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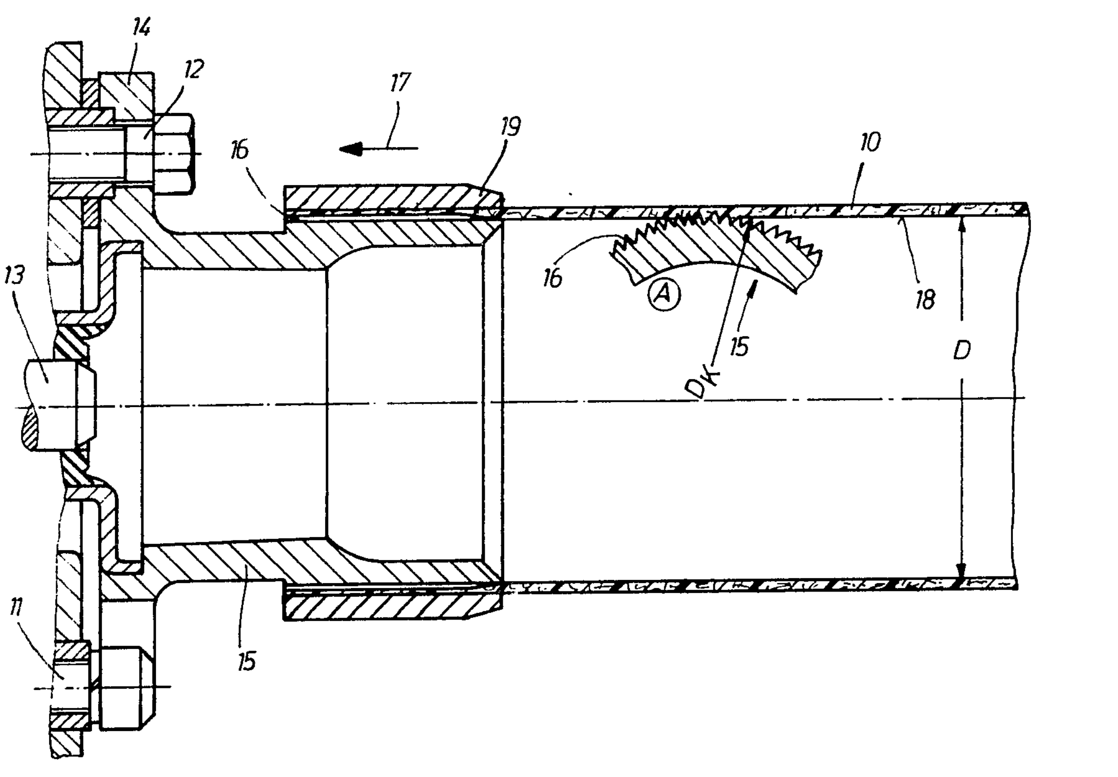
(54) A connecting junction for fibre reinforced plastics tube

(57) The connecting junction is for joining a fibre-reinforced plastics tube 10 which comprises a drive shaft of a vehicle to a connecting element 15, (29). The connecting element, which may be of metal has peripheral toothing or splining 16, (30) and is pressed onto the tube 10 so that the toothing 16, (30) cuts into the tube 10 to provide a rotationally fast connection. The connecting element 15, 29 may fit onto the outer or inner periphery of the tube and a concentric supporting element 19, (32) is secured to the other periphery of the tube to provide additional strength.

(A) is a segmental cross-section of the connecting element.

The cross section of the toothing (16) may be triangular or trapezoidal and may have rounded or straight flanks.

