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(54) A ROTOR HEAD FOR A ROTARY WING AIRCRAFT

(71) We, MESSERSCHMITT-BÖLKOW-BLOHM Gesellschaft mit beschränkter Haftung, of 8000 Munchen, German Federal Republic a Company organised and existing under the laws of the German Federal Republic, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a rotor for rotary wing aircraft wherein the blades do not have flap or drag hinges, but in which the rotor blades are mounted in a resilient clamp device.

With such "hingless" rotor assemblies the rotor head requires at least two bearings for each blade so that forces and bending moments can be absorbed. These bearings tend to be bulky in structure which leads to a certain degree of vulnerability from damage particularly in military helicopters. Periodical maintenance is also necessary involving dismantaling. With rotor blades and the rotor head constructed from fibre-reinforced composite materials forces have to be transmitted into the bearing through special fittings from both the rotor blade and from the rotor head.

According to this invention there is provided a rotor for a rotary wing aircraft wherein each rotor blade is connected to the rotor head structure through a plurality of resilient plates secured to the blade shank, the plates extending radially from the longitudinal axis of the blade shank.

Preferably the plates have a length, in the direction of the longitudinal blade axis which is greater than their width. Each blade shank may have four plates secured thereto and each disposed to form an angle (β) with respect to the plane of rotation of the rotor which is less than an angle (α) formed with a plane passing vertically through the rotational axis of the rotor.

The plates are preferably connected with to two spars positioned in spaced parallel relationship and extending alongside each blade shank, the spars being connected with the rotor head.

In the rotor the plates provide the radial and the axial load bearing support for the blades, enabling them to perform pitch angle movements and providing a means for absorbing lead-lag and bending moments. The distribution of the supporting function over a number of plate surfaces enables the conduction of the forces from the blade into the rotor head to be spread instead of being concentrated into a special blade root fitting. A structure can thus be used which, in the case of fibre-reinforced composite materials, is of particularly light weight and not especially vulnerable to damage.

With four plates for each rotor blade, the parts which are particularly subject to repeated stress are visible without dismantling and can be checked easily.

The structure for the blade mounting can be obtained in a number of different ways. For example the rotor blades can all be in one plane with spars, bridge pieces and ties associated with each blade forming a head structure serving to accommodate the rotor blade shanks and plates.

With four rotor blades arranged in two pairs the two blade planes may be superposed each two opposed blades having a common spar and a common centre bridge piece.

Alternatively the rotor blades may have sleeves housing the plates and disposed around an extension of the rotor hub.

Further preferred features of a rotor head according to the invention are described in the following in conjunction with the accompanying drawings showing several embodiments by way of exampls. In the drawings:-

Figure 1 shows a plan view of a first

embodiment with two pairs of rotor blades each pair being situated one above the other,

Figure 2 shows a section on II-II of Figure 1,

Figure 3 shows a section on III-III of Figure 1 to a larger scale,

Figure 4 shows a section as Figure 3 but with the rotor blade flexed,

Figure 5 shows the arrangement of the fibres in the plate structures,

Figures 6 to *8* show the forces and moments acting through the plate structures from a rotor blade,

Figure 9 shows in plan view a second embodiment with the rotor blades lying in one plane,

Figure 10 shows a section on the line X-X of Figure 9,

Figure 11 shows in plan view and partly in section, a third embodiment with rotor blade shanks joined to form a crosshead, and

Figure 12 shows a section on the line XII-XII of Figure 11.

In the embodiments described the rotor has no flap or drag hinges and has four rotor blades. In Figures 1 and 2 four rotor blades 1, 2, 3 and 4, have the blade shanks 1*a*, 2*a*, 3*a* and 4*a* joined in a rotor head 5 with the blades 1 and 3 positioned above the blades 2 and 4. The rotor blade shanks are connected with four resilient plates 6, 7, 8 and 9, with strength in the shear mode and secured in the shanks so that the planes of the plates intersect along the longitudinal axis A of the rotor blade shank. The plates 6 to 9 have a length in the direction 10 greater than the width 11, and are positioned so as to form an angle α with a plane B passing vertically through the rotation axis which is larger than an angle β formed with a plane C which is parallel with the plane of the rotor blades and perpendicular to plane B. The plates 6 to 9 of the upper rotor blade shanks 1*a* and 3*a* are connected along the longer sides opposite the rotor blade with spars 12 and 13 which are joined together with bridge pieces 14 at the centre and ties 15 at the extremities to form a box 5*a* for the plates. The plates 6 to 9 of the lower rotor blade shanks 2*a* and 4*a* are connected to spars 16 and 17 and bridge pieces 18 and ties 19 to form a box 5*b*.

