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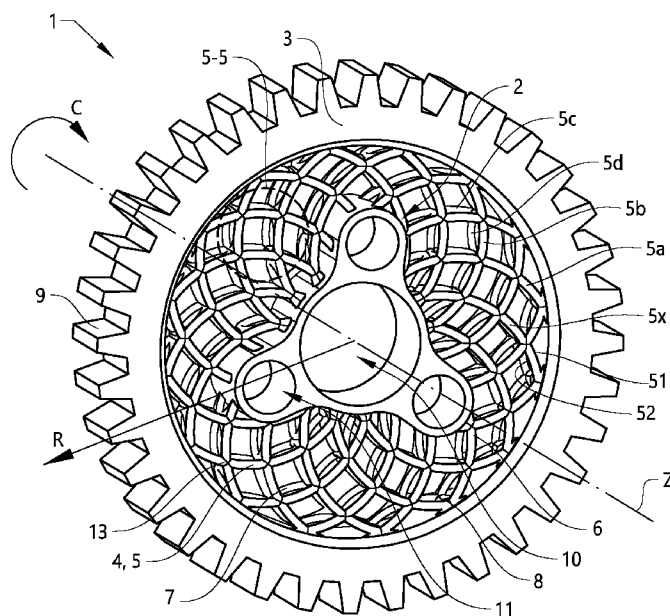
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(54) Title: A GEAR WHEEL

Fig. 3



(57) Abstract: A gear wheel (1) having an axial direction (Z), a radial direction (R) and a circumferential direction (C), comprising a centrally located hub (2), an outer transmission portion (3) located radially (R) outward from the hub (2) and surrounding the hub (2) in the circumferential direction (C), and an intermediate portion (4) connecting the hub (2) to the outer transmission portion (3). The intermediate portion (4) comprises a set (5X) of spokes (5), each spoke (5) in at least a subset of spokes having a curved shape with a convex side and a concave side so as to partly extend also in the circumferential direction (C), wherein each spoke (5) in said set (5X) connects the hub (2) to the outer transmission portion (3) in the radial direction (R) and the circumferential direction (C), wherein each spoke (5) is connected to at least a second spoke (5).



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A GEAR WHEEL

TECHNICAL FIELD

The invention relates to a gear wheel for a transmission unit. The invention also relates to a gear assembly for a powertrain system and a vehicle comprising such gear wheel. By way of example, the gear assembly may be installed in any one of an engine, such as an internal combustion engine, a driven axle, a transfer box, a differential, and a reduction hub.

The invention is applicable on any types of vehicles and machines using a transmission unit including gear wheels. Vehicles can be trucks, buses and construction equipment. Although the invention will be described with respect to a truck, the invention is not restricted to this particular vehicle, but may also be used in other machines using gear wheels for transmission, for example cars, windmills, boats, trains, bicycles, motorcycles and/or in any other type of application for transmitting a rotational motion by means of a gear wheel.

BACKGROUND

The invention relates to a gear wheel for a transmission unit. Gear wheels can be arranged in a number of different ways dependent on type of transmission unit and device the transmission unit is used with. A typical gear wheel has an axial direction, a radial direction and a circumferential direction, comprising a centrally located hub, an outer transmission portion located radially outward from the hub and surrounding the hub in the circumferential direction, and an intermediate portion connecting the hub to the outer transmission portion. The gear wheel interacts with a second gear wheel in order to transfer power. In most applications, the gear wheels are operated under dynamic conditions which in turn means that the power transferred from one gear wheel to another gear wheel may change of direction. Also, the torque intensity may vary in different installations and between gear wheels. In order to deal with these different situations, gears are conventionally designed with high safety coefficients to avoid premature break down. As a consequence, gears are generally quite massive components. Drawbacks resulting from these conventional gear wheel designs may thus relate to payload and negative environmental aspects. Further, rotating inertial mass may typically contribute to slower rotational acceleration, thus having a negative impact on aspects such as

drivability response, or result in oversized dimensions of the engine or of the driving machine. In addition, the variation in power between gear wheels causes stress on the gear wheel and is also transferred to an output axis and thereto attached devices.

5 SUMMARY

An object of the invention is to provide an improved gear wheel in terms of weight of the structure making up the gear wheel.

The object is achieved by a gear wheel according to claim 1. According to a first aspect,
10 there is provided a gear wheel having an axial direction, a radial direction and a circumferential direction. The axial direction coincides with a rotational centre axis of the gear wheel. The axial direction is perpendicular to the radial direction and the circumferential direction coincides with a rotational direction of the gear wheel.

15 The gear wheel comprises a centrally located hub, an outer transmission portion located radially outward from the hub and surrounding the hub in the circumferential direction, and an intermediate portion connecting the hub to the outer transmission portion. The intermediate portion comprises a set of spokes, wherein each spoke in at least a subset of spokes has a curved shape with a convex side and a concave side so as to partly extend
20 also in the circumferential direction. Each spoke in said set connects the hub to the outer transmission portion in the radial direction and the circumferential direction and each spoke is connected to at least a second spoke.

In this manner, it becomes possible to reduce the weight of the gear wheel in an efficient
25 manner without compromising on other demands on the structure of the gear wheel relating to functionality, stability and reliability. It is also believed that the example embodiments of the invention provide for increased thermal dissipation due to the above-mentioned configuration of the spokes, which provides a hollow shape, while ensuring that there is a number of surfaces of thermal exchanges. That is, a gear wheel having
30 numerous spokes results in a hollow structure.

The interconnecting spokes provide improved stability and robustness during ordinary use of the gear wheel and without compromising on factors such as weight and dimensions.

Further, the example embodiment may contribute to improved dampening abilities that remedies or at least alleviates stress on the gear wheel and dampens power pulses transferred to an output axis and thereto attached devices. In this context, it is believed that each spoke may act as a flexible spring able to lightly bend to absorb jolt due to sudden variation of torque.

Further advantages and advantageous features of the invention are disclosed in the following description and in the dependent claims.

According to one example embodiment each spoke is connected to a number of other spokes creating a mesh-like structure in a radial plane. The radial plane coincides with the radial direction being perpendicular to the axial direction.

The interconnecting spokes provide further improved stability and robustness during ordinary use of the gear wheel and without compromising on factors such as weight and dimensions.

According to one example embodiment, the set of spokes comprises a first set of spokes and a second set of spokes extending between the hub and the outer transmission portion. The spokes in each set of spokes are distributed circumferentially around the gear wheel. According to one example embodiment, the spokes are evenly distributed around the gear wheel creating a corresponding mesh-like structure. However, the spokes can be distributed unevenly if the gear wheel is rotationally balanced.

The first and second sets of spokes are directed in circumferentially opposite directions and are directly connected to each other in connection points where the spokes meet. The first set of spokes has a curvature in a clock-wise circumferential direction starting from the hub. The second set of spokes has a curvature in a clock-wise circumferential direction starting from the outer transmission portion. Hence, the convex side of each spoke of the first set of spokes faces the concave side of a neighbouring spoke of the first set of spokes, and the convex side of each spoke of the second set of spokes faces the concave side of a neighbouring spoke of the second set of spokes.