Fig.1



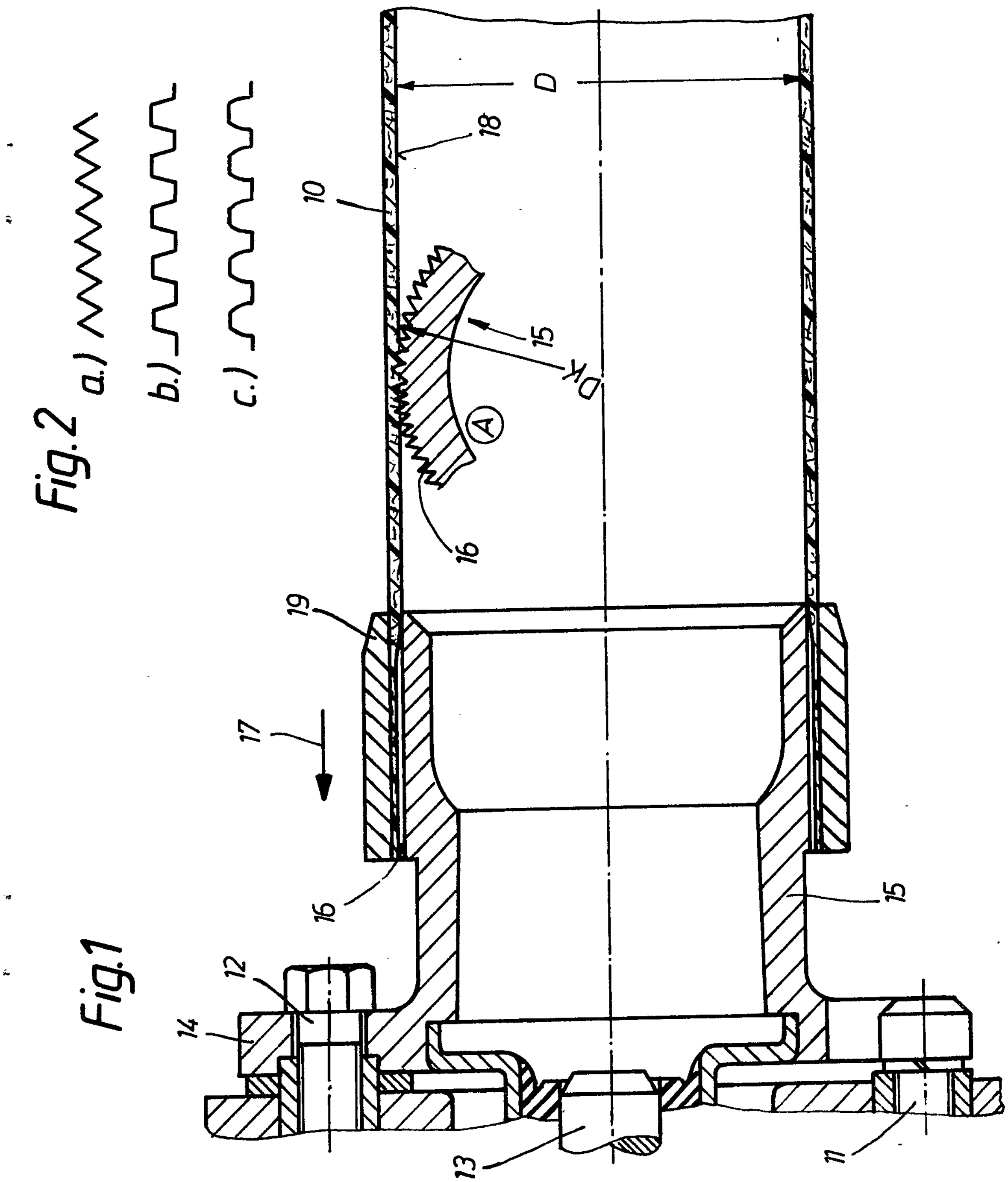


Fig.2

Fig.1

Fig. 3

