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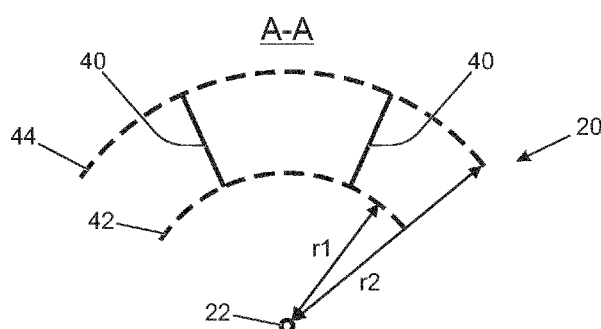


Fig.4

(57) Abstract: A driveshaft tube 20 extending lengthwise in a longitudinal direction, comprising: material defining, in transverse radial cross-section, a plurality of azimuthally separated radially extending projections 40 extending radially between an azimuthally extending inner limit 42 at a first radius and an azimuthally extending outer limit 44 at a second radius, wherein the first radius is at least 20% of the second radius; and material 50 extending azimuthally along one or both of the inner limit and the outer limit interconnecting the azimuthally separated radially extending projections, wherein the azimuthally separated radially extending projections extend wholly between the inner limit at the first radius and the outer limit at the second radius, and in the longitudinal direction for at least 20% of the length of the driveshaft tube.



DRIVESHAFT TUBE

TECHNICAL FIELD

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The present disclosure relates to a driveshaft tube. In particular, but not exclusively it relates to a driveshaft tube for a vehicle.

Aspects of the invention relate to a driveshaft tube, a method, and a vehicle.

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BACKGROUND

A driveshaft tube, also known as a propeller shaft, is used as a mechanical drivetrain component for transmitting torque and rotation between two locations in a vehicle. Some vehicles employ a centre driveshaft tube to deliver power from an engine, transmission or transfer case to a differential at the other end of the vehicle. A pair of short transverse drive axles is a pair of short driveshaft tubes commonly used to send power from a central differential, transmission, or transaxle to respective vehicle wheels.

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It is desirable to reduce the rotational mass of the vehicle drivetrain by utilizing lightweight thin-walled driveshaft tubes. However lightweight thin-walled driveshaft tubes can lack bending stiffness and torsional stiffness. As a result, the driveshaft tube is able to oscillate in normal use, in a manner that is distracting to a vehicle occupant.

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It is an aim of the present invention to address disadvantages of the prior art.

SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a driveshaft tube, a method and a vehicle as claimed in the appended claims.

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According to an aspect of the invention there is provided a driveshaft tube extending lengthwise in a longitudinal direction, comprising: a first portion configured to receive torque from a component, a second portion configured to transfer torque to another component and

a third portion. The third portion is made from material defining, in transverse radial cross-section, a plurality of azimuthally separated radially extending projections extending radially between an azimuthally extending inner limit at a first radius and an azimuthally extending outer limit at a second radius, wherein the first radius is at least 20% of the second radius; and material at the inner limit and/or the outer limit and/or between the inner limit and the outer limit interconnecting the azimuthally separated radially extending projections, wherein the azimuthally separated radially extending projections extend wholly between the inner limit at the first radius and the outer limit at the second radius, and in the longitudinal direction for at least 20% of a length of the driveshaft tube wherein the radially extending portions of the third portion do not receive torque from or transfer torque to any other component.

This provides the advantage of increasing the bending and/or torsional stiffness of the driveshaft tube without significantly increasing the mass of the driveshaft tube.

The material interconnecting the azimuthally separated radially extending projections may be at only one of the inner limit and the outer limit such that the azimuthally separated radially extending projections are cantilevered at one limit and unattached (free-standing) at the other limit. For example, the material interconnecting the azimuthally separated radially extending projections may be at only the inner limit such that the azimuthally separated radially extending projections are free-standing and outwardly projecting at the outer limit. Alternatively, the material interconnecting the azimuthally separated radially extending projections may be at only the outer limit such that the azimuthally separated radially extending projections are free-standing and inwardly projecting at the inner limit.

This provides the advantage of enabling a smaller and lighter driveshaft tube than an equivalent without ribs, but having the same bending stiffness. Reducing weight and/or increasing stiffness of the driveshaft tube increases the bending frequency at which a bending mode of vibration equates to the rotational speed of the driveshaft tube.

Alternatively, the material interconnecting the azimuthally separated radially extending projections may be at both of the inner limit and the outer limit. The interconnecting material at the inner limit and at the outer limit may form concentric tube shapes connected to each other by the azimuthally separated radially extending projections.

The material defining the plurality of azimuthally separated radially extending projections and the material interconnecting the azimuthally separated radially extending projections may be formed from continuous material, for example, a common piece of continuous material.

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This provides the advantage that the completed driveshaft tube can be formed quickly and at a reduced cost, has increased strength, and avoids chemical interactions between different materials.

10 The material defining the plurality of azimuthally separated radially extending projections may comprise aluminium and the material interconnecting the azimuthally separated radially extending projections may comprise aluminium. In other examples the material defining the plurality of azimuthally separated radially extending projections comprises a first material and the material interconnecting the azimuthally separated radially extending projections
15 comprises a second different material. The first material can be selected from the group comprising: steel; aluminium; composite material. The second material can be a different material selected from that group.

This provides the advantage that a completed length of driveshaft tube can be formed using
20 a single moulding or extrusion process, facilitated by the use of an easily workable metal.

The first radius and/or second radius may be constant over at least an incremental length of the driveshaft tube in the longitudinal direction. The azimuthally separated radially extending projections may extend longitudinally in the longitudinal direction for at least 20% of a length
25 of the driveshaft tube and while extending longitudinally, extend wholly between a constant value of the inner limit at a constant value of the first radius and a constant value of the outer limit at a constant value of the second radius. The azimuthally separated radially extending projections may extend longitudinally in the longitudinal direction for at least 20% of a length of the driveshaft tube without change in azimuth.

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This provides the advantage that a completed length of driveshaft tube can be readily formed using an extrusion process.

According to another aspect of the invention there is provided a method of forming a driveshaft tube extending lengthwise in a longitudinal direction comprising forming a first portion configured to receive torque from a component, forming a second portion configured to transfer torque to another component, and forming a third portion. Forming a third portion comprises providing material defining, in transverse radial cross-section, a plurality of azimuthally separated radially extending projections extending radially between an azimuthally extending inner limit at a first radius and an azimuthally extending outer limit at a second radius, wherein the first radius is at least 20% of the second radius; and providing material at the inner limit and/or the outer limit and/or between the inner limit and the outer limit interconnecting the azimuthally separated radially extending projections, wherein the azimuthally separated radially extending projections extend wholly between the inner limit at the first radius and the outer limit at the second radius, and in the longitudinal direction for at least 20% of a length of the driveshaft tube.