The differently oriented spokes have the advantage of further improved distribution of loads occurring during rotation of the gear wheel and dampening of power pulses.

In order to describe further the relationship between the different spokes, one could describe the mesh-like structure in its smallest repetitive pattern. Here, the convex side of a first spoke of the first set of spokes faces the concave side of a neighbouring second spoke of the first set of spokes, and wherein the convex side of a third spoke of the second set of spokes faces the concave side of a neighbouring fourth spoke of the second set of spokes, and wherein the convex side of the first spoke faces the convex side of the third spoke and the concave side of the fourth spoke.

10 The first and second sets of spokes are arranged in a first layer in a first radial plane and the inter-connected spokes, i.e. that each spoke is connected to at least a second spoke, create the mesh-like structure. The interconnected spokes build a mesh-like structure comprising a trapezoid-like pattern.

15 According to one example embodiment, the set of spokes comprises a third set of spokes having a curvature in a clock-wise circumferential direction starting from the hub and a fourth set of spokes having a curvature in a clock-wise circumferential direction starting from the outer transmission portion. Hence, the third and fourth set of spokes are directed in circumferentially opposite directions. Just as the first and second sets of spokes, the
20 third and fourth sets of spokes are directed in circumferentially opposite directions and are directly connected to each other in connection points where the spokes meet. Furthermore, the third and fourth sets of spokes are arranged in a second layer in a second radial plane creating a mesh-like structure in the radial plane. According to one example embodiment, the spokes are evenly distributed around the gear wheel creating a
25 corresponding mesh-like structure. However, the spokes can be distributed unevenly if the gear wheel is rotationally balanced. The convex side of each spoke of the third set of spokes faces the concave side of a neighbouring spoke of the third set of spokes, and the convex side of each spoke of the fourth set of spokes faces the concave side of a neighbouring spoke of the fourth set of spokes.

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A gear wheel having spokes distributed on at least two different and parallel plans (layers) provides for a gear wheel that is lighter in comparison to prior art gear wheels for the same tensile strength and maximum torque supported. It has also been observed that a gear wheel with different layers of spokes is particularly advantageous for thicker gear
35 wheels.

As mentioned above, it should thus also be noted that the gear wheel may comprise more than one layer of set of spokes. In other words, according to one example embodiment of the invention, the gear wheel comprises a plurality of layers of set of spokes. By way of example, the gear wheel may comprise two layers of set of spokes, three layers of set of spokes or even more layers of set of spokes.

The further set of spokes provide further improved stability and robustness during ordinary use of the gear wheel and without compromising on factors such as weight and dimensions. The differently oriented spokes have the advantage of optimizing distribution of loads occurring during rotation of the gear wheel with optimized mass of the gear. The design of the gear according to the example embodiments of the invention further provides for a dampening effect to be optimized resulting, for instance, in an increased level of durability of the gear wheel.

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In order to describe further the relationship between the different spokes, one could describe the mesh-like structure in its smallest repetitive pattern. Here, the convex side of a fifth spoke of the third set of spokes faces the concave side of a neighbouring sixth spoke of the third set of spokes, and wherein the convex side of a seventh spoke of the fourth set of spokes faces the concave side of a neighbouring eighth spoke of the fourth set of spokes, and wherein the convex side of the fifth spoke faces the convex side of the seventh spoke and the concave side of the eighth spoke.

According to one example embodiment, the first and the second layers of spokes are separated in the axial direction being perpendicular to the radial direction. According to one example, the first and second layers are flat, i.e. have an extension in a flat plane, and arranged in parallel to each other. Here, flat relates to a two dimensional extension in the radial direction with an even extension in the axial direction. According to one example, the first and second layers have an essentially two dimensional extension in the radial direction with an un-even extension in the axial direction, i.e. the thickness of the first and/or the second layers in the axial direction may vary. According to one example, the first and second layers may be non-flat, i.e. three dimensional, where the first and second layers have a general extension in the radial direction but with an undulating, curved or slanted surface with relation to a flat plane extending in the radial direction. A

slanted surface may diverge or converge from the hub towards the outer transmission portion.

According to one example embodiment, the intermediate portion comprises connecting
5 means connecting the first and second layers in the axial direction.

The first and the second layers together with the connecting means provide improved stability and robustness during ordinary use of the gear wheel and without compromising on factors such as weight and dimensions.

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According to one example embodiment, the connecting means comprises separate linking units connecting each spoke to at least a second spoke in the axial direction.

The separate linking units provide further improved stability and robustness during
15 ordinary use of the gear wheel and without compromising on factors such as weight and dimensions.

According to one example embodiment, the connecting means comprises interconnecting linking units connecting one separate linking unit to at least a second separate linking unit
20 in the radial direction.

The separate linking units provide further improved stability and robustness during ordinary use of the gear wheel and without compromising on factors such as weight and dimensions.

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According to one example embodiment, each spoke has an elongated shape corresponding to a part of an ellipse, preferably a part of a circle.

According to one example, the spokes have a common centre axis coinciding with the
30 centre axis of the gear wheel. However, the invention is not restricted to such an embodiment, but other design features are possible. Depending on the design of the hub and the design layout of the spokes, the spokes can have different or the same length between the hub and the outer transmission portion.

According to one example embodiment, each spoke is connected to at least a second spoke in the radial direction creating the mesh. The number of contact points and type of arrangement vary depending on e.g. type of installation and the dimensions of the gear wheel, etc. The connection points can be symmetrically or asymmetrically distributed.

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The connection points between the spokes can be done by any known means, but preferably a 3-D printing technology, i.e. an additive manufacturing process, is used to create the gear wheel and the spokes together.

- 10 According to one example embodiment, the outer transmission portion comprises teeth for transmitting rotational motion to another gear wheel or the like. It should be noted that the shapes and dimensions may vary for different types of gear wheels and different types of installations. Typically, the teeth may be provided in the shape of straight teeth. However, the gear wheel may also be a spur gear, a helicoidally gear, or even a conical gear.
- 15 Hence, the gear wheel may for instance comprise conically shaped gear.

According to one example embodiment, each spoke in each set of spokes has a curved shape with a convex side and a concave side.

- 20 According to one example embodiment, the set of spokes comprises a fifth set of spokes extending between the hub and the outer transmission portion. The spokes in the fifth set are distributed circumferentially around the gear wheel and have a straight shape.

- With reference to all embodiments above, the spokes may have any cross-section
- 25 dependent on design need. For example, the cross-section may be oval, circular, polygonal or undulating and the spokes may be solid or hollow. The entire gear wheel may be made from the same material or different parts in the gear wheel may be made from different material. The choice of material is dependent on intended use, for example, metal, alloys, plastic, composite or any other suitable material or combination of materials.
- 30 The spokes may also have the same or different length and the same or different curvature. The number of spokes is a design parameter dependent on intended use and can vary dependent on e.g. size of gear wheel, rotational speed, material, load and number of connection points between the spokes.