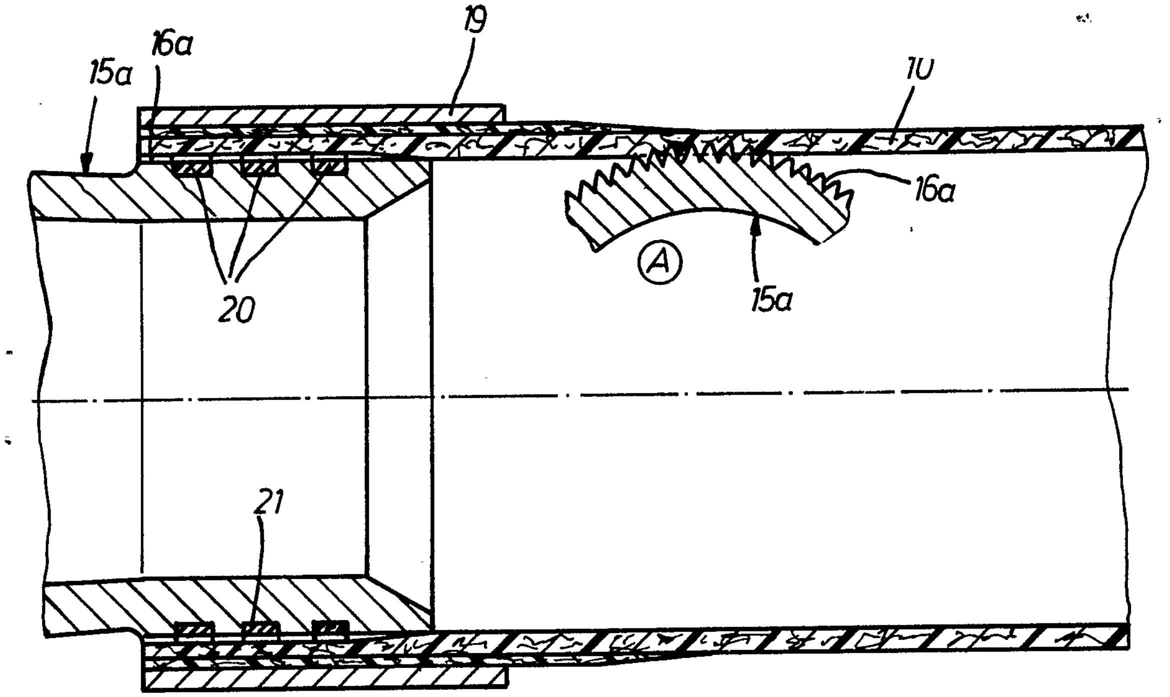
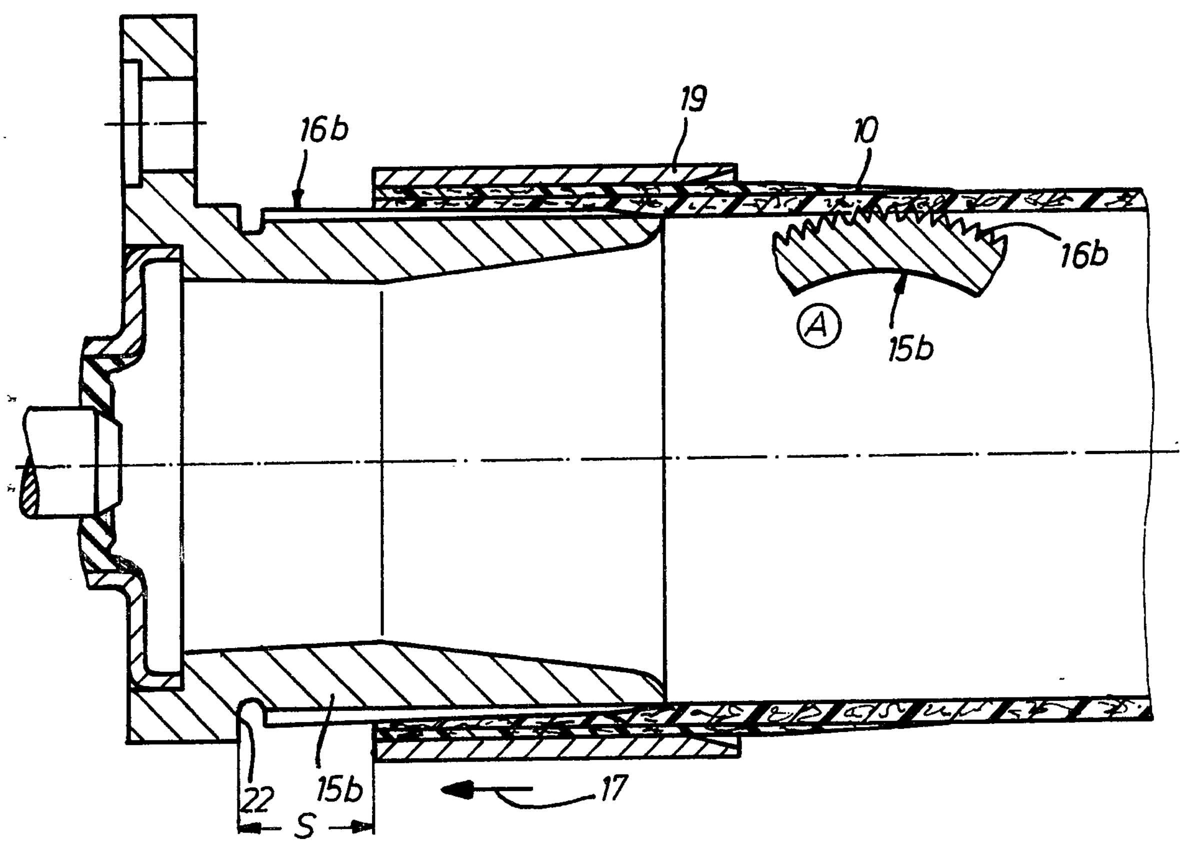