The material defining the plurality of azimuthally separated radially extending projections and the material interconnecting the azimuthally separated radially extending projections may be moulded from a common piece of continuous material.

This provides the advantage that a completed length of driveshaft tube can be readily formed using an extrusion process.

According to a further aspect of the invention there is provided a driveshaft tube extending lengthwise in a longitudinal direction, comprising: material defining, in transverse radial cross-section, a plurality of azimuthally separated radially extending projections extending radially between an azimuthally extending inner limit and an azimuthally extending outer limit; and material at one or both of the inner limit and the outer limit interconnecting the azimuthally separated radially extending projections.

According to a further aspect of the invention there is provided a driveshaft tube extending lengthwise in a longitudinal direction, comprising: a first portion configured to receive torque from a component, a second portion configured to transfer torque to another component and a third portion The third portion comprising material defining, in transverse radial cross-section, a plurality of angularly spaced ribs extending radially between a circumferentially extending inner limit at a first radius and a circumferentially extending outer limit at a second

radius, wherein the first radius is at least 20% of the second radius; and material at the inner limit and/or the outer limit and/or between the inner limit and the outer limit interconnecting the angularly spaced ribs, wherein the angularly spaced ribs extend wholly between the inner limit at the first radius and the outer limit at the second radius, and in the longitudinal
5 direction for at least 20% of a length of the driveshaft tube.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features
10 thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally
15 claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

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Fig. 1 illustrates an example of a vehicle;

Fig. 2 illustrates an example of a driveshaft tube;

Fig. 3A illustrates an example of a cylindrical coordinate system in a first plane and Fig. 3B illustrates an example of the cylindrical coordinate system in a second plane;

25 Fig. 4 illustrates an example of azimuthally separated radially extending projections for a driveshaft tube;

Fig. 5A illustrates another example of a driveshaft tube, Fig. 5B illustrates another example of a driveshaft tube, and Fig. 5C illustrates another example of a driveshaft tube;

30 Fig. 6A illustrates another example of a driveshaft tube, Fig. 6B illustrates another example of a driveshaft tube, and Fig. 6C illustrates another example of a driveshaft tube;

DETAILED DESCRIPTION

The Figures illustrate a driveshaft tube 20 extending lengthwise in a longitudinal direction, comprising: material defining, in transverse radial cross-section, a plurality of azimuthally separated radially extending projections 40 extending radially between an azimuthally extending inner limit 42 at a first radius r_1 and an azimuthally extending outer limit 44 at a second radius r_2 , wherein the first radius r_1 is at least 20% of the second radius r_2 ; and material 50 at one or both of the inner limit 42 and the outer limit 44 interconnecting the azimuthally separated radially extending projections 40, wherein the azimuthally separated radially extending projections 40 extend wholly between the inner limit 42 at the first radius r_1 and the outer limit 44 at the second radius r_2 , and in the longitudinal direction for at least 20% of a length of the driveshaft tube 20.

Fig. 1 illustrates an example of a suitable vehicle 10 within which the driveshaft tube 20 (not illustrated) could be incorporated. The vehicle 10 may be a passenger vehicle. Passenger vehicles generally have kerb weights of less than 5000 kg.

A driveshaft tube is used as a mechanical drivetrain component for transmitting torque and rotation between two locations in the vehicle 10. The vehicle 10 may have a centre driveshaft tube to deliver power from an engine, transmission or transfer case to a differential at the other end of the vehicle 10. A driveshaft tube 20 may be used for each of a pair of short transverse drive axles, used to send power from a central differential, transmission, or transaxle to respective vehicle wheels.

The driveshaft tube 20 is lightweight and thin-walled but manufactured, as described below, for good bending stiffness and/or torsional stiffness. This avoids or reduces oscillations in normal use.

Fig. 2 illustrates schematically a driveshaft tube 20 for a vehicle 10 such as the vehicle 10 shown in Fig. 1. The driveshaft tube 20 can be configured to form part of the vehicle drivetrain and therefore to withstand a torque load greater than 50Nm, greater than 100Nm or greater than 200Nm without failure.

The driveshaft tube 20 can be configured as a transverse drive axle for driving a single wheel or as a centre driveshaft for transmitting torque for driving multiple wheels.

The driveshaft tube 20 of Fig. 2 extends lengthwise in a longitudinal direction. The total length LT of the driveshaft tube 20 in the longitudinal direction can be between 300 mm and 4000 mm. The outside diameter W of the driveshaft tube 20, transverse to the longitudinal direction, can be between 20 mm and 300 mm. The total length LT exceeds the outside diameter W.

A centreline axis 22 of the driveshaft tube 20 extends lengthwise in the longitudinal direction. The driveshaft tube 20 has rotational symmetry about the centerline axis 22. The driveshaft tube 20 can define, at least in part, a circular cylinder or a faceted cylinder. The driveshaft tube 20 can be described with reference to a cylindrical coordinate system as shown in Figs. 3A to 3B.

According to the cylindrical coordinate system, a vector **R** is described using three orthogonal coordinates: a radial distance r ; an azimuth ϕ ; and a lengthwise distance z . The radial distance r refers to a magnitude (Euclidean distance) of the vector **R** measured orthogonally from the centreline axis 22. The lengthwise distance z is a magnitude along the centreline axis 22. The azimuth ϕ is the angle between a reference direction REF (on a plane that is orthogonal to the to the centerline axis 22 and contains the point defined by the vector **R**) orthogonal to the centreline axis 22 and the direction of a straight line projection (on the plane) from the centerline axis 22 to the point defined by the vector **R**.

Referring to the cylindrical coordinate system, an azimuthally extending line is defined as a line following a path described by a change in azimuth ϕ (holding the radial distance r and lengthwise distance z constant). An azimuthally extending line can be described as a circumferential line.

Referring to the cylindrical coordinate system, a radially extending line is defined as a path described by a change in radial distance r (holding in the azimuth ϕ and lengthwise distance z constant).

Referring to the cylindrical coordinate system, azimuthally separated radially extending lines are defined as lines each following a separate path defined by a change in radial distance r (holding azimuth ϕ and lengthwise distance z constant), and the paths are separated from

one another by different azimuth ϕ . An azimuthal separation can be described as an angular spacing.

Referring to the cylindrical coordinate system, a transverse radial cross-section of the driveshaft tube 20 is defined as a cross-section in the chosen plane orthogonal to the centreline axis 22 shown in Fig. 3B.

When the driveshaft tube 20 of Fig. 2 is in use carrying a torque load, internal and external forces act on the driveshaft tube 20, to impart oscillation-inducing loads on the driveshaft tube 20 along the length LT of the driveshaft tube 20. The driveshaft tube 20 is fixed at its longitudinal ends to other vehicle components so that the ends of the driveshaft tube 20 are externally restrained against oscillation in the radial direction. However, along the central longitudinal span of the driveshaft tube 20, the driveshaft tube 20 may be externally unrestrained against oscillation in the radial direction. For illustrative purposes, Fig. 2 shows a length LP representing the length of a central longitudinal region along the span of the driveshaft tube 20.