The plates are connected with the spars, bridge pieces and ties by connectors 20, such as screws. Figure 1 shows only the screws 20 serving to connect the plate 6 with the bridge pieces 14 and the ties 15. All the spars 12, 13, 16 and 17 have side lugs 22 with bores through which bolts 23 serve to connect the boxes 5*a* and 5*b*. After extraction of bolts 23 the box 5*a* can be rotated to lie over the box 5*b*, as a result of which the rotor blades can be placed one above the other for transport. A rotor head drive shaft 24 is provided underneath the box 5*b*.

In Figure 3 the connection of plates 6 to 9 to the blade shanks 1*a* and to the box 5*a* is shown in greater detail. The plates where they come together at the rotor blade axis A are secured in slots 26 of the blade shank 1*a*. The part 27 of the plates which are held in the shank is only a fraction of the entire width 11. The sides of the slots 26 extend along circular arcs 28 preventing the plates from being bent sharply. The plates 6 to 9 are reinforced to provide better absorption and transmission of forces at the connection with the spars 12 and 13 and ties 15.

When torque is applied around the blade axis A deflection as shown in Figure 4 occurs. The rotor blade shank 1*a* may rotate about the blade axis A through an angle of $\triangle$. The angle of rotation is shown on an exaggerated scale, and produces a S-shape flexural deformation of the plates 6 to 9. Owing to the fact that the plates have a very small thickness in comparison to the free bending length 11, the deformation has a small restoring moments. The flexural deformation results in a slight reduction of distance 31, which is very small in relation to the length 11, so that the required expansion remains small in comparison with the permissible expansion of the material of which the plates are made. In addition the ties 15 are formed so that they can undergo deformation in the length 32 with only limited applied force. This ensures that the restoring moments occurring when the rotor blade 1 turns about the axis A and which are a result of the reduction of length 33 of the clamping points for the plates, are small.

All parts of the rotor head are preferably of fibre-reinforced composite material, particularly fibre-reinforced plastics material. This material has proved highly satisfactory for the stresses occurring in a hingeless rotor. The reinforcement fibres to be used for this purpose may comprise, according to the type of stress, glass, particularly S-glass, or carbon or plastic fibres, such as "KEVLAR" (a Registered Trade Mark). Among the plastics suitable for the matrix are epoxide resins. A diagram of the box 5*b* with the mounting system for the rotor blade 2 is shown in Figure 5 which indicates a preferred arrangement for the reinforcement fibres 35 in the plates 6 and 7. The reinforcement fibres of both plates form an acute angle γ to the rotor blade axis A.

The arrangement described for the fibres 35 in the plates ensure that the high forces P_A along the blade axis (see Figures 6 to 8), which have to be transmitted by the plates to the rotor head, can be mainly taken up by oblique tractive forces 36 in the plates 6 and 7, or 8 and 9. The flap and drag moments M_a in the rotor blade shank 2*a* as shown

Figure 7 occur as tractive forces 36 and compressive forces 37. Owing to the prestressing of the fibres as a result of forces P_A, the plates, as shown in the resultant diagram of Figure 8, of the forces of Figures 6 and 7, are able to absorb, as tractive forces 36, the compressive forces 37 resulting from bending moments. This action is further assisted by the considerable length of the plates. Because the plates come together in various directions on the rotor blade axis they can also take up by tractive stresses, any radial forces which occur between the rotor blades and the rotor head. Since, moreover, the plates are positioned at a small angle β in relation to the direction of the force caused by the drag flexure and at a larger angle α in relation to the direction of the force caused by the flap flexure, it is possible for the rotor blades to be mounted rigidly in relation to the rotor head for drag flexure and less rigidly for flap flexure. In addition, in the event of rotation about the rotor blade axis and simultaneous tractive stresses, the plates are protected by the radii 28 from unacceptable flexural stresses and sharp bending angles. The construction described thus enables full use to be made of the advantages of fibre-reinforced composite materials, which are able to absorb far higher forces in traction than in compression. The plates are also prevented from buckling.