Fig. 4



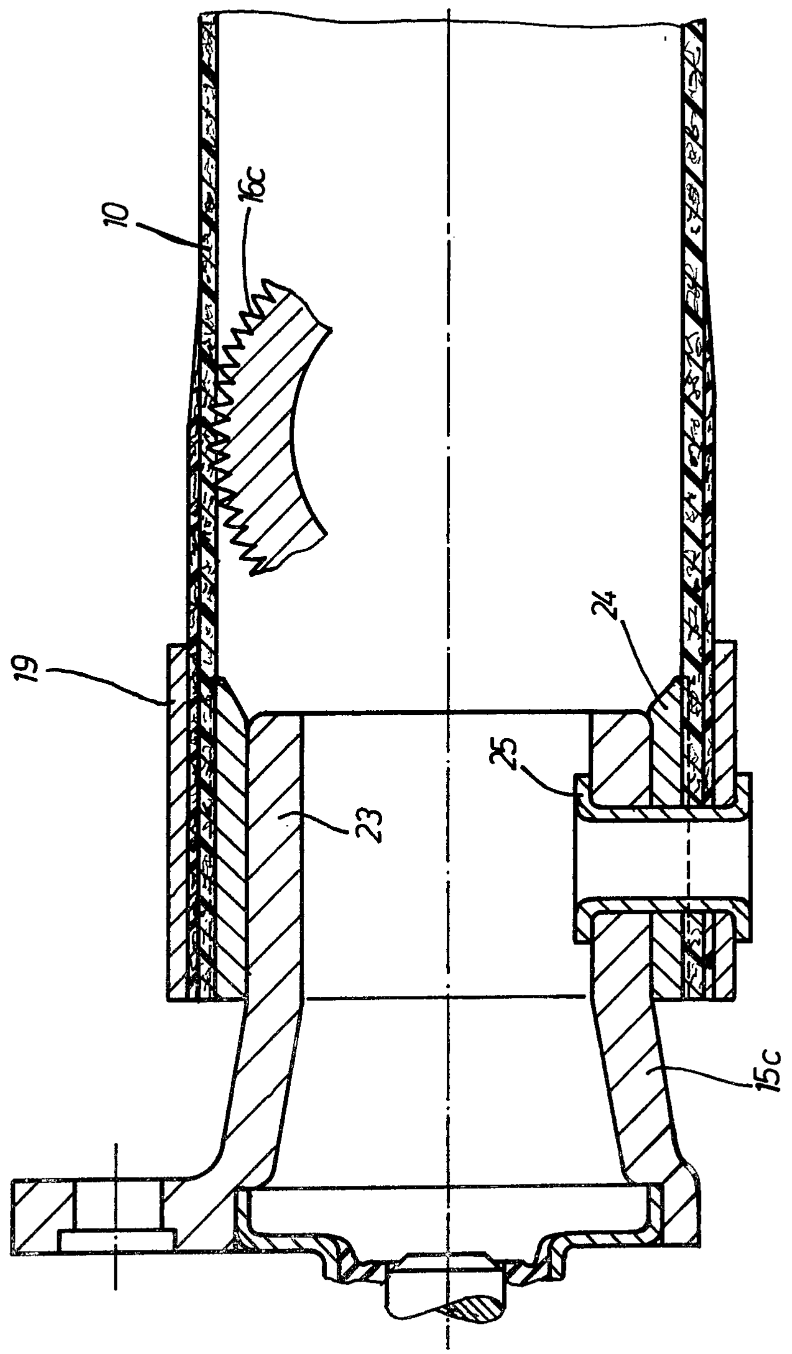


Fig.5

Fig. 7

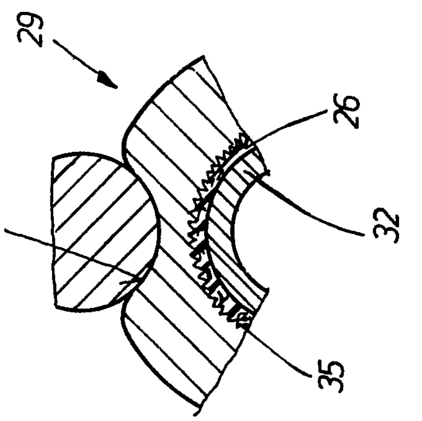
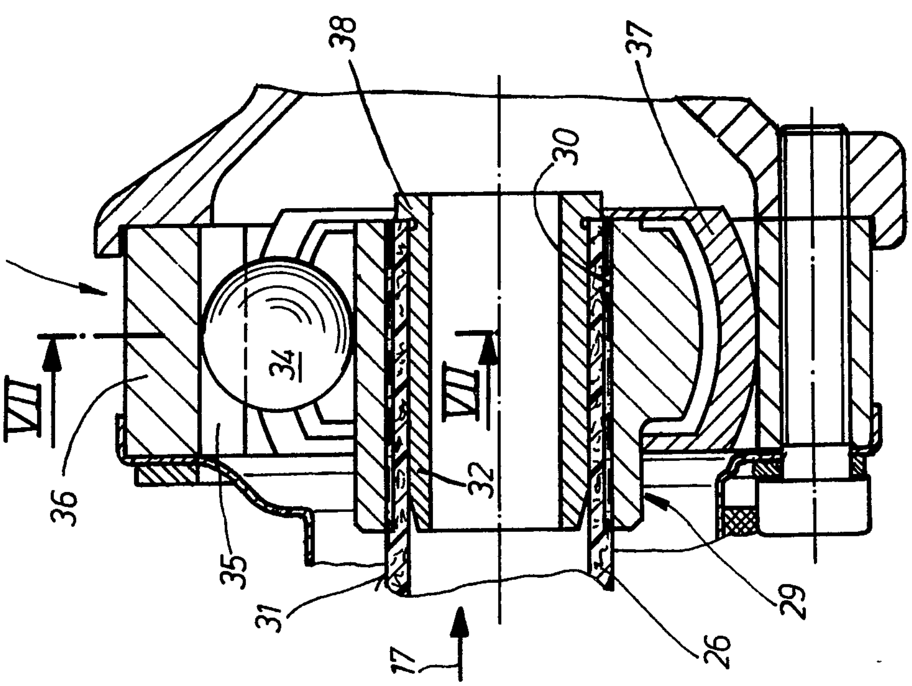


Fig.6



SPECIFICATION

Connecting junction for fibre-reinforced plastics tubes

The invention relates to a connecting junction for fibre-reinforced plastics tubes, particularly but not exclusively for driving or driven hollow shafts of motor vehicles, the fibre-reinforced plastics tube being joined in a rotationally fast manner to a connecting element which is arranged concentrically to said tube.