Along the central longitudinal region, the bending stiffness of the driveshaft tube 20 is a primary factor controlling the ability of the driveshaft tube 20 to resist deflection of the driveshaft tube 20 in the radial direction. The length LP can extend over 20% or more of the length LT of the driveshaft tube 20. If the bending stiffness of the driveshaft tube 20 is insufficient, the driveshaft tube 20 can oscillate significantly in use, especially in its resonant mode or modes. The oscillation comprises reciprocating movement of the driveshaft tube 20 in the radial direction. The magnitude of the oscillation is greatest along the central longitudinal region. The oscillation can fatigue the driveshaft tube 20 and/or increase noise, vibration and harshness experienced by vehicle occupants.

It will be understood that the driveshaft tube 20 need not necessarily be fixed at its longitudinal ends but rather may be constrained at any torque transfer portion such that it can receive torque from one or more vehicle components and transfer torque to one or more other vehicle components. The driveshaft also includes one or more other portions which do not receive torque from or transfer torque to vehicle components. One or more of these other portions may include features as described below to increase the stiffness of a driveshaft tube. These other portions may or may not be contiguous with the torque transfer portions.

Various examples will be described showing how the stiffness of the driveshaft tube 20 can be increased without significantly increasing the mass of the driveshaft tube 20.

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Fig. 4 shows a transverse radial cross-section A-A through a driveshaft tube 20 such as the one shown in Fig. 2. Fig. 4 shows an example of azimuthally separated radially extending projections 40 ('projections') for increasing the bending and/or torsional stiffness of the driveshaft tube 20.

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Only a single arbitrary sector of the driveshaft tube 20 is shown in Fig. 4 for illustrative purposes.

The sector shows two of the plurality of projections 40. Any number of projections 40 can be provided while preserving the balance of the driveshaft tube 20, such that rotation of the driveshaft tube 20 does not produce any resultant centrifugal force or couple in the driveshaft tube 20 as a result of the number of projections 40. In some examples, a minimum of three projections 40 can be provided. Up to ten, twenty, thirty or even up to a hundred projections 40 can be provided in other examples. In some examples, the driveshaft tube 20 in transverse radial cross section has rotational symmetry about the centreline axis 22.

The projections 40 shown in Fig. 4 extend radially between an azimuthally extending inner limit 42 at a first radius r_1 and an azimuthally extending outer limit 44 at a second radius r_2 . The inner limit 42 is illustrated in Fig. 4 by a dashed line at first radius r_1 . The outer limit 44 is illustrated in Fig. 4 by another dashed line at second radius r_2 . The radial separation distance of the outer limit 44 from the inner limit 42 is constant around the whole circumference of the driveshaft tube 20.

The projections 40 extend wholly, without interruption, between the inner limit 42 at the first radius r_1 and the outer limit 44 at the second radius r_2 . Therefore the inner limit and outer limit represent radially separated limits between which the projections 40 must each extend continuously, i.e. free from holes or other discontinuities.

The first radius r_1 is at least 20% of the second radius r_2 . In other examples the first radius r_1 is between 20% and 90% of the second radius r_2 , between 20% and 70% of the second radius r_2 , or between 40% and 90% of the second radius r_2 .

- 5 Each of the projections 40 described in relation to Fig. 4 additionally extends lengthwise in the longitudinal direction along the z-axis for a predetermined distance, as required for adequately stiffening the driveshaft tube 20. The projections 40 extend wholly between the inner limit 42 at the first radius r_1 and the outer limit 44 at the second radius r_2 , and lengthwise in the longitudinal direction for at least 20% of the total length LT of the driveshaft tube 20. The length limitation of 20% represents a length over which the projections 40 must each extend continuously, i.e. free from holes or other discontinuities, in the longitudinal direction. Therefore the projections 40 are continuous and unbroken between the inner limit 42, the outer limit 44, and along at least 20% of the length LT of the driveshaft tube 20. In other examples, the length limitation may be greater, for example at least 30%, 40%, 50% of 15 60% of the length LT.

In some examples the length limitation further represents a length over which the projections 40 must each extend without change in azimuth, i.e. in a straight line. In some examples the length limitation represents a length over which the projections 40 must each extend wholly 20 between a constant value of the inner limit at a constant value of the first radius and a constant value of the outer limit at a constant value of the second radius.

In some examples, the projections 40 extend lengthwise in a non-helical manner, for example each projection 40 can extend parallel to the centreline axis 22, such that the 25 azimuth of the projection 40 remains constant, over at least an incremental length of the projection in the z-axis direction. In other examples, the azimuth remains constant over a length greater than 10%, 50% or 90% of the length LT of the driveshaft tube 20.

In some examples, the first radius r_1 and/or the second radius r_2 is constant over at least an 30 incremental length of the driveshaft tube 20 in the longitudinal direction. In other examples, the first radius r_1 and/or the second radius r_2 is constant over a length greater than 10%, 50% or 90% of the length LT of the driveshaft tube 20.

In some examples, each projection 40 has a constant thickness over at least an incremental radial distance along the projection. Thickness is measured tangentially to the azimuthal direction. In other examples, the projection 40 has a constant thickness over a radial distance greater than 10%, 50% or 90% of the distance between the inner limit 42 and the outer limit 44, i.e. the length of the projection. In other examples the projection 40 is tapered such that the thickness of the projection 40 decreases towards the centreline axis 22.

In some examples the projections 40 can be provided to only the central longitudinal region of the driveshaft tube 20, meaning that the projections 40 do not extend lengthwise as far as longitudinally separated peripheral ends of the driveshaft tube 20. In some examples a portion of the driveshaft tube extending over at least some of the length of the driveshaft tube 20 is configured to collapse in a vehicle impact. The portion may be free from projections 40, and may be less stiff than other portions of the driveshaft tube 20. The portion may be configured to collapse at least partially telescopically.

In some examples, additional azimuthally disposed radially extending projections 40 can be provided which differ from the projections 40 described above with regard to their radial extension and/or azimuthal separation, as long as the balance of the driveshaft tube 20 is preserved, such that rotation of the driveshaft tube 20 does not produce any resultant centrifugal force or couple in the driveshaft tube 20 as a result of the differences. In other examples all of the projections 40 on the driveshaft tube 20 have identical radially extending lengths and azimuthal separations.

Figs. 5A to 5C illustrate examples of how the projections 40 can be located with respect to the rest of the driveshaft tube 20. Figs. 5A to 5C illustrate arbitrary sectors of the driveshaft tube 20 in the plane of the cross-section A-A, as described above in relation to Fig. 4.

Figs. 5A to 5C show that each projection 40 is interconnected with a neighbouring projection 40 by material 50 ('interconnecting material') at one or both of the inner limit 42 and the outer limit 44 interconnecting the projections 40. The interconnecting material 50 extends azimuthally or substantially azimuthally to define, at least in part, the circular or faceted cylinder shape of the driveshaft tube 20.