Figures 9 and 10 show four rotor blades 1 to 4 situated in a common plane, with each blade having associated spars, bridge pieces and ties to form a box 38 to accommodate the blade shanks and plates. The boxes are interconnected so that mutually opposed spars are aligned with the ties of the other spars, that is the spars 13 are aligned with the ties 18*b* and the spars 12 with the ties 18*a*.

A further embodiment of a rotor head with the rotor blades in a common plane is shown in Figures 11 and 12. The rotor blades 1, 2, 3 and 4 in this case are rigidly connected, by lugs 40 and bolts 41 and 42, to lugs 43 on sleeves 44. The rotor blades may be made in one piece with the sleeves 44. Plates 46, 47, 48 and 49 are secured in the sleeves 44 and are secured to shanks 50,51,52 and 53 of a crosshead 54.

In Figure 11 the shanks 50 and 51 are sectioned in two different planes in accordance with the section lines XI*a*-XI*a* and XI*b*-XI*b* of Figure 12. The section XI*a*-XI*a* passes directly through the smallest cross section of the rotor blade shank 50, along the slots for the plates 46 and 47, and shows to the right hand side the connection of the plates 46 to the sleeve 44*a*. The plate 46 is inserted in a slot 56 cut into the longitudinal edge of the sleeve 44*a* and is connected by means of screws 57. Similarly, the other plates 47, 48 and 49 are inserted in corresponding slots along the edges of the sleeve 44*a*.

The section XI*b*-XI*b* shown in Figure 12 passes through dead centre of the sleeve 44*b* and the rotor blade shanks 51. The surface shape of the plates 46, 47, 48 and 49 describes a parallelogram. The forces and moments are absorbed in the same way as been described in Figures 1 to 8.

It is possible for a rotor head to have more or less than the four blades of the described embodiments.

WHAT WE CLAIM IS:-

1. A rotor for a rotary wing aircraft wherein each rotor blade is connected to the rotor head structure through a plurality of reslient plates secured to the blade shank, the plates extending radially from the longitudinal axis of the blade shank.

2. A rotor in accordance with Claim 1, wherein the plates have a length in the direction of the longitudinal blade axis which is greater than their width.

3. A rotor in accordance with Claims 1 or 2, wherein each blade shank has four plates secured thereto and each disposed to form an angle (β) with respect to the plane of rotation of the rotor which is less than an angle (α) formed with a plane passing vertically through the rotational axis of the rotor.

4. A rotor in accordance with any preceding Claim 1 to 3, wherein the plates are connected with two spars positioned in spaced parallel relationship and extending alongside each blade shank, the spars being connected with the rotor head structure.

5. A rotor in accordance with Claim 4, wherein the spars are joined towards the centre of the rotor head by bridge pieces and at the outside ends with ties, the bridge pieces and ties being connected to the plates.

6. A rotor in accordance with Claim 5, wherein the spars, bridge pieces and ties associated with each rotor blade forma box structure into which the rotor blade shank extends, the plates securing the shank to the box.

7. A rotor in accordance with Claim 6, wherein the innermost ends of adjacent spars associated with adjacent blades are joined to form an integral crosshead structure.

8. A rotor in accordance with Claim 6, wherein the rotor blades are arranged in two or more pairs lying in respective planes one above the other, the blades of a pair being opposed with two spars common to both shanks and a single bridge piece joining the centres of the spars.

9. A rotor in accordance with Claim 8, wherein the spars of each blade pair are detachably inter-connected with the spars of

another blade pair whereby one or both pairs of blades may be pivoted about the rotational axis of the rotor on release of the inter-connection.