The hub is a centre point for attachment of external devices. The hub may comprise a through opening for housing a shaft. The through opening may comprise attachment means for engaging the shaft, for example splines or the like. The through opening may also rotatably house the shaft, for example the gear wheel may be rotated about the shaft.

- 5 The hub may comprise attachment means for attaching to a device position next to the gear wheel, for example through openings arranged at a distance from the centre of the gear wheel. The attachment means may comprise one or a plurality of radially extending attachment means and the spokes are arranged with different or same length lengths accordingly. It should be noted that the attachment means can be adapted dependent on
10 design needs and could have any suitable form and that the spokes are arranged with different or same lengths accordingly.

According to one example embodiment, the gear wheel is obtained by additive manufacturing. By way of example the gear wheel is obtained by additive manufacturing,
15 of a metallic powder material.

Additive manufacturing, sometimes also called free-form fabrication, is a method for forming three- dimensional articles through successive fusion of chosen parts of powder layers applied to a worktable. There are several different types of additive manufacturing
20 apparatus. One type of additive manufacturing technology is Powder Bed Fusion (PBF), which produces a solid part using a thermal source that induces fusion (sintering or melting) between the particles of a metallic powder material one layer at a time. One example of a PDF technology is Electron Beam Melting (EBM), which is an additive manufacturing where an electron emitting cathode in an electron acceleration column is
25 the source for electron beam generation, which in turn is acting as an energy beam for melting the power material.

According to a second aspect of the present invention, there is provided a vehicle comprising a gear wheel according to the above. Effects and features of the second
30 aspect are largely analogous to those described above in relation to the first aspect of the present invention

According to a third aspect of the present invention, there is provided a gear assembly comprising a gear wheel according to the above. Effects and features of the third aspect
35 are largely analogous to those described above in relation to the first aspect of the

present invention. By way of example, the gear assembly may be installed in any one of an engine, such as an internal combustion engine, a driven axle, a transfer box, a differential, and a reduction hub.

5 BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a more detailed description of embodiments of the invention cited as examples.

10 In the drawings:

Fig. 1 schematically shows a side view of a vehicle,

Fig. 2 schematically shows a top view of a powertrain in a vehicle,

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Fig. 3 schematically shows a perspective view of gear wheel according to the invention,

Fig. 4 schematically shows a cross-section and perspective view of the gear wheel in figure 3,

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Fig. 5 depicts an excision of an area 5-5 in figure 3 of a first layer of meshed spokes, and

Fig. 6 depicts an excision of an area 5-5 in figure 3 of a second layer of meshed spokes.

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DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

With reference to figures 1-6, the invention relates to gear wheel 1 with improved dampening performance.

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Fig. 1 schematically shows a side view of a vehicle 100 comprising a powertrain 101 comprising a gear assembly 102 comprising the gear wheel 1 according to the invention.

Fig. 2 schematically shows a top view of the powertrain 101 comprising the gear
35 assembly 102 and the gear wheel 1 according to the invention. In this example, the gear

assembly is a gear box. The gear assembly 102 is arranged to connect and transfer power from a crankshaft 103, i.e. a propulsion unit output shaft, of an engine 105 to a gearbox shaft 104, i.e. a transmission input shaft. Hence, the invention relates also to a gear assembly 102 comprising the gear wheel 1 and a vehicle comprising such gear wheel 1 and gear assembly 102. In other examples, the gear assembly may be installed in an internal combustion engine, or in any other type of installation using a gear wheel, such as in a driven axle, a transfer box, a differential, and a reduction hub.

Figures 3 and 4 schematically show a gear wheel 1 having an axial direction Z, a radial direction R and a circumferential direction C. The axial direction Z coincides with a rotational centre axis of the gear wheel 1. The axial direction Z is perpendicular to the radial direction R and the circumferential direction C coincide with a rotational direction of the gear wheel 1.

Figures 3 and 4 schematically shows that the gear wheel 1 comprises a centrally located hub 2, an outer transmission portion 3 located radially R outward from the hub 2 and surrounding the hub 2 in the circumferential direction C, and an intermediate portion 4 connecting the hub 2 to the outer transmission portion 3. The intermediate portion 4 comprises a set 5X of spokes 5, wherein each spoke 5 in at least a subset of spokes 5 has a curved shape with a convex side 51 and a concave side 52 so as to partly extend also in the circumferential direction C. Each spoke 5 in said set 5X connects the hub 2 to the outer transmission portion 3 in the radial direction R and the circumferential direction C and each spoke 5 is connected to at least a second spoke 5.

Figures 3 and 4 show that each spoke 5 is connected to a number of other spokes 5 creating a mesh-like structure in a radial plane.

According to one example embodiment and as illustrated in figures 3-4, the set 5X of spokes 5 comprises a first set 5a of spokes 5 and a second set 5b of spokes 5 extending between the hub 2 and the outer transmission portion 3. The spokes 5 in each set 5a, 5b of spokes 5 are distributed circumferentially around the gear wheel 1. In figures 3 and 4 the spokes 5 are evenly distributed around the gear wheel 1 creating a corresponding mesh-like structure. However, the spokes 5 can be distributed unevenly if the gear wheel is rotationally balanced.

In figures 3 and 4 the first and second set 5a, 5b of spokes 5 are directed in circumferentially opposite directions and are directly connected to each other in connection points 13 where the spokes meet. The first set 5a of spokes 5 has a curvature in a clock-wise circumferential direction starting from the hub 2. The second set 5b of spokes 5 has a curvature in a clock-wise circumferential direction starting from the outer transmission portion 3. Hence, the convex side 51 of each spoke of the first set 5a of spokes 5 faces the concave 52 side of a neighbouring spoke of the first set 5a of spokes 5, and the convex side 51 of each spoke of the second set 5b of spokes 5 faces the concave 52 side of a neighbouring spoke of the second set 5b of spokes 5.

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In order to describe further the relationship between the different spokes, one could describe the mesh-like structure in its smallest repetitive pattern as schematically shown in figure 5. Figure 5 depicts an excision of an area 5-5 in figure 3. Here, the convex side 51 of a first spoke 511 of the first set 5a of spokes 5 faces the concave 52 side of a neighbouring second spoke 512 of the first set 5a of spokes 5. Further the convex side 51 of a third spoke 521 of the second set 5b of spokes 5 faces the concave 52 side of a neighbouring fourth spoke 522 of the second set 5b of spokes 5. Moreover, the convex side 51 of the first spoke 511 faces the convex 51 side of the third spoke 521 and the concave side 52 of the fourth spoke 522.

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Figures 3-5 schematically shows that the first and second sets 5a, 5b of spokes 5 are arranged in a first layer 6 in a first radial plane and the inter-connected spokes 5 create the mesh-like structure. The radial plane coincide with the radial direction R being perpendicular to the axial direction Z. The interconnected spokes 5 build a mesh-like structure comprising a trapezoid-like pattern 12 indicated with a dotted line in figure 5.