In Fig. 5A, the interconnecting material 50 extends azimuthally along only the inner limit 42 but no interconnecting material 50 extends azimuthally along the outer limit 44. Therefore each projection 40 is supported at only one end, at the inner limit 42. Each projection 40 is unsupported at its opposite end, at the outer limit 44. Each projection 40 is therefore cantilevered. The projections 40 are exterior projections 40 meaning that the projections 40 are visible from the exterior of the driveshaft tube 20. This gives the driveshaft tube 20 the appearance of a circular tube of interconnecting material 50 with exterior projections 40 forming external fin-like structures, for example similar to the shape of a pinion.

In Fig. 5B, the interconnecting material 50 extends azimuthally along only the outer limit 44, but no interconnecting material 50 extends azimuthally along the inner limit 42. Therefore each projection 40 is supported at only one end, at the outer limit 44. Each projection 40 is unsupported at its opposite end, at the inner limit 42. Each projection 40 is therefore cantilevered. The projections 40 are interior projections 40 meaning that the projections 40 are only visible in the interior of the driveshaft tube 20. This gives the driveshaft tube 20 the appearance of a circular tube of interconnecting material 50 with interior projections 40 forming interior fin-like structures, similar to the appearance of a ring gear with teeth extending radially inwardly.

In some examples, the first radius r_1 of the example driveshaft tube 20 of Fig. 5A can be less than the second radius r_2 of the example driveshaft tube 20 of Fig. 5B, as a result of the bending stiffness benefit provided by locating the projections 40 on the exterior side (Fig. 5A), rather than on the interior side (Fig. 5B) of the interconnecting material 50.

In Fig. 5C, the interconnecting material 50 extends azimuthally along the outer limit 44 and additionally interconnecting material 50 extends azimuthally along the inner limit 42. Therefore each projection 40 is supported at both ends, at the inner limit 42 and at the outer limit 44. This gives the driveshaft tube 20 the appearance of two concentric tubes interconnected with each other by the projections 40.

In this example, cutouts 74 in the shapes of annular circle sectors are formed between neighbouring projections 40 and between the inner limit 42 and the outer limit 44. The cutouts 74 can advantageously be hollow, or can contain material that is different from the

material defining the projections 40 and from the interconnecting material 50, and is of a lower density for absorbing noise and/or vibration.

5 Figs. 6A to 6C illustrate examples of driveshaft tubes 20. Figs. 6A to 6C are transverse radial cross-section views in the section A-A. Figs. 6A to 6C respectively show all of the elements visible in Figs. 5A to 5C, however the entire cross-sections of the driveshaft tubes 20 are shown, rather than arbitrary sectors. In addition, the material thickness is shown.

10 Fig. 6A shows an example of a driveshaft tube 20, containing all of the elements of Fig. 5A. The interconnecting material 50 defines, at least in part, a distal circumferential surface 64 of a circular tube 60. The circular tube 60 of interconnecting material 50 is defined by a proximal circumferential surface 62 and the distal circumferential surface 64, which are proximal and distal with respect to the centroid on the centreline axis 22.

15 The distal circumferential surface 64 of the circular tube 60 extends azimuthally along the inner limit 42 and forms a discontinuous exterior surface of the driveshaft tube 20, the discontinuities corresponding to the projections 40. Corner portions 61 where the projections 40 and the distal circumferential surface 64 meet may be chamfered, curved or right angled. However between each projection, at least one location on the distal circumferential surface
20 64 touches the inner limit 42.

The proximal circumferential surface 62 extends azimuthally and forms a continuous interior surface of the driveshaft tube 20. None of the proximal circumferential surface 62 touches the inner limit 42.

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Fig. 6A also shows that the proximal circumferential surface 62 of the circular tube 60 defines and encloses an interior portion 65 of the driveshaft tube 20. The interior portion 65 is either fully hollow, or contains material that is different from the material defining the projections 40 and from the interconnecting material 50, and is of a lower density.

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In Fig. 6A, each projection 40 starts at a point on the inner limit 42 in contact with the circular tube 60 at the distal circumferential surface 64. Each projection 40 extends from the inner limit 42 to the outer limit 44. Each projection 40 extends no further than the outer limit 44.

Therefore the inner limit 42 is exterior and the outer limit 44 is exterior with respect to the circular tube 60.

Fig. 6A is analogous to Fig. 5A because projections are interconnected with each other at the inner limit but not at the outer limit.

In the example of Fig. 6A, but not necessarily all examples, the driveshaft tube 20 comprises forty projections 40.

Fig. 6B shows a further example of a driveshaft tube 20, containing all of the elements of Fig. 5B. The differences between Fig. 6B and Fig. 6A are explained herein.

In Fig. 6B, the interconnecting material 50 defines, at least in part, the proximal circumferential surface 64 of the circular tube 60.

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The proximal circumferential surface 62 of the circular tube 60 extends azimuthally along the outer limit 44 and forms a discontinuous interior surface of the driveshaft tube 20, the discontinuities corresponding to the projections 40. Corner portions 61 where the projections 40 and the proximal circumferential surface 62 meet can be chamfered, curved or right angled. However between each projection, at least one location on the proximal circumferential surface 62 touches the outer limit 44.

20

The distal circumferential surface 64 extends azimuthally and forms a continuous exterior surface of the driveshaft tube 20. None of the distal circumferential surface 64 touches the outer limit 44.

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In Fig. 6B, each projection 40 starts at a point on the outer limit 44 in contact with the circular tube 60 at the proximal circumferential surface 62. Each projection 40 extends from the outer limit 44 to the inner limit 42. Each projection 40 extends no further inwardly than the inner limit 42.

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Fig. 6B shows the projections 40 terminating at the inner limit 42, therefore the inner limit 42 defines and encloses a fully hollow interior portion 65 of the driveshaft tube 20. The fully hollow interior portion 65 can then optionally be filled with material that is different from the

material defining the projections 40 and from the interconnecting material 50, and is of a lower density. Gaps, extending between neighbouring projections 40 extending between the inner limit 42 and outer limit 44, increase the hollow space available.

- 5 Fig. 6B is analogous to Fig. 5B because no interconnecting material 50 extends along the inner limit 42. Therefore the projections 40 are cantilevered as described in relation to Fig. 5B.

10 In the example of Fig. 6B, but not necessarily all examples, the driveshaft tube 20 comprises forty projections 40.

Fig. 6C shows a further example of a driveshaft tube 20, containing all of the elements of Fig. 5C. The differences between Fig. 6C and Figs. 6A and 6B are explained herein.