10. A rotor in accordance with any one of Claims 1 to 3, wherein each rotor blade is secured to a sleeve forming the blade shank, the plates connecting the sleeve to an extension of the rotor head which passes into the sleeve.

11. A rotor in accordance with Claim 10, wherein each plate is of trapezoidal shape in plan and is secured in a slot in the sleeve.

12. A rotor in accordance with any one of Claims 1 to 9, wherein the shanks of the rotor blades have longitudinal slots each being of a depth extending in proximity to the longitudinal axis of the shank, the surfaces defining the slots having a curved contour which widens from the axis along a circular arc.

13. A rotor in accordance with any one of Claims 4 to 9, wherein the spars with the ties are elastically deformable to apply a restoring force to deflection of the plates.

14. A rotor in accordance with any preceding claim, wherein the plates are of a fibre-reinforced composite material with the fibres extending parallel and obliquely with respect to the longitudinal axis of the blade shanks and in a direction from the blade shanks away from the blade tips, an acute angle being formed between the fibres of two opposed plates.

15. A rotor in accordance with Claim 14, arranged such that when under operation a rotor blade is subject to a force acting along the longitudinal axis of the shank and to a bending force with the fibres in the plate subject to a force of magnitude along the longitudinal axis to stress same whereby, with the bending forces the fibres are subject only to resultant tractive force and not compressive force.

16. A rotor for a rotary wing aircraft constructed and arranged substantially as herein described with reference to and as shown in Figures 1 to 8 or 9 and 10 or 11 and 12 of the accompanying drawings.

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1584099 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