Figures 3-4 schematically shows a further example embodiment, wherein the set 5X of spokes 5 comprises a third set 5c of spokes 5 having a curvature in a clock-wise circumferential direction starting from the hub 2 and a fourth set 5d of spokes 5 having a curvature in a clock-wise circumferential direction starting from the outer transmission portion 3. Hence, the third and fourth set 5c, 5d of spokes 5 are directed in circumferentially opposite directions and are directly connected to each other in connection points 13 where the spokes 5 meet. Just as the first and second sets 5a, 5b of spokes 5, the third and fourth sets 5c, 5d of spokes are arranged in a second layer 7 in a second radial plane creating a mesh-like structure in a radial plane. In figures 3 and 4 the

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spokes 5 are evenly distributed around the gear wheel 1 creating a corresponding mesh-like structure. However, the spokes 5 can be distributed unevenly if the gear wheel is rotationally balanced. The convex side 51 of each spoke of the third set 5c of spokes 5 faces the concave 52 side of a neighbouring spoke 5 of the third set 5c of spokes 5, and the convex side 51 of each spoke of the fourth set 5d of spokes 5 faces the concave 52 side of a neighbouring spoke of the fourth set 5d of spokes 5. The interconnected spokes 5 build a mesh-like structure comprising a trapezoid-like pattern 12 indicated with a dotted line in figure 6.

- 10 In order to describe further the relationship between the different spokes, one could describe the mesh-like structure in its smallest repetitive pattern as schematically shown in figure 6. Figure 6 depicts an excision of an area 5-5 in figure 3. Here, the convex side 51 of a fifth spoke 513 of the third set 5c of spokes 5 faces the concave 52 side of a neighbouring sixth spoke 514 of the third set 5c of spokes 5, and wherein the convex side 51 of a seventh spoke 523 of the fourth set 5d of spokes 5 faces the concave 52 side of a neighbouring eighth spoke 524 of the fourth set 5d of spokes 5, and wherein the convex side 51 of the fifth spoke 513 faces the convex 51 side of the seventh spoke 523 and the concave side 52 of the eighth spoke 524.
- 20 Figures 3-4 schematically shows that the first and the second layers 6, 7 of spokes 5 are separated in the axial direction Z being perpendicular to the radial direction R.

Figures 3-4 schematically shows that the intermediate portion 4 comprises connecting means 8 connecting the first and second layers 6, 7 in the axial direction Z. Figures 3-4 schematically shows that the second layers 6, 7 are arranged in parallel to each other. According to one example, the first and second layers 6, 7 are flat, i.e. have an extension in a flat plane, and arranged in parallel to each other. Here, flat relates to a two dimension extension in the radial direction with an even extension in the axial direction. According to one example, the first and second layers 6, 7 have an essentially two dimensional extension in the radial direction R with an un-even extension in the axial direction Z, i.e. the thickness of the first and/or the second layers in the axial direction Z may vary. According to one example, the first and second layers 6, 7 may be non-flat, i.e. three dimensional, where the first and second layers 6, 7 have a general extension in the radial direction R but with an undulating, curved or slanted surface with relation to a flat plane

extending in the radial direction R. A slanted surface may diverge or converge from the hub towards the outer transmission portion.

According to one example embodiment, the connecting means 8 comprises separate
5 linking units 8a connecting each spoke 5 to at least a second spoke 5 in the axial direction Z, as illustrated in e.g. Fig. 4.

According to one example embodiment, the connecting means 8 comprises
10 interconnecting linking units 8b connecting one separate linking unit to at least a second separate linking unit in the radial direction R.

According to one example embodiment, each spoke 5 has an elongate shape corresponding to a part of an ellipse, preferably a part of a circle.

15 Figure 3 schematically shows that the spokes 5 have a common centre axis Z-Z. However, the invention is not restricted to such an embodiment, but other design features are possible. Depending on the design of the hub and the design layout of the spokes, the spokes 5 can have different or the same length between the hub 2 and the outer transmission portion 3.

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Figures 3-4 schematically shows an example embodiment where each spoke 5 is connected to at least a second spoke 5 in the radial direction R creating the mesh. The connections between the spokes can be evenly or unevenly distributed.

25 The connection points 13 between the spokes 5 can be done by any known means, but preferably a 3-D printing technology (additive manufacturing) is used to create the gear wheel and forge the spokes together.

Figures 3-4 schematically shows that the outer transmission portion 3 comprises teeth 9
30 for transmitting rotational motion to another gear wheel or the like.

According to example embodiment, each spoke 5 in each set 5X of spokes has a curved shape with a convex side and a concave side.

According to one example embodiment (although not shown), the set 5X of spokes 5 comprises a fifth set of spokes 5 extending between the hub 2 and the outer transmission portion 3. The spokes 5 in the fifth set are distributed circumferentially around the gear wheel 1 and have a straight shape.

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Figures 3-4 schematically shows that the hub 2 is a centre point for attachment of external devices. The hub may comprise a through opening 10 for housing a shaft (not shown). The through opening 10 may comprise attachment means (not shown) for engaging the shaft, for example splines or the like. The through opening 10 may also rotatably house
10 the shaft, for example the gear wheel may be rotated about the shaft. The hub 2 may comprise attachment means 11 for attaching to a device position next to the gear wheel, for example through openings arranged at a distance from the centre of the gear wheel. Figures 3-4 shows that the attachment means 11 comprises three radially extending attachment means 11 and that the spokes 5 are arranged with different or same length
15 lengths accordingly. It should be noted that the attachment means 11 can be adapted dependent on design needs and could have any suitable form and that the spokes 5 are arranged with different or same lengths accordingly.

It is to be understood that the present invention is not limited to the embodiments
20 described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims.

CLAIMS

1. A gear wheel (1) having an axial direction (Z), a radial direction (R) and a circumferential direction (C), comprising a centrally located hub (2), an outer transmission portion (3) located radially (R) outward from the hub (2) and surrounding the hub (2) in the circumferential direction (C), and an intermediate portion (4) connecting the hub (2) to the outer transmission portion (3), characterized in that the intermediate portion (4) comprises a set (5X) of spokes (5), wherein each spoke (5) in at least a subset of spokes (5) having a curved shape with a convex side and a concave side so as to partly extend also in the circumferential direction (C), wherein the spokes (5) in said set (5X) connects the hub (2) to the outer transmission portion (3) in the radial direction (R) and the circumferential direction (C), wherein each spoke (5) is connected to at least a second spoke (5).
2. A gear wheel (1) according to claim 1, wherein the set (5a, 5b) of spokes (5) comprises a first set (5a) of spokes (5) and a second set (5b) of spokes (5) extending between the hub (2) and the outer transmission portion (3), wherein the spokes (5) in each set (5a, 5b) of spokes (5) are distributed circumferentially around the gear wheel (1), wherein the first and second set (5a, 5b) of spokes (5) are directed in circumferentially opposite directions so that the convex side (51) of each spoke of the first set (5a) of spokes (5) faces the concave (52) side of a neighbouring spoke of the first set (5a) of spokes (5), and the convex side (51) of each spoke of the second set (5b) of spokes (5) faces the concave side of a neighbouring spoke of the second set (5b) of spokes (5).
3. A gear wheel (1) according to claim 2, wherein the first set (5a) of spokes (5) has a curvature in a clock-wise circumferential direction starting from the hub (2).
4. A gear wheel (1) according to claim 2 or 3, wherein the second set (5b) of spokes (5) has a curvature in a clock-wise circumferential direction starting from the outer transmission portion (3).
5. A gear wheel (1) according to any one of claims 2-4, wherein the first and second sets (5a, 5b) of spokes (5) are arranged in a first layer (6) in a first radial plane.
6. A gear wheel (1) according to any one of claims 2-5, wherein the set (5X) of spokes (5) comprises a third set (5c) of spokes (5) having a curvature in a clock-wise circumferential direction starting from the hub (2).