- 15 In Fig. 6C, the interconnecting material 50, extending along both the inner limit 42 and the outer limit 44, defines, at least in part, opposing surfaces 70, 62 of two concentric circular tubes: an inner circular tube 66 contained within an outer circular tube 60. The outer circular tube 60 corresponds to the circular tube 60 described in relation to Figs. 5A, 5B, 6A, 6B. The inner circular tube 66 comprises a proximal circumferential surface 68 and a distal circumferential surface 70, which are proximal and distal with respect to the centroid on the centreline axis 22. Both the proximal circumferential surface 68 and the distal circumferential surface 70 of the inner circular tube 66 are not visible external to the driveshaft tube 20 in normal use.

- 25 In Fig. 6C, the distal circumferential surface 70 of the inner circular tube 66 extends azimuthally along the inner limit 42 and forms a discontinuous interior surface of the driveshaft tube 20, the discontinuities corresponding to the projections 40. Corner portions 61 where the projections 40 and the distal circumferential surface 70 of the inner circular tube 66 meet can be chamfered, curved or right angled. However between each projection, at least one location on the distal circumferential surface 70 of the inner circular tube 66 touches the inner limit 42.

In Fig. 6C, the proximal circumferential surface 62 of the outer circular tube 60 extends azimuthally along the outer limit 44 and forms a discontinuous interior surface of the

driveshaft tube 20, the discontinuities corresponding to the projections 40. Corner portions 61 where the projections 40 and the proximal circumferential surface 62 of the outer circular tube 60 meet can be chamfered, curved or right angled. However between each projection, at least one location on the proximal circumferential surface 62 of the outer circular tube 60 touches the outer limit 44.

In Fig. 6C, the distal circumferential surface 64 of the outer circular tube 60 extends azimuthally and forms a continuous exterior surface of the driveshaft tube 20. None of the distal circumferential surface 64 of the outer circular tube 60 touches the outer limit 44. The proximal circumferential surface 68 of the inner circular tube 66 extends azimuthally and forms an interior surface of the driveshaft tube 20, which is discontinuous in Fig. 6C but can be continuous in other examples. None of the proximal circumferential surface 68 of the inner circular tube 66 touches the inner limit 42.

In Fig. 6C, each projection 40 starts at a point on the outer limit 44 in contact with the outer circular tube 60 at the proximal circumferential surface 62. Each projection 40 extends from the outer limit 44 to the inner limit 42 to contact the inner circular tube 66 at the distal circumferential surface 70 of the inner circular tube 66.

Fig. 6C additionally shows continuations 41 of the projections 40, extending past the inner circular tube 66 and all the way to the centroid on the centreline axis 22. The continuations 41 of the projections 40 start at locations on the proximal circumferential surface 68 of the inner circular tube 66, and extend towards the centroid at least until neighbouring continuation projections 41 meet adjacent the centroid.

In some examples, the continuation projections 41 do not need to azimuthally align with the projections 40 extending between the inner limit 42 and the outer limit 44, and/or the number of continuation projections 41 does not need to match the total number of projections 40 between the inner limit 42 and the outer limit 44.

In Fig. 6C, the annular circle sector cutouts 74 as described in relation to Fig. 5C are present bounded by the proximal circumferential surface 62 of the outer circular tube 60 and the distal circumferential surface 70 of the inner circular tube 66, and between neighbouring projections 40.

In Fig. 6C, additional cutouts 76 are present between each of the continuation projections 41, bounded at least by the proximal circumferential surface 68 of the inner circular tube 66, and two neighbouring continuation projections 41. The additional cutouts 76 can be annular
5 circle sector shapes, or sector shapes, depending on the configuration of the continuation projections 41. The annular circle sector cutouts 74 and/or the additional cutouts 76 in the interior portion 65 of the driveshaft tube 20 can be hollow, or contain material that is different from the material defining the projections 40 and from the interconnecting material 50, and is of a lower density.

10 In the example of Fig. 6C, but not necessarily all examples, the driveshaft tube 20 comprises eight projections 40.

With reference to any one or more of the preceding examples, the material defining the
15 projections 40 and/or the interconnecting material 50 and/or the continuation projections 41 comprises metallic material. In some examples, the material is a composite material. In some examples, the metallic material is easily workable and can be used in an extrusion processes. For example the metallic material can be any material having a Young's Modulus within the range 50 GPa to 150 GPa, less than 160 GPa, or less than 210 GPa. The metallic
20 material can comprise Aluminium. In other examples, the material defining the projections 40 and/or the interconnecting material 50 and/or the continuation projections 41 comprises carbon fibre.

In some examples, the material defining the projections 40 and the interconnecting material
25 50 are formed from a common piece of continuous material. This means that no joins, discontinuities, or any other evidence of post-formed fabrication of the projections 40 to the interconnecting material 50 are present at locations on the inner limit 42 and/or outer limit 44 touching the projections 40.

30 According to some, but not necessarily all aspects of the disclosure there is provided a method of forming a driveshaft tube 20 extending lengthwise in a longitudinal direction comprising:

providing material defining, in transverse radial cross-section, a plurality of azimuthally separated radially extending projections 40 extending radially between an azimuthally

extending inner limit 42 at a first radius r_1 and an azimuthally extending outer limit 44 at a second radius r_2 , wherein the first radius r_1 is at least 20% of the second radius r_2 ; and providing material 50 extending azimuthally along one or both of the inner limit 42 and the outer limit 44 interconnecting the azimuthally separated radially extending projections 40, wherein the azimuthally separated radially extending projections 40 extend wholly between the inner limit 42 at the first radius r_1 and the outer limit 44 at the second radius r_2 , and in the longitudinal direction for at least 20% of the length of the driveshaft tube 20.

In some examples, the projections 40 and the interconnecting material 50 are moulded from a common piece of continuous material. In some examples, the moulding process includes an extrusion process. In some examples, the projections 40 and the interconnecting material 50 are co-moulded. In other examples, the projections 40 and the interconnecting material 50 are pressed or bonded to each other.

Although embodiments of the present invention have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the invention as claimed. For example, the examples described with reference to any one of: Fig. 5A, Fig. 5B, Fig. 5C, Fig. 6A, Fig. 6B, Fig. 6C, can be combined with any other of the examples described with reference to any one of: Fig. 5A, Fig. 5B, Fig. 5C, Fig. 6A, Fig. 6B, Fig. 6C to form a driveshaft tube 20 that is a hybrid of the examples defined hereinbefore.

Features described in the preceding description may be used in combinations other than the combinations explicitly described.

25

Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

Although features have been described with reference to certain embodiments, those features may also be present in other embodiments whether described or not.