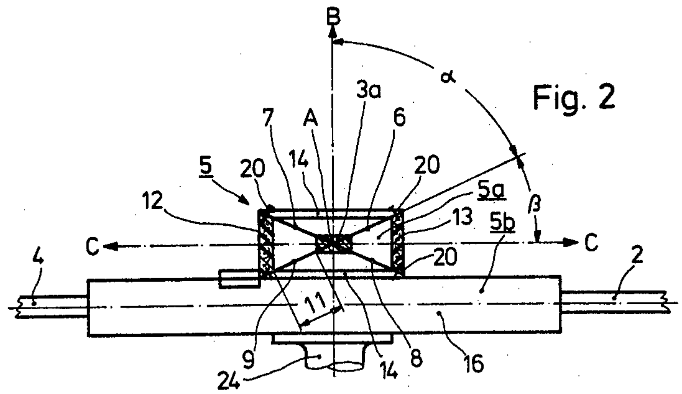

Fig. 2

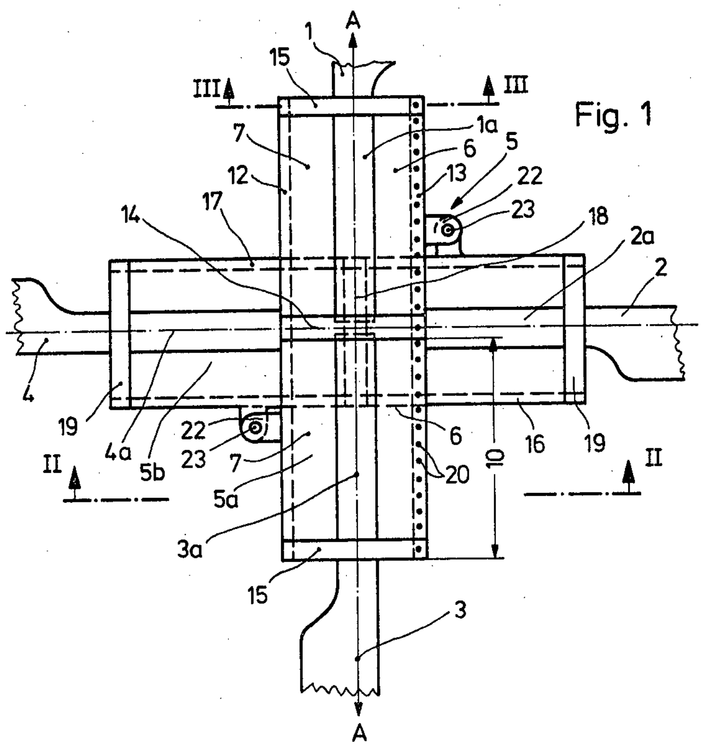

Fig. 1

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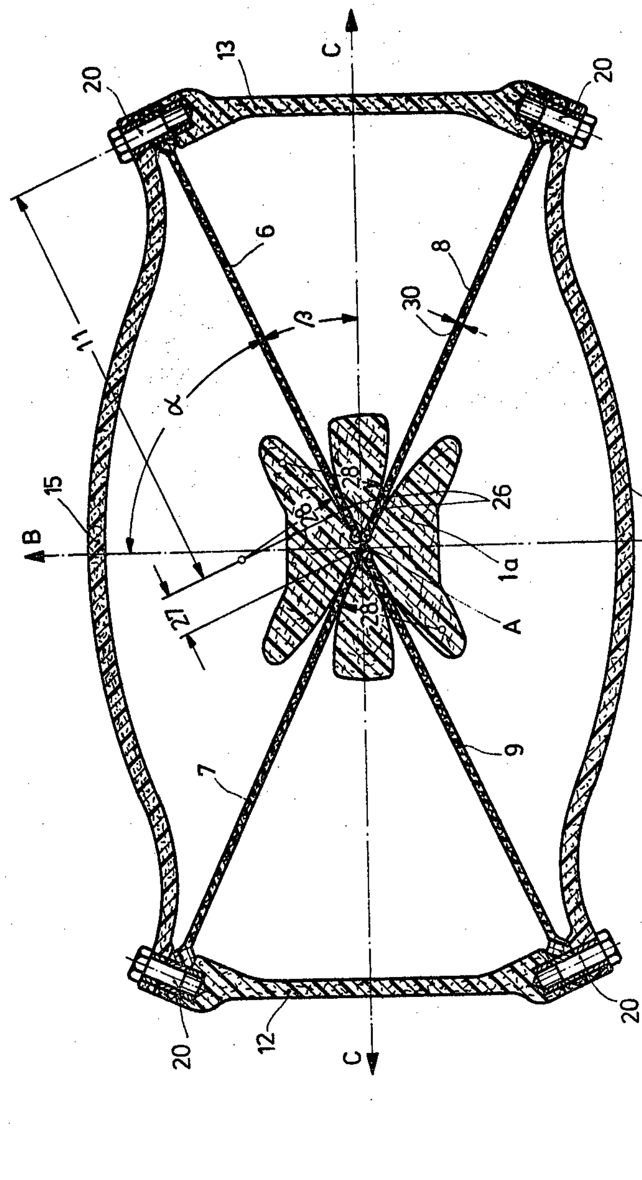