As a result of intensive efforts in automotive engineering to reduce vehicle weight, it has become increasingly common to substitute materials of lower density, especially plastics, for conventional materials such as, for example, steel. In so doing, difficulties naturally arise with those parts which have to transmit high forces or torque. The cardon shaft, but also the axle shafts leading to the wheels from the differential are particular examples of such parts.

It is already known from US Patent Specification 4,089,190 to manufacture drive shafts as such from a carbon fibre-reinforced plastics material. In fact, when the fibres are arranged specifically in respect of the direction of power transmission, fibre-reinforced plastics tubes of this type are entirely suitable, in terms of strength, for transmitting high torques. The difficulty is to produce a heavy-duty rotation-proof connecting junction of the fibre-reinforced plastics tube to a driving shaft, or—when the fibre-reinforced plastics tube itself is the driving shaft—to a driven shaft.

One connecting junction has already been proposed in which a plastics tube reinforced with carbon fibres is provided with connecting elements at its two ends. The connecting elements each consist of two coaxial sleeves between which the respective end of the fibre-reinforced plastics tube is glued in. The inner sleeve is designed, here, as a hexagon. In the region between the sleeves, the ends of the fibre-reinforced plastics tube are provided with perforations which are filled with the adhesive. The connection already proposed is, therefore, essentially a frictional connection.

A certain positive locking of the connection depends merely on the limited strength of the introduced adhesive after it has hardened. Thus, the torque is transmitted into the fibre-reinforced plastics tube in several ways. Essentially, the glued bond between the outer surface of the fibre-reinforced plastics tube and the inner wall of the outer sleeve is provided for this purpose, that is to say frictional rotary connection. If this frictional rotary connection were to fail, the above-mentioned positively locked connection via the perforations filled with adhesive and via the hexagon of the inner sleeve is relied upon.

The above-described connecting junction according to the state of the art has, on the one hand, the disadvantage that a relatively large number of parts co-ordinated with one another are required. Furthermore, centering problems arise when these parts have to be aligned exactly coaxially to one another. Also, it is at the very least doubtful whether the proposed connecting junction is at all capable of transmitting the high torque which occurs in motor vehicle drive lines. Finally, the proposed connecting junction also requires a relatively large assembly space, on the one hand because of the plurality of parts used, but on the other hand also because a gap of considerable width must be provided for the adhesive layer to be introduced, so that the hardened adhesive layer is subsequently capable of accommodating temperature changes in the manufacture and operation of the shaft in question, or the changes in length of the connecting parts which are associated with these temperature changes. To be emphasized as a special disadvantage of the proposed connecting junction is the fact that the adhesive connection does not possess the long-term durability demanded in motor vehicles.

The object of the present invention is to design a connecting junction for fibre-reinforced tubes, in such a way that it can be produced simply, makes do with only a few parts, permits a space-saving method of construction and, furthermore, can transmit high torques even in continuous operation, with a required degree of durability.

According to the invention there is provided a connecting junction for fibre-reinforced plastics tubes, in which the fibre-reinforced plastics tube is secured in a rotationally fast manner to a connecting element arranged concentrically to said tube, wherein the connecting element has a peripheral toothing and is pressed onto the fibre-reinforced plastics tube in such a way that the connecting element effects a positively locked rotationally fast junction with the fibre-reinforced plastics tube.

The invention makes it possible, in a surprising way, to produce a positively locked hollow-shaft junction which is suitable for transmitting extremely high torques and in which a toothing needs to be formed into the connecting element only. The corresponding counter-toothing in the fibre-reinforced plastics tube is obtained automatically as a result of the action of the above-mentioned toothing in the connecting element. Here, the connecting element can appropriately consist of metal, for example steel, whereas the hollow-shaft to be connected to it in a rotationally fast manner can be made of a carbon fibre-reinforced plastics material.

It is, of course, already known, per se, to make positively locked rotary connections by means of splines on the parts which are to be connected to one another. However, in contrast to known shaft or hollow-shaft splines, it must be remembered, in the present invention that the corresponding toothing in the fibre-reinforced plastics tubes is not formed beforehand by machining, but is obtained only at the time of assembly with the connecting element. Per se, it would have been expected here that, because of the notch effect arising as a result of the incising action of the toothing of the connecting element, a considerable weakening of the fibre-reinforced plastics tube in terms of strength, precisely in the region of connection, should have occurred. However, it has been shown, in practice, that the ability of the fibre-reinforced plastics tube to absorb or to transmit high torsional moments is in no way impaired by the "notch effect". Rather, the connecting junction according to the invention has proved, in tests, to be eminently suitable for motor vehicles.