30

Whilst endeavoring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features

hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

CLAIMS

1. A driveshaft tube extending lengthwise in a longitudinal direction, comprising:
 - a. a first portion configured to receive torque from a component
 - b. a second portion configured to transfer torque to another component
 - c. a third portion comprising:

material defining, in transverse radial cross-section, a plurality of azimuthally separated radially extending projections extending radially between an azimuthally extending inner limit at a first radius and an azimuthally extending outer limit at a second radius, wherein the first radius is at least 20% of the second radius; and material at the inner limit and/or the outer limit and/or between the inner limit and the outer limit interconnecting the azimuthally separated radially extending projections, wherein the azimuthally separated radially extending projections extend wholly between the inner limit at the first radius and the outer limit at the second radius, and in the longitudinal direction for at least 20% of a length of the driveshaft tube wherein the radially extending portions of the third portion do not receive torque from or transfer torque to any other component.
2. A driveshaft tube as claimed in claim 1, wherein the material interconnecting the azimuthally separated radially extending projections is at only one of the inner limit and the outer limit such that the azimuthally separated radially extending projections are cantilevered.
3. A driveshaft tube as claimed in claim 2, wherein the material interconnecting the azimuthally separated radially extending projections is at the inner limit.
4. A driveshaft tube as claimed in claim 2, wherein the material interconnecting the azimuthally separated radially extending projections is at the outer limit.
5. A driveshaft tube as claimed in claim 1, wherein the material interconnecting the azimuthally separated radially extending projections is at both of the inner limit and the outer limit.

5 6. A driveshaft tube as claimed in any preceding claim, wherein the material defining the plurality of azimuthally separated radially extending projections and the material interconnecting the azimuthally separated radially extending projections are formed from a common piece of continuous material.

10 7. A driveshaft tube as claimed in any preceding claim, wherein the material defining the plurality of azimuthally separated radially extending projections comprises aluminium and wherein the material interconnecting the azimuthally separated radially extending projections comprises aluminium.

15 8. A driveshaft tube as claimed in any preceding claim, wherein the first radius is constant over at least an incremental length of the driveshaft tube in the longitudinal direction.

19 9. A method of forming a driveshaft tube extending lengthwise in a longitudinal direction comprising: forming a first portion configured to receive torque from a component, forming a second portion configured to transfer torque to another component, and forming a third portion, wherein forming a third portion comprises:

20 providing material defining, in transverse radial cross-section, a plurality of azimuthally separated radially extending projections extending radially between an azimuthally extending inner limit at a first radius and an azimuthally extending outer limit at a second radius, wherein the first radius is at least 20% of the second radius; and

25 providing material at the inner limit and/or the outer limit and/or between the inner limit and the outer limit interconnecting the azimuthally separated radially extending projections, wherein the azimuthally separated radially extending projections extend wholly between the inner limit at the first radius and the outer limit at the second radius, and in the longitudinal direction for at least 20% of the length of
30 the driveshaft tube.

10. A method as claimed in claim 9, wherein the material defining the plurality of azimuthally separated radially extending projections and the material interconnecting the azimuthally separated radially extending projections are moulded from a common piece of continuous material.

5

11. A vehicle comprising the driveshaft tube as claimed in any one of claims 1 to 8.

12. A driveshaft tube extending lengthwise in a longitudinal direction, comprising:

a. a first portion configured to receive torque from a component

10

b. a second portion configured to transfer torque to another component

c. a third portion comprising:

material defining, in transverse radial cross-section, a plurality of angularly spaced ribs extending radially between a circumferentially extending inner limit at a first radius and a circumferentially extending outer limit at a second radius, wherein the first radius is at least 20% of the second radius; and

15

material at the inner limit and/or the outer limit and/or between the inner limit and the outer limit interconnecting the angularly spaced ribs, wherein the angularly spaced ribs extend wholly between the inner limit at the first radius and the outer limit at the second radius, and in the longitudinal direction for at least 20% of a length of the driveshaft tube.

20

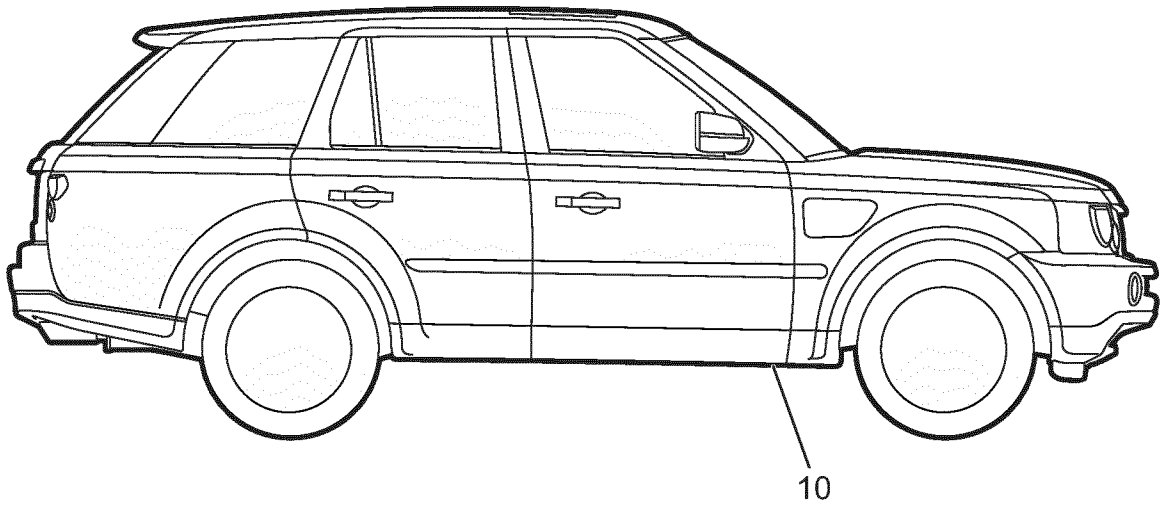


Fig. 1

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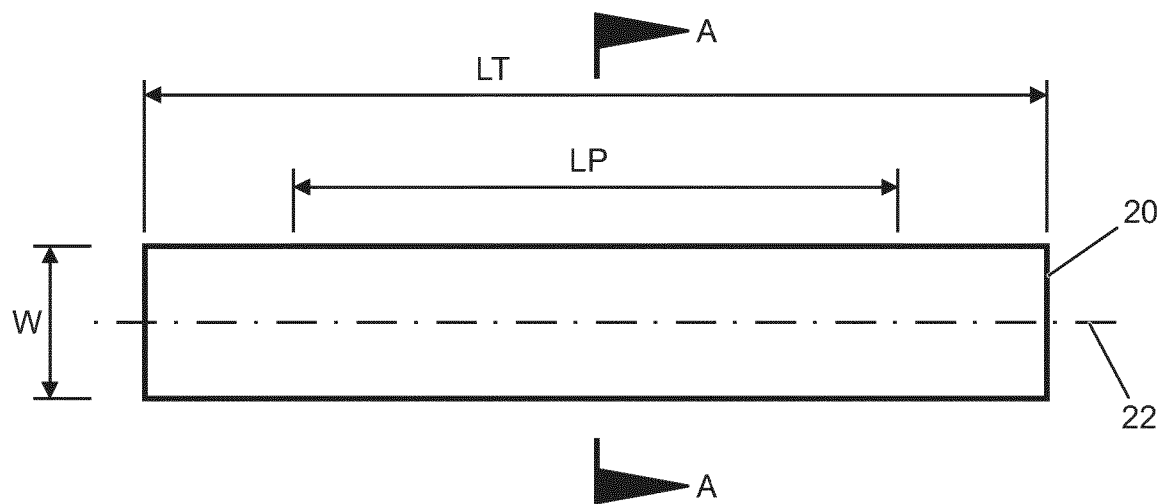