Fig. 3

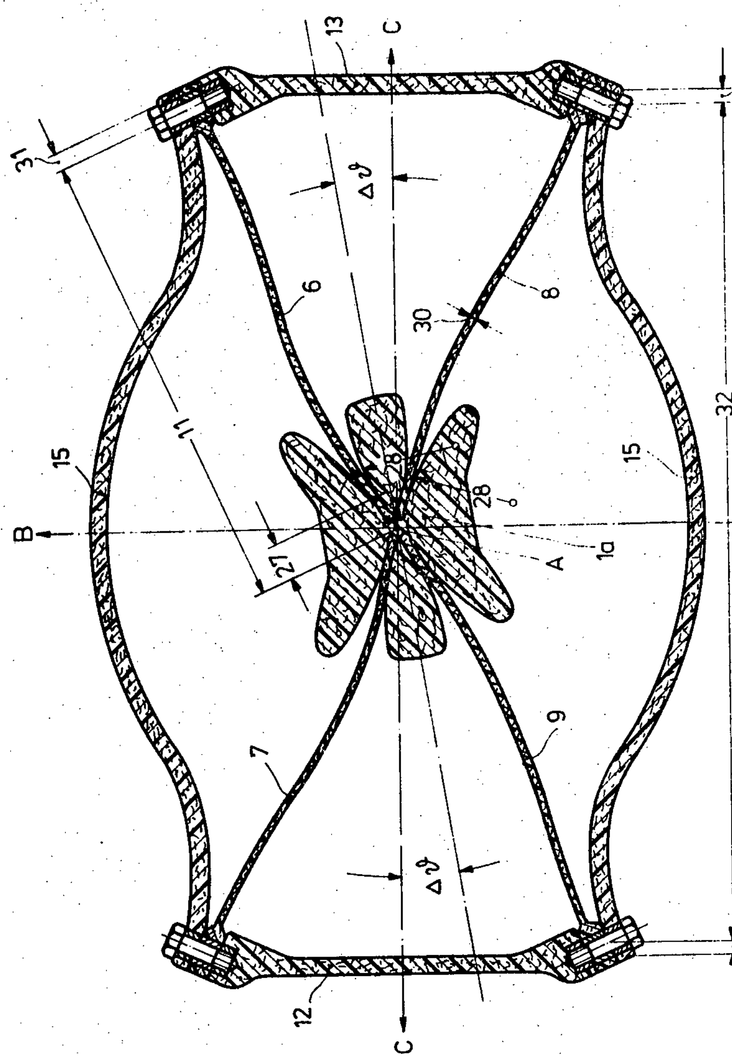


Fig. 4

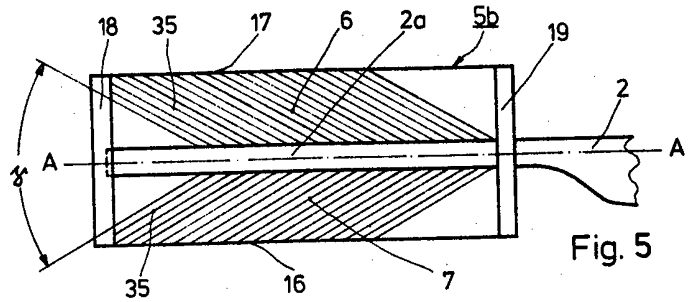


Fig. 5

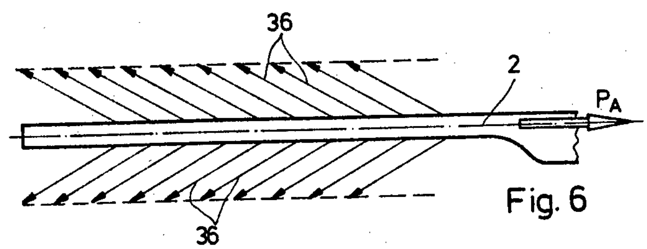


Fig. 6

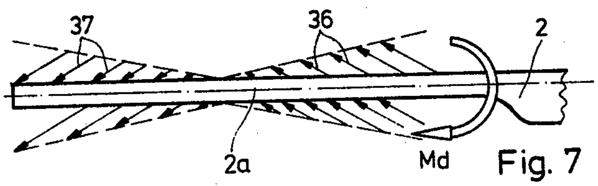


Fig. 7

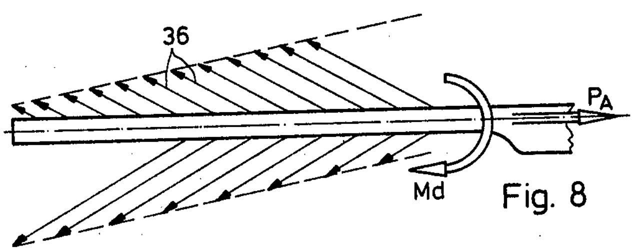
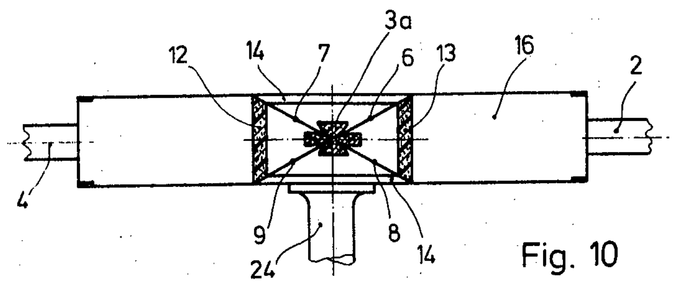