When the basic idea of the invention has been put into practice, it has been shown to be appropriate to support, in the opposite direction, the raidial forces which are exerted by the toothing of the connecting element onto the fibre-reinforced pastics tube. In a development of the basic idea of the invention, it is therefore proposed to arrange the fibre-reinforced plastics tube concentrically between the connecting element having the peripheral toothing, and a sleeve-like supporting element. In a practical realisation of the basic idea of the invention, it is also proposed that the connecting element should have an external toothing and that the fibre-reinforced plastics tube be pushed, onto the external toothing of the connecting element, in such a way that the external toothing cuts into or engages with the inner wall of the fibre-reinforced plastics tube. However—conversely—it is also possible as an alternative to provide the sleeve-shaped connecting element with an internal toothing and to push it onto the assigned end of the fibre-reinforced plastics tube in such a way that the internal toothing cuts into or engages wirh the outer wall of the fibre-reinforced plastics tube. Furthermore, the connecting element and supporting element can—in a one-part or multipart design—each be provided with a toothing on their sides facing one another, so that, when a plastics tube is inserted between them, and the connecting element and supporting element are joined in a rotationally fast manner, torques can be transmitted directly both from the connecting element and from the supporting element to the fibre-reinforced plastics tube inserted between them.

Embodiments of the invention will now be described by way of example and with reference to the accompanying drawings in which:

Figure 1 shows, in longitudinal section, one embodiment of a connecting junction with an externally toothed connecting element engaging into the hollow shaft,

Figure 2 shows three possible tooth forms for the toothing of the connecting element,

Figures 3 to 5 show, in an illustration similar to Fig. 1, further embodiments of a connecting junction, each with an externally toothed connecting element,

Figure 6 shows, in longitudinal section, an embodiment of a connecting junction with an internally toothed connecting element engaging round the hollow shaft, and

Figure 7 shows a segment-shaped out-out of a cross-sectional representation of the embodiment according to Fig. 6.

According to Fig. 1, 10 designates a hollow shaft made of a fibre-reinforced plastics material, for example a carbon fibre-reinforced plastics. This can be, for example the cardan shaft of a motor vehicle, which is coupled, at 11,12 to the transmission output shaft indicated as a stub and designated by 13. The flanging of the cardan shaft of a motor vehicle to the transmission output, is, moreover, assumed to be known.

The connecting flange which is provided for connecting the cardan shaft 10 to the transmission output in a manner proof against relative rotation is designated by 14. This flange is not directly an integral part of the fibre-reinforced plastics shaft 10 itself, but rather of a sleeve-shaped metal connecting element 15. Part of the connecting element 15 is also shown in cross-section—designated by A—in the form of a segment-shaped cut-out. Particularly the cross-sectional representation of the part 15 makes it clear that the connecting element 15 has a peripheral toothing 16, the teeth of which run axially in the manner of a spline, the crown-circle diameter D_K being larger than the inside diameter D of the fibre-reinforced plastics tube 10. The two parts 15 and 10 are brought into the assembly position evident from Fig. 1, due to the fact that the part 10 is pushed onto the connecting element 15 in the direction of the arrow 17. As a result of the applied pressure to be exerted in so doing, on the one hand, and of the diameter differences (D_K and D), on the other hand, the toothing 16 of the metal connecting element 15 automatically cuts into the inner wall 18 of the fibre-reinforced plastics tube 10 and thereby provides a junction positively locked against relative rotation between the parts 10 and 15. Serving to support the positively locked toothed joint between the parts 10 and 15 is a sleeve-like supporting element 19 which consists of metal or other appropriate material and which can be attached to the outer surface of the fibre-reinforced plastics tube 10, for example, by shrinking, winding or pressing.

The embodiment according to Fig. 3 corresponds essentially to the embodiment according to Fig. 1, and parts corresponding to one another bear the same reference numerals. The difference from the embodiment according to Fig. 1 is merely that the connecting element 15*a* possesses on its outer periphery several circumferential grooves 20 which are spaced from one another and which, in the assembly position emerging from Fig. 3, are filled with a resin or a similar plastics material. The grooves 20 are filled with resin which is designated in Fig. 3 by reference 21. As a result, on the one hand, an axial fixing of parts 10, 15*a* and, furthermore, a better transmission of the torque from the part 10 and the part 15*a*, or vice versa, are achieved.

The embodiment according to Fig. 4 also corresponds essentially to the embodiment according to Fig. 1, so that here also the respective parts bear the same reference numerals. The essential feature of the embodiment according to Fig. 4, which differs from the above-described embodiments, is that the connecting element 15*b* has a toothing 16*b* with a tooth depth which increases uniformly to a maximum depth in the axial direction of assembly as indicated by the arrow 17 of the fibre-reinforced plastics tube 10. On the one hand, this measure makes it easier to assemble the parts 10 and 15*b*, because at the beginning, the pressing forces to be applied in the direction of the arrow 17 are comparatively small, owing to the initially still small tooth depth of the toothing 16*b* and they increase only gradually up to the end position. Fig. 4 shows, for example the final assembly position of the parts 10 15*b*. It becomes clear from this that it would be possible, per se, to push the fibre-reinforced plastics tube 10 a further displacement distance *s* onto the toothing 16*b*, until it came to rest with its end face against an axial stop 22. This remaining distance *s* is provided for possible accidents, for example a frontal impact of the vehicle against an obstruction, in which the parts 10 and 15*b* can be pushed into one another. A possibility of this kind would be provided, for example, if the fibre-reinforced plastics tube 10 were used as cardan shaft. During the time in which the parts 10, 15*b* execute the above-described axial movement relative to one another, the toothing 16*b* cuts itself more and more deeply into the fibre-reinforced plastics tube 10, as a result of which, advantageously, a part of the kinetic energy generated in the accident is converted into deformation energy and thus used up.