Fig. 2

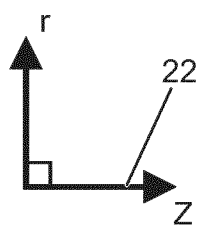


Fig. 3A

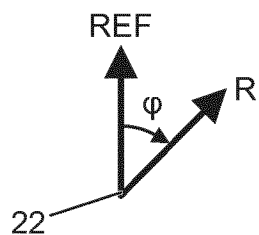


Fig. 3B

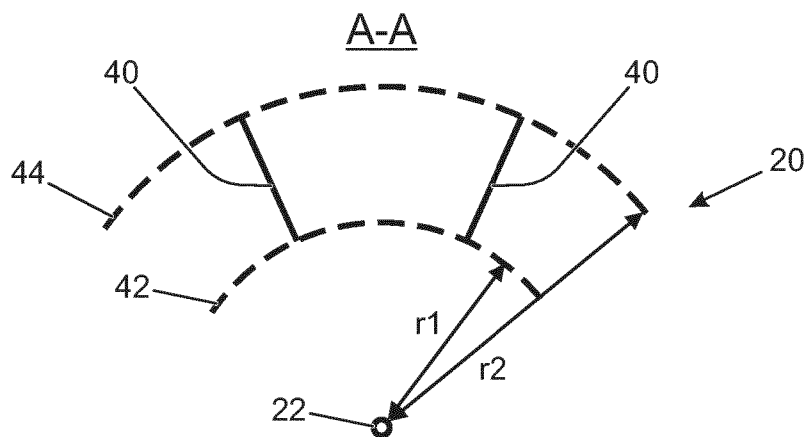


Fig. 4

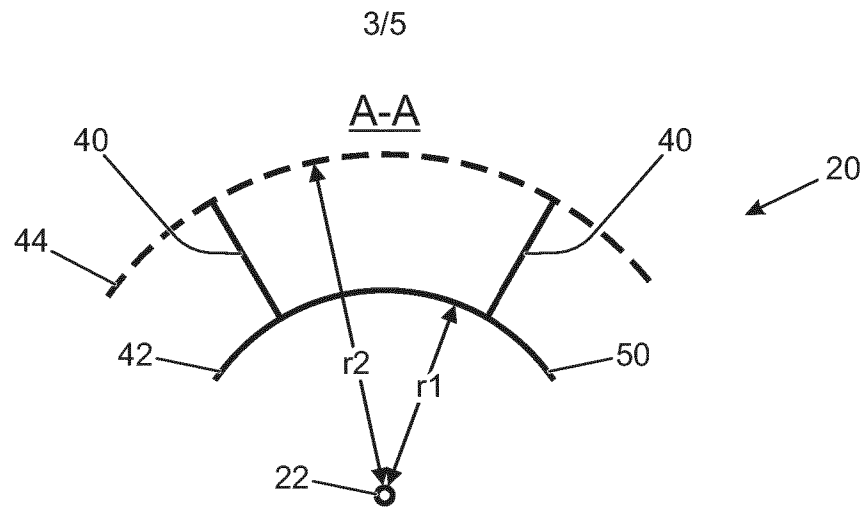


Fig.5A

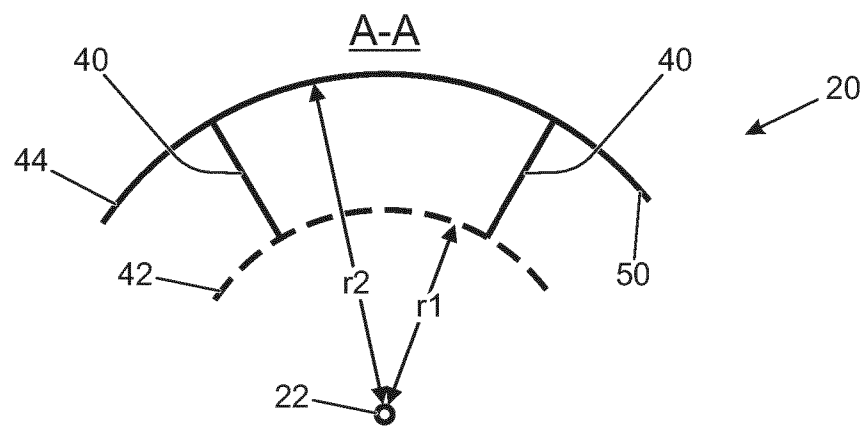


Fig.5B

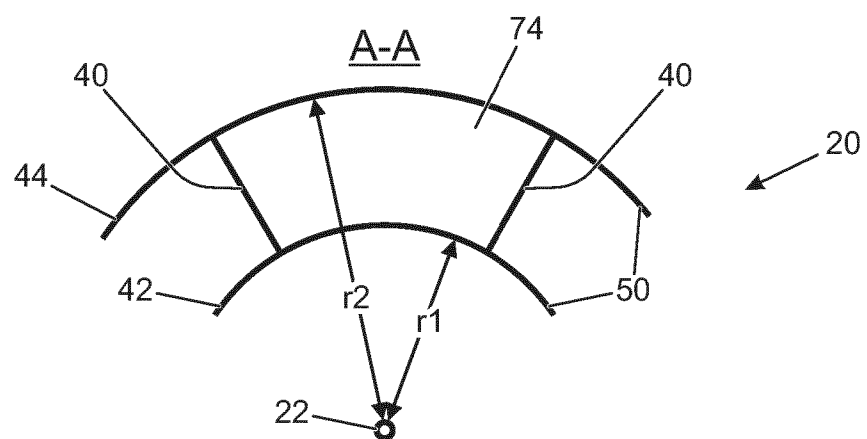


Fig.5B

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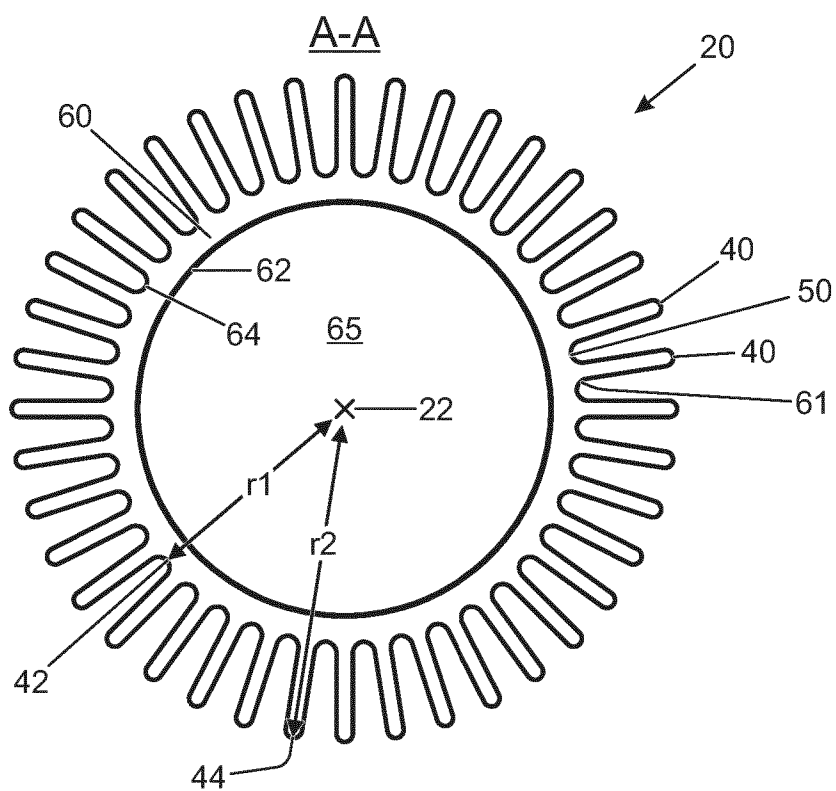


Fig.6A

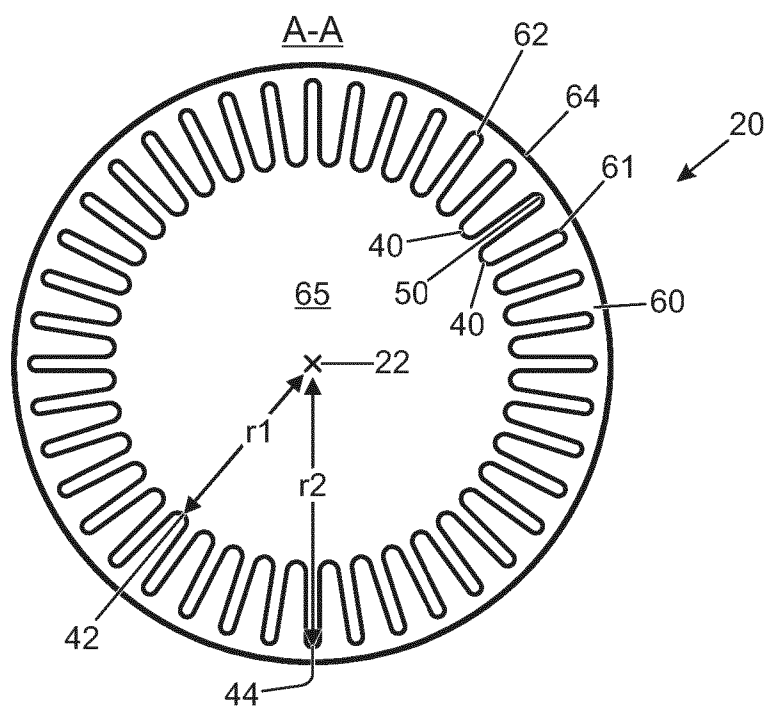


Fig.6B

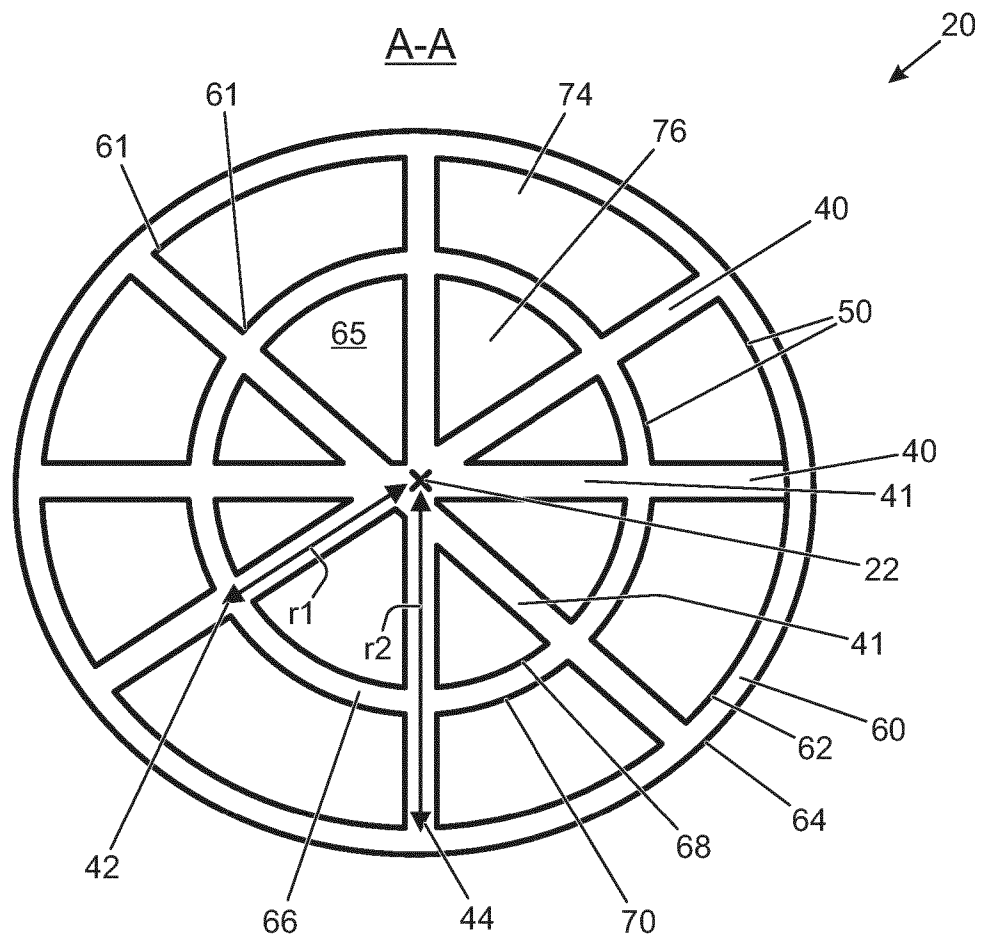


Fig.6C

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/073261

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60K17/22 F16C3/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60K F16C B33Y A01B F16D F16F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

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X	US 2015/275959 A1 (GABRYS JONATHAN W [US] ET AL) 1 October 2015 (2015-10-01) paragraphs [0006], [0007], [0028], [0035] - [0037]; figures 3A-3C	1-4,6-12
X	DE 23 02 551 A1 (ZEIDLER WILLI) 1 August 1974 (1974-08-01) figures 1-4	1,5-7, 9-12
X	US 2003/129022 A1 (BRISSETTE RONALD N [US] ET AL) 10 July 2003 (2003-07-10) figures 1-6	1-4,6-12
	-/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

8 January 2018

Date of mailing of the international search report

16/01/2018

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/073261

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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