7. A gear wheel (1) according to any one of claims 2-6, wherein the set (5X) of spokes (5) comprises a fourth set (5d) of spokes (5) having a curvature in a clock-wise circumferential direction starting from the outer transmission portion (3).

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8. A gear wheel (1) according to claims 6 and 7, wherein the third and fourth sets (5c, 5d) of spokes are arranged in a second layer (7) in a second radial plane.

9. A gear wheel (1) according to any one of claims 6-8, wherein the convex side (51) of each spoke of the third set (5c) of spokes (5) faces the concave (52) side of a neighbouring spoke (5) of the third set (5c) of spokes (5), and the convex side (51) of each spoke of the fourth set (5c) of spokes (5) faces the concave (52) side of a neighbouring spoke of the fourth set (5c) of spokes (5).

10. A gear wheel (1) according to claims 5 and 8, wherein the first and the second layers (6, 7) of spokes (5) are separated in the axial direction (Z) being perpendicular to the radial direction (R).

11. A gear wheel (1) according to claim 10, wherein the intermediate portion (4) comprises connecting means (8) connecting the first and second layers (6, 7) in the axial direction (Z).

12. A gear wheel (1) according to claim 11, wherein the connecting means (8) comprises separate linking units connecting each spoke (5) to at least a second spoke (5) in the axial direction (Z).

13. A gear wheel (1) according to claim 12, wherein the connecting means (8) comprises interconnecting linking units connecting one separate linking unit to at least a second separate linking unit in the radial direction (R).

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14. A gear wheel (1) according to any one of the preceding claims, wherein each spoke (5) has a shape corresponding to a part of an ellipse, preferably a part of a circle.

15. A gear wheel (1) according to any one of the preceding claims, wherein the spokes (5) have a common centre axis (Z-Z)

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16. A gear wheel (1) according to claim 15, wherein each spoke (5) is connected to at least a second spoke (5) in the radial direction (R) creating a mesh.

5 17. A gear wheel (1) according to any one of the preceding claims, wherein the outer transmission portion (3) comprises teeth (9).

18. A gear wheel (1) according to any one of the preceding claims, wherein each spoke (5) in each set (5X) of spokes having a curved shape with a convex side and a concave
10 side.

19. A gear wheel (1) according to any one of claims 1-17, wherein the set of spokes (5) comprises a fifth set of spokes (5) extending between the hub (2) and the outer transmission portion (3), wherein the spokes (5) in the fifth set are distributed
15 circumferentially around the gear wheel (1) and wherein the spokes (5) in the fifth set have a straight shape.

20. A gear wheel (1) according to any one of the preceding claims, wherein the gear wheel is obtained by additive manufacturing, preferably of a metallic powder material.
20

21. A gear assembly comprising a gear wheel (1) according to any one of the preceding claims.

22. A vehicle comprising a gear wheel (1) according to any one of the preceding claims 1-
25 20 or a gear assembly (102) according to claim 21.