As an additional measure to the splining described, the cylindrical inner space of the fibre reinforced plastics tube 10 could also be made to diverge conically outwards at its end. This measure, also, would contribute to making assembly easier.

In an alternative embodiment shown in Fig. 5—differing from the above-described embodiments—the connecting element designated here by 15*c* consists of two parts arranged concentrically to one another, namely, on the one hand, a tubular inner part 23 and, on the other hand, a sleeve-shaped outer part 24 which encloses the part 23 concentrically and is connected thereto in a manner proof against rotation and which has external toothing 16*c* engaging with the fibre-reinforced plastics tube 10. The parts 23, 24 are joined together, namely both in the axial direction and in the direction of rotation, by means of a pressed-in metal sleeve 25 resembling a tubular rivet. However, in the embodiment according to Fig. 5, the metal sleeve 25 passes through not only the two parts 23, 24 of the connecting element 15*c* but also the fibre-reinforced plastics tube 10 itself and the supporting element 19 which surrounds the latter. The metal sleeve 25 which is pressed into radial bores, appropriately aligned with one another, in the parts 19, 10, 24 and 23, not only guarantees an axial fixing of these parts relative to one another, but also exerts a certain additional toothing effect in the direction of rotation. It it is, of course, appropriate not only to provide the one metal sleve 25 shown in Fig. 5, but to arrange several such metal sleeves ar regular intervals about the periphery of the tube. It would also be possible to modify the embodiment illustrated in Fig. 5, so that the metal sleeve resembling a tubular rivet passes through only the parts 19, 10 and 24, a junction secured against relative rotation being effected between the parts 24 and 23 by means of toothing.

The embodiment according to Fig. 5 with a continuous metal sleeve 25 has, however, the fundamental advantage that a sufficient radial depth is available for the hole wall.

In the embodiment according to Figs. 6 and 7, the fibre-reinforced plastics tube designated here by 26 is used as the half-shaft of a motor vehicle. Figs. 6 and 7 illustrate the outer end of such a half-shaft, at which end the driving forces are transmitted to the assigned vehicle wheel (not shown) via a constant-velocity joint. In the embodiment according to Figs. 6 and 7, the connecting element for the fibre-reinforced plastics tube 26 is designated by 29. Differing from the embodiments according to Figs. 1 and 3 to 5, it does not engage into the fibre-reinforced plastics tube 26 on the inside, but rather engages over the latter on its outer periphery. As illustrated especially in Fig. 7, the connecting element 26 has an internal toothing 30 by means of which it cuts into the outer wall 31 of the fibre-reinforced plastics tube 26. In the embodiment according to Figs. 6 and 7, a sleeve-shaped supporting body 32 which is pushed (for example pressed or shrunk) into the end of the fibre-reinforced plastics tube 26 is provided for supporting radially the tooth forces of the connecting element 29 which are, in this case, directed radially inwards.

A further special feature of the embodiment according to Figs. 6 and 7 is that here the connecting element 29 constitutes a the same time the radially inner driving part of the constant-velocity joint. As shown in Fig. 7, the driving part (connecting element 29) of the constant-velocity joint has on its periphery several (at least three) spherical depressions 33, in each of which a ball 34 is held. As illustrated in Fig. 6, the upper part of the balls 34 engages into a groove-shaped recess 35 of an annular radially outer part 36 of the constant-velocity joint. The balls 34 are held in the centre by a cage 37, the driving torque of the half-shaft (fibre-reinforced plastics tube 26) is thus transmitted from the inner bearing part (connecting element 29) via the balls 34 to the outer part 36 whence it is introduced to the vehicle wheel (not shown).

As also shown in Fig. 6, the possibility arises of modifying the embodiment shown there, so that the sleeve-shaped supporting body 32 has a flange 38 which engages radially over the fibre-reinforced plastics tube 26 at its end which can then be joined firmly to the connecting element 29. It would also be conceivable to make the parts 29, 32 in one piece. An even firmer interlocking of the fibre-reinforced plastics tube 26 with the parts 29, 32 is effected if the supporting part 32 is likewise provided on its outer periphery with a toothing which cuts into the fibre-reinforced plastics tube from inside.

As a further alternative, it is, of course, possible to apply even to the embodiment according to Figs. 6 and 7 the arrangement described with reference to Fig. 4 by providing a spline-like toothing of increasing depth between the parts 26 and 29. However, in so doing, the crown-circle diameter of the toothing (internal toothing 30) of the connecting part 29 must—in a kinamatic reversal decrease uniformly in the direction of assembly 17. Additionally or alternatively to this measure, the outside diameter of the fibre-reinforced plastics tube 26 can also be made to taper uniformly towards the end. As a result, it is likewise ensured that assembly is made easier, as already mentioned above.

