.

11 A rotor according to Claim 9, wherein interruptions of the rotor geometry between the individual tube parts of the rotor project radially inwardly in annular corrugated configuration.

12. A rotor according to any one of the preceding Claims, wherein the rotor is vertically mounted and is supported at its lower end by means of a cup bearing.

13. A rotor according to any one of the Claims 1 to 11, wherein the rotor is supported at at least one end by means of a magnetic bearing.

14 A rotor according to any one of the preceding Claims, wherein the rotor is mounted vertically and is centred at its upper end, by means of a magnetic bearing.

15. A rotor according to any one of Claims 1 to 11 and 14, wherein the rotor is supported and centred on one or both sides by means of a gas bearing.

16. A rotor according to any one of the preceding Claims, wherein the rotor is driven by means of a gas jet via a turbine.

17. A method for producing a rotor according to Claim 1, comprising the preparation of a substrate, the surface contour of which corresponds to the shape of the rotor and

depositing elemental boron on the surface of the substrate by gas phase separation.

18. A method according to Claim 17, wherein the boron is deposited in the external surface of the substrate.

19. A method according to Claim 17, wherein the substrate is a hollow member with corresponding internal surfaces and wherein the elemental boron is depositied on the internal wall of the substrate.

20. A method according to any one of Claims 17 to 19, wherein the substrate is of metal

21. A method according to claim 20, wherein the substrate is of tungsten.

22. A method according to any one of Claims 17 to 19, wherein the substrate is of graphite.

23. A method according to any one of Claims 17 to 19 wherein the substrate is of

24. A method according to any of the Claims 17 to 23, wherein the substrate remains as an integral constituent of the boron member which is to be produced.

25. A method according to any one of Claims 17 to 23, wherein parts of the substrate remain as integral constituents in the boron member which is to be produced.

26. A method according to any one of Claims 17 to 23, wherein the substrate is removed after the production of the boron member.

27. A rotor substantially as herein described with reference to and as shown in the accompanying drawings.

28. A method for producing a rotor substantially as herein described with reference to the accompanying drawings.

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