Fig. 8


3a
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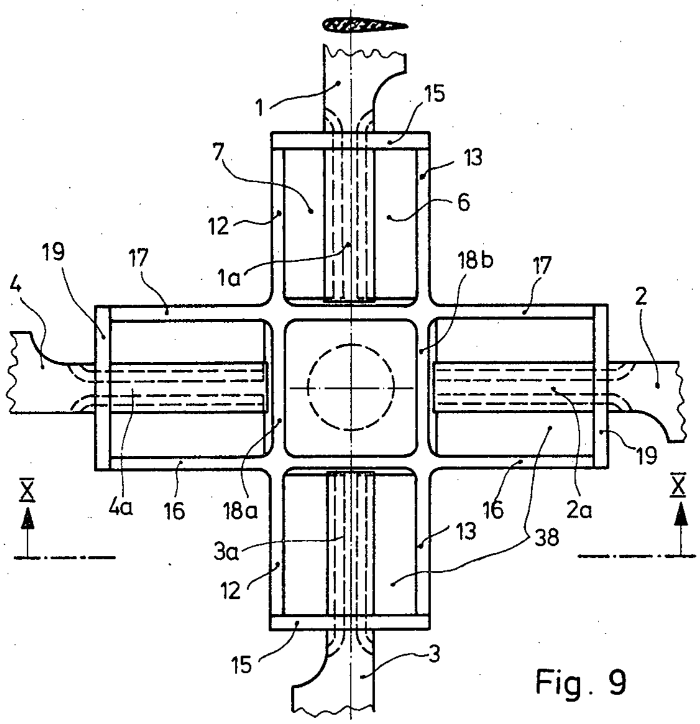
7
6
13
16
2
4
9
24
8
14

Fig. 10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15
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13
12
6
1a
19
17
18b
17
4
2
X
4a
16
18a
16
2a
19
X
3a
13
38
12
15
3

Fig. 9

1584099 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 6

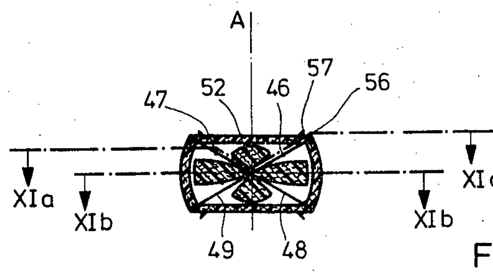

Fig. 12

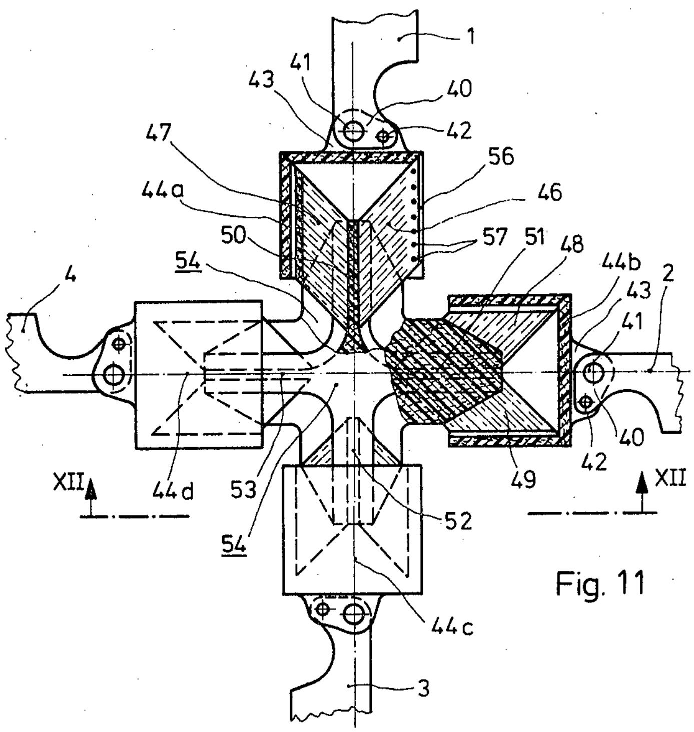

Fig. 11