CLAIMS

1. A connecting junction for fibre-reinforced plastics tubes, in which the fibre-reinforced plastics tube is secured in a rotationally fast manner to a connecting element arranged concentrically to said tube, wherein the connecting element has a peripheral toothing and is pressed onto the fibre-reinforced plastics tube in such a way that the connecting element effects a positively locked rotationally fast junction with the fibre-reinforced plastics tube.

2. A connecting junction according to claim 1, wherein the fibre-reinforced plastics tube is arranged concentrically between the connecting element having the peripheral toothing and a supporting element.

3. A connecting junction according to claim 1 or 2, wherein the connecting element has an external toothing and the fibre-reinforced plastics tube is pushed onto the external toothing of the connecting element, in such a way that the external toothing cuts into or engages with the inner wall of the fibre-reinforced plastics tube.

4. A connecting junction according to claim 2 or 3, wherein that end of the fibre-reinforced plastics tube which is connected to the external toothing of the connecting element is surrounded by a sleeve part which comprises said supporting element.

5. A connecting junction according to claim 4, wherein the sleeve part fits round the end of the fibre-reinforced plastics tube.

6. A connecting junction according to claim 5 wherein the sleeve part is fitted to the plastics tube with a degree of pre-stressing.

7. A connecting junction according to any one of the preceding claims, wherein the connecting element has in the toothing region at least one circumferential groove which is incised at least as far as the tooth base and which is filled with resin or with a technically equivalent plastics material.

8. A connecting junction according to any one of the preceding claims, wherein the connecting element consists of a tubular inner part and of a sleeve-shaped outer part which encloses the latter concentrically and is joined to the latter in a rotationally fixed manner and which has the external toothing.

9. A connecting junction according to claim 8, wherein the tubular inner part, the sleeve-shaped outer part, the end of the fibre-reinforced plastics tube and the outer supporting element are additionally joined to one another in a positively locked manner by one or more radially directed pressed-in metal sleeves comprising tubular rivet (s).

10. A connecting junction according to claim 1 or 2, wherein the connecting element is provided with the peripheral toothing on its inner periphery and is pushed onto the assigned end of the fibre-reinforced plastics tube in such a way that the peripheral toothing cuts into or engages with the outer wall of the fibre-reinforced plastics tube.

11. A connecting junction according to claim 10, for axle shafts of motor vehicles with torque transmission by means of a constant-velocity joint, wherein the connecting element is also adapted to constitute the radially inner driving part of the constant-velocity joint.

12. A connecting junction according to claim 2, 10 or 11, wherein a sleeve-shaped supporting body located in the end of the fibre-reinforced plastics tube serves as a supporting element.

13. A connecting junction according to claim 12 wherein the supporting body is fitted in the end of the plastics tube.

14. A connecting junction according to claim 12 or 13 wherein the sleeve-shaped

supporting body has an external toothing engaging with the inner wall of the fibre-reinforced plastics tube and is joined to the connecting element to form a single component by means of a flange which engages radially over the end of the fibre-reinforced plastics tube.

15. A connecting junction according to any one of the preceding claims, wherein the connecting element has a splining with a tooth depth which increases uniformly to a maximum in the axial direction of assembly of the fibre-reinforced plastics tube with the connecting element.

16. A connecting junction according to claim 14, wherein, an axial stop for the end position of the fibre-reinforced plastics tube during the axial displacement of same is provided at that end of the splining which has maximum tooth depth.

17. A connecting junction according to claim 15 or 16 wherein the splining is provided on the outer periphery of the connecting element and has a crown-circle diameter which increases uniformly in the direction of assembly of the fibre-reinforced plastics tube with the connecting element.

18. A connecting junction according to claim 15, 16 or 17, wherein the fibre-reinforced plastics tube has, at its end which engages with the connecting part an inside diameter which increases uniformly outwards.

19. A connecting junction according to claim 15 or 16 wherein the splining is provided on the inner periphery of the connecting part and has an inside diameter (crown-circle diameter) which decreases uniformly in the direction of assembly of the fibre-reinforced plastics tube with the connecting element.

20. A connecting junction according to claim 15, 16 or 19, wherein the fibre-reinforced plastics tube has, at its end which engages with the connecting part an outside diameter which decreases uniformly in the direction of assembly.

21. A connecting junction according to any one of the preceding claims, wherein the connecting element is joined in a positively locked fashion to the supporting element in rotationally fast manner and the connecting element and supporting element are each provided with peripheral toothing on their sides facing one another.

22. A connecting junction according to any one or more of the preceding claims, wherein the toothing of the connecting element is triangular in cross-section.

23. A connecting junction according to any one or more of claims 1 to 21, wherein the toothing on the connecting element is trapezoidal.

24. A connecting junction according to claim 22 or 23, wherein the toothing on the connecting element has straight flanks.

25. A connecting junction according to claim 22 or 23, wherein the toothing on the connecting element has rounded flanks.

26. A connecting junction for a fibre-reinforced plastics tube comprising a driving or driven shaft of a motor vehicle, substantially as described herein with reference to and as illustrated in Figs. 1 and 2, or Figs. 1 and 2 as modified by Figs. 3 or 4, or 5, or 6 and 7 of the accompanying drawings.

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