Fig. 1

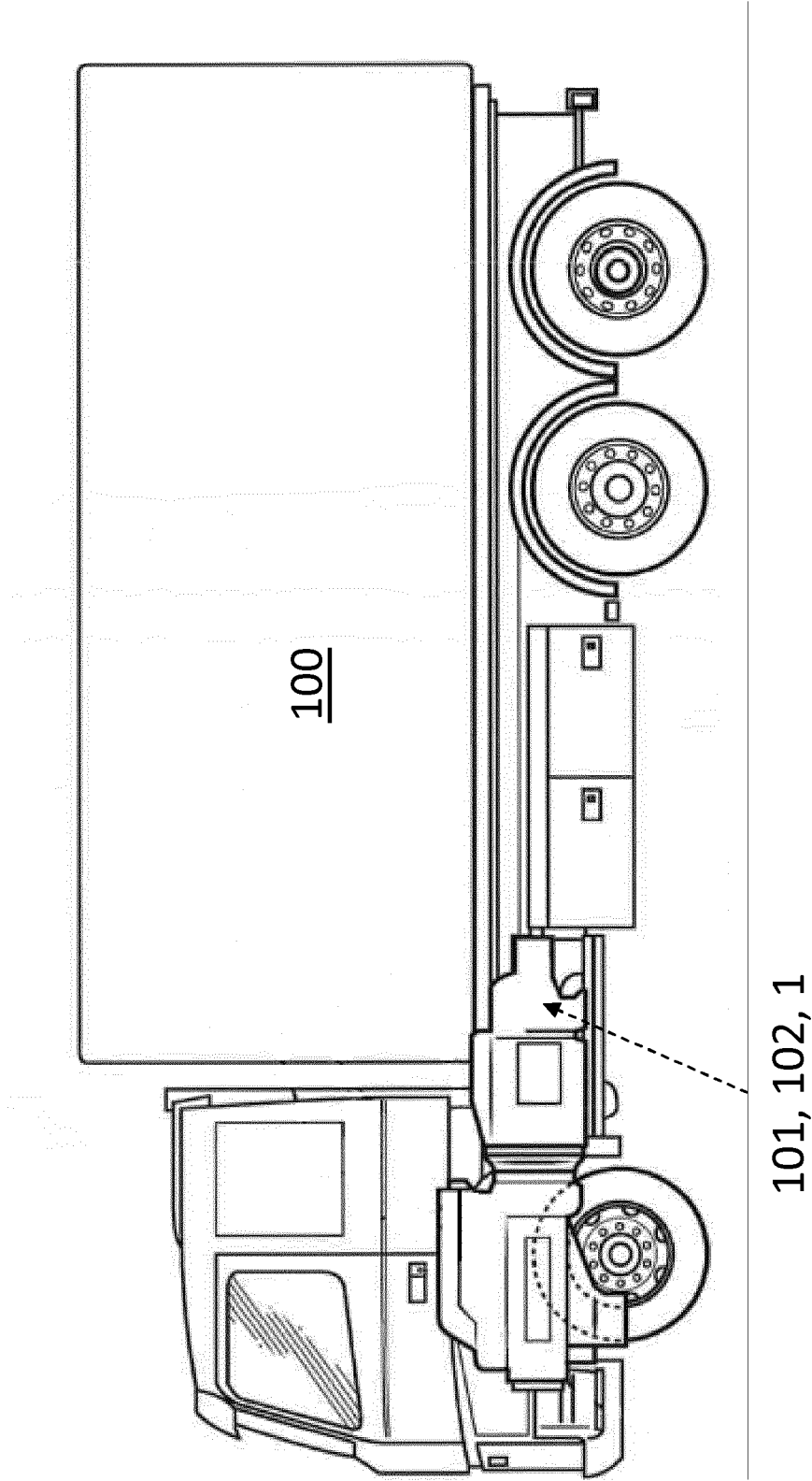


Fig. 2

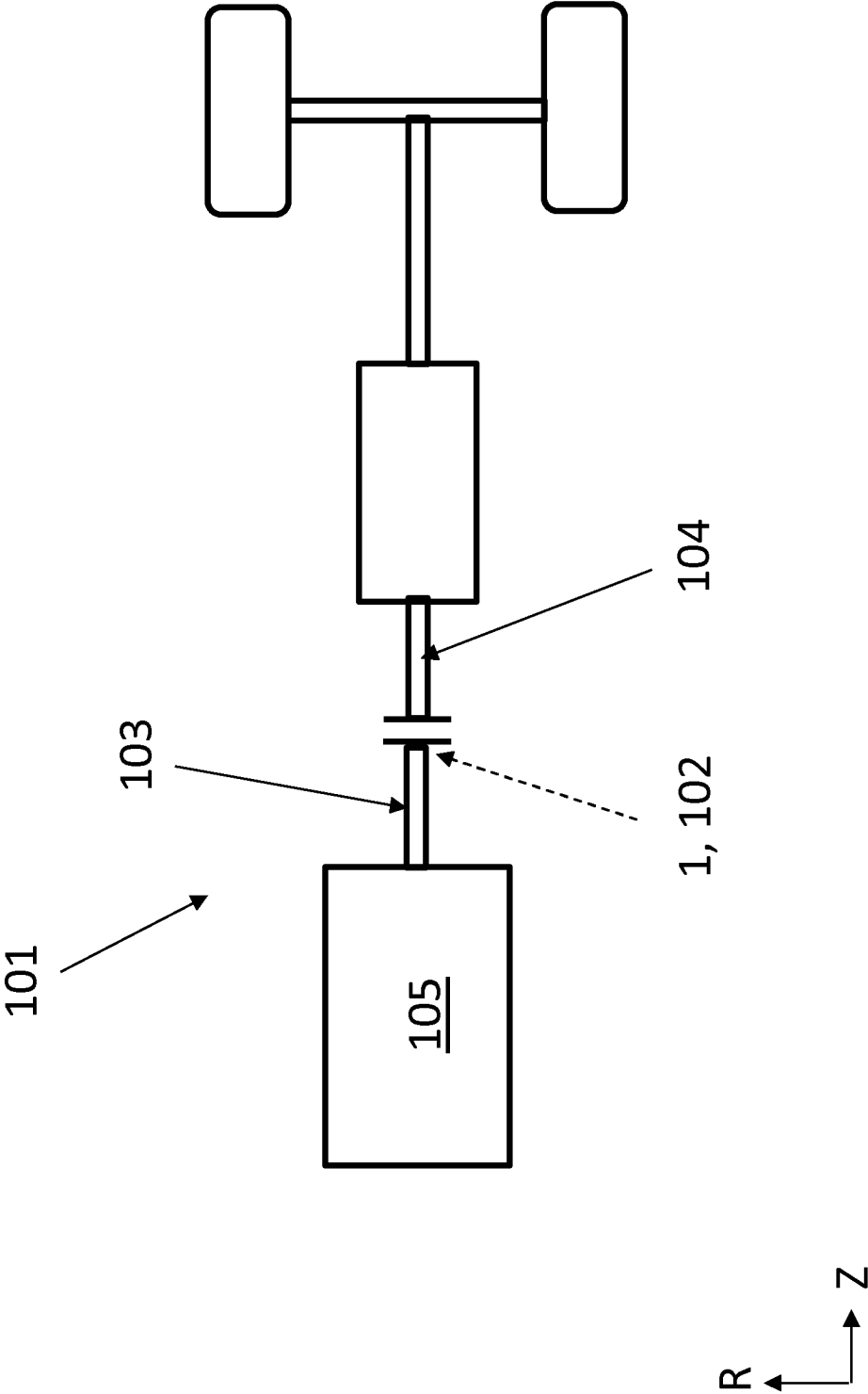


Fig. 3

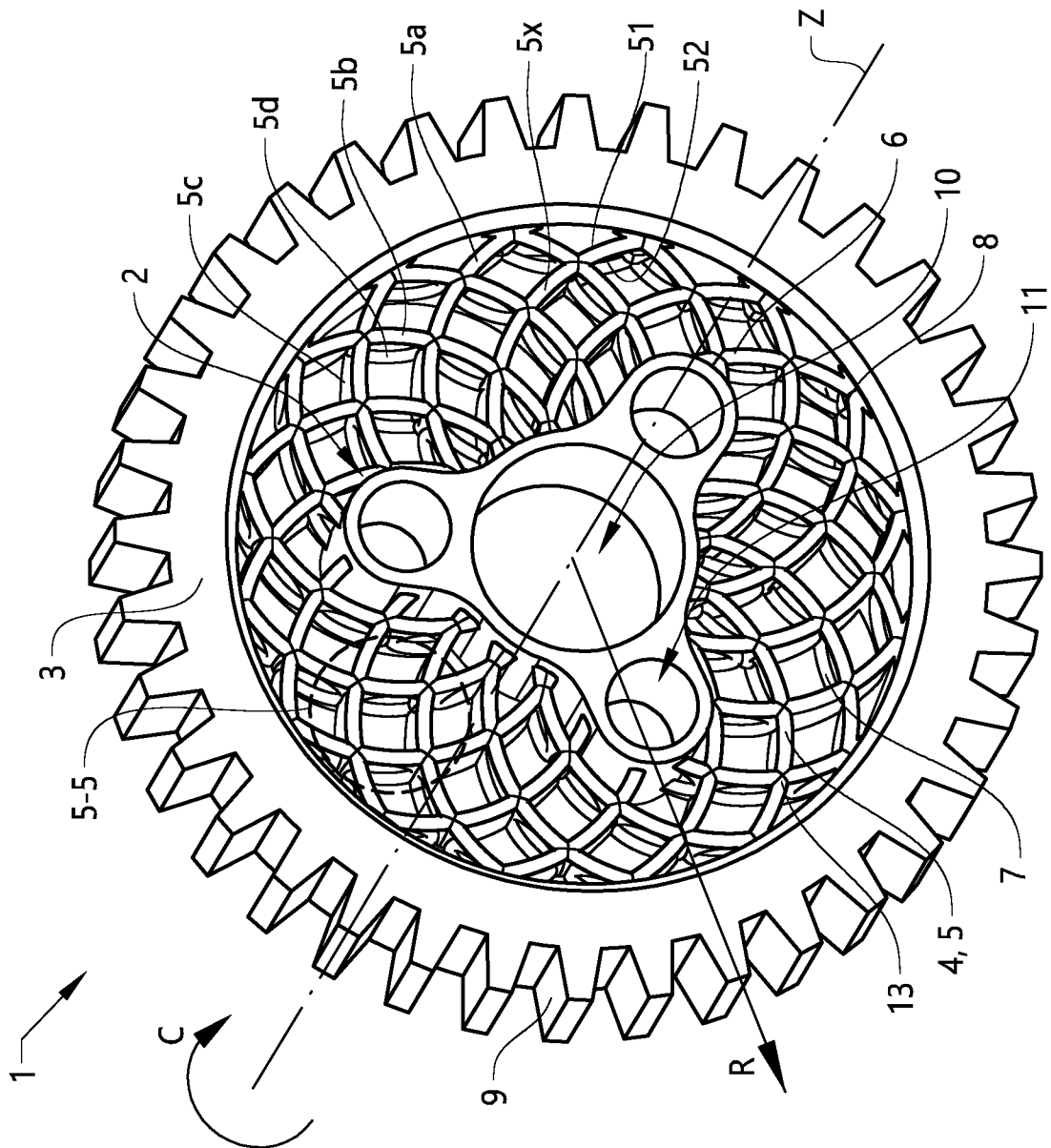


Fig. 4

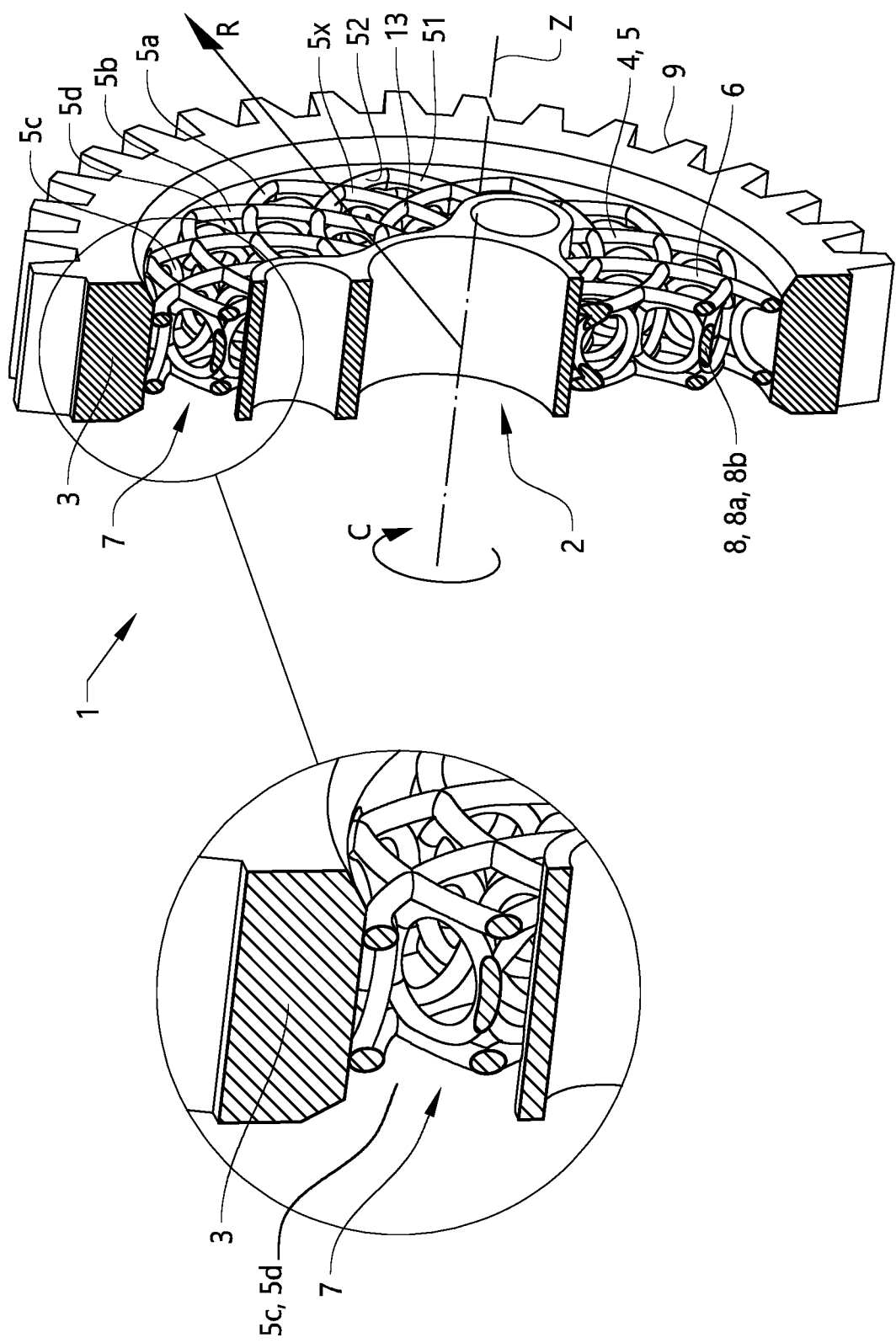


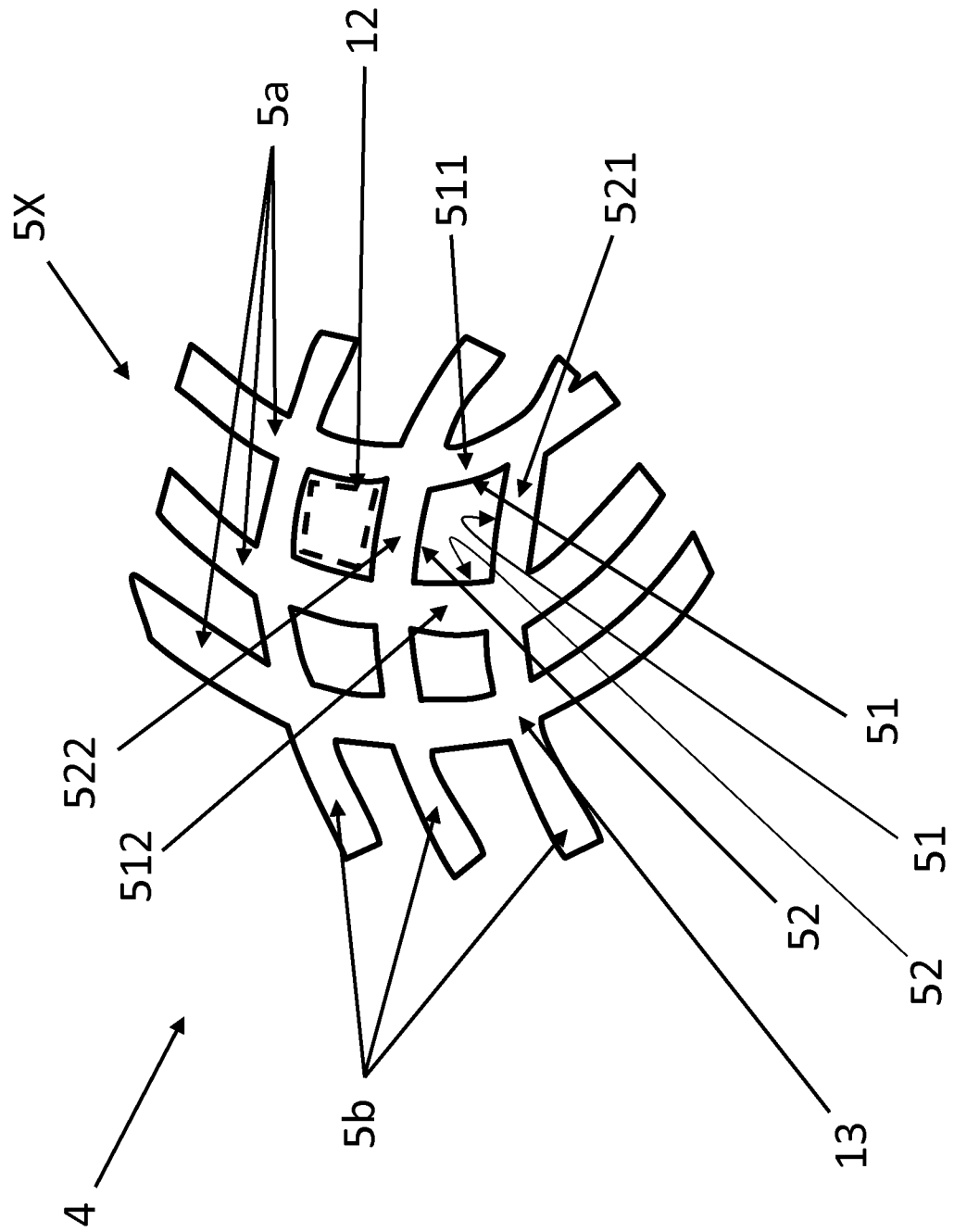
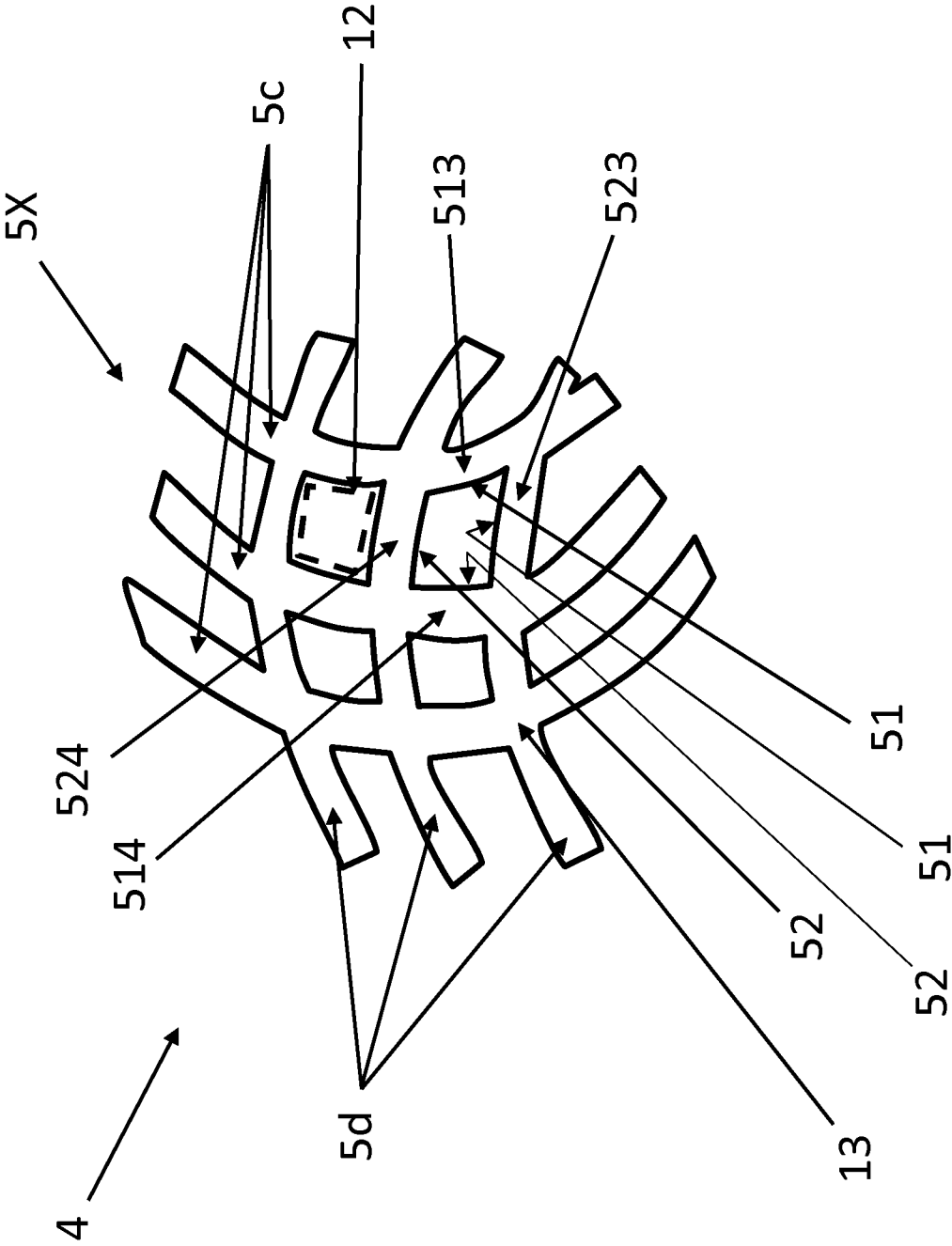
Fig. 5

Fig. 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/086295

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16H55/14 F16H55/17
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)
F16H

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2012 102777 A1 (ZF LENKSYSTEME GMBH [DE]) 2 October 2013 (2013-10-02)	1-19,21, 22
Y	figures 1, 3, 7	20
X	DE 10 2014 003441 A1 (FRAUNHOFER GES ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E V [DE]) 10 September 2015 (2015-09-10)	1-5,14, 17-22
Y	figures 1, 2, 5 paragraph [0013]	20
X	US 3 304 795 A (ROUVEROL WILLIAM S) 21 February 1967 (1967-02-21)	1-5,14, 17-19, 21,22
	figure 3	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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11/09/2019

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2018/086295

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102012102777 A1	02-10-2013	NONE	
DE 102014003441 A1	10-09-2015	NONE	
US 3304795 A	21-02-1967	NONE	