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(71) Applicant *(for all designated States except US)*: **APPLIED MATERIALS, INC.** [US/US]; 3050 Bowers Ave., Santa Clara, CA 95054 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **COUSTIER, Fabrice** [FR/FR]; 46 Chemin de la Champagne, F-01220 Divonne Les Bains (FR). **ROTUNDO, Daniel** [CH/CH]; 17 Avenue Alexandre-Vinet, CH-1815 Clarens (CH). **ROSSET, Jean-Marc** [CH/CH]; Les Tuileries, Rue Es Prises 6, CH-1422 Grandson (CH). **LOMBARD DE BUFFIERES, Frédérique** [CH/CH]; Le Grand-Chemin 128, CH-1066 Epalinges (CH). **SUMI, Romain** [CH/CH]; Ch. de la Source 11, CH-1032 Romanel-s-Lausanne (CH).

(74) Agents: **KRAUSHAAR, Marc** et al.; Zimmermann & Partner, Isartorplatz 1, 80331 Munich (DE).

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(54) **Title**: PULLEY TIRE, PULLEY WHEEL AND PULLEY FOR A WIRE SAW DEVICE, AND METHOD FOR ASSEMBLING PULLEY

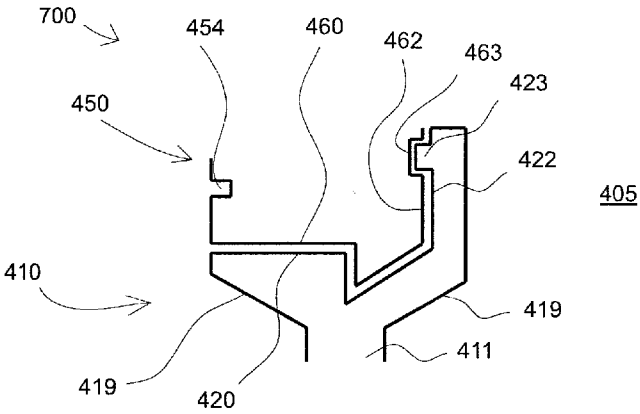


Fig.7

(57) **Abstract**: A pulley tire (450) is provided, for a pulley of a wire saw device having a wire forming a wire web, the pulley (700) comprising a wheel (410) and the tire (450). The tire (450) is essentially ring- shaped about an axis and has: a wire guiding portion extending circumferentially about the axis along a radially outer side of the tire for guiding the wire; and a wheel receiving portion (460) extending circumferentially about the tire axis along a radially inner side of the tire (450), the wheel receiving portion (460) being shaped for receiving the wheel therein by sliding the tire axially in direction of a mounting side onto the wheel. The wheel receiving portion has a support surface (468) facing towards the axis for supporting the tire on the wheel; a forward stopper face (462) facing towards the mounting side for stopping a movement of the tire relative to the wheel in direction to the mounting side, and a snap-in profile portion (464) having a backward stopper face (465), the backward stopper face (465) being adjacent to the support surface (468) and facing away from the mounting side for stopping a movement of the tire relative to the wheel in direction away from the mounting side.

WO 2011/086403 A1

PULLEY TIRE, PULLEY WHEEL AND PULLEY FOR A WIRE SAW DEVICE, AND METHOD FOR ASSEMBLING PULLEY

FIELD OF THE INVENTION

[0001] Embodiments of the present invention relate to a pulley of and for a wire saw device having a wire forming a wire web. More particularly, they relate to a pulley configured for a wire saw device, such as a wire saw device for cutting or sawing hard materials such as blocks of silicon or quartz, e.g., for cutting silicon wafers, for a squarer, for a cropper or the like. Further embodiments of the present invention relate to a tire for such a pulley, and to a wheel for such a pulley. Further embodiments relate to a wire saw device having such a pulley. Further embodiments of the present invention relate to a method of assembling such a pulley.

BACKGROUND OF THE INVENTION

[0002] Wire saw devices exist for cutting blocks or bricks, thin slices, e.g. semiconductor wafers, from a piece of hard material such as silicon. In such devices a stretched wire is fed from a spool and is both guided and tensioned by pulleys for guiding the wire in the cutting area. The wire that is used for sawing is generally provided with an abrasive material. As one option, the abrasive material can be provided as a slurry. This may be done shortly before the wire touches the material to be cut. Thereby, the abrasive is carried to the cutting position by the wire for cutting the material. As another option, the abrasive can be provided on the wire with a coating. For example, diamond particles can be provided on a metal wire, e.g. with a coating, wherein the diamond particles are imbedded in the coating of the wire. Thereby, the abrasive is firmly connected with the wire.

[0003] Generally, there is a tendency to use thinner wires in order to reduce the thickness of the cut and, thereby, to decrease the material wasted. There is also a desire to use diamond wires. Further, there is a desire to increase the cutting speed for improving the throughput of wire saw devices. The maximum speed for moving the piece through the web, and also the maximum effective cutting area within a given amount of time, is limited by several factors including wire speed, hardness of the material to be sawed, disturbing influences, desired

precision, and the like. When the speed is increased and / or diamond wires are used, the strain on the pulleys is also increased. For guiding the wire reliably and stably, the pulley may include a wheel and a separate tire. In this case, the pulley is assembled from several parts. This assembly of wheel and separate tire implies a further manufacturing step and hence additional cost. Also, the assembly of the pulley should be done very carefully because the pulley should guide the wire properly even if exposed to strong forces due to the high tension and to vibrations of the wire. Hence, the above-mentioned problems of avoiding damage or breakage of the wire are even more critical at higher sawing speeds.

SUMMARY

[0004] In view of the above, a pulley tire according to claim 1, a pulley wheel according to claim 11, a pulley according to claims 22 and 23, a wire saw device according to claim 24, and a method according to claim 25 are provided. Further advantages, features, aspects and details are apparent from the dependent claims, the description and drawings.

[0005] According to one embodiment, a pulley tire for a pulley of a wire saw device is provided, the pulley including a wheel and the tire. The tire has an axis and includes: a wire guiding portion extending circumferentially about the axis along a radially outer side of the tire; and a wheel receiving portion extending circumferentially about the tire axis along a radially inner side of the tire, the wheel receiving portion being shaped for receiving the wheel therein by sliding the tire axially in direction of a mounting side onto the wheel. The wheel receiving portion has a forward stopper face facing towards the mounting side, and a snap-in profile portion having a backward stopper face, the backward stopper face facing away from the mounting side.

[0006] According to a further embodiment, a pulley wheel for a pulley of a wire saw device is provided, the pulley including the wheel and a tire. The wheel is rotatable about an axis and has: a tire receiving portion extending circumferentially about the tire axis along a radially outer side of the wheel, the tire receiving portion being shaped for receiving the tire thereon by sliding the tire axially in direction of a mounting side onto the wheel. The tire receiving portion has a forward stopper counter-face facing away from the mounting side, and a counter snap-in profile portion having a backward stopper counter-face, the backward stopper counter-face facing towards the mounting side.

[0007] According to a yet further embodiment, a pulley for a wire saw device is provided. The pulley is rotatable about an axis and includes a pulley tire according to any embodiment described herein, and a pulley wheel, especially one according to any embodiment described herein. The wheel receiving portion of the tire and a tire receiving portion of the wheel are shaped form-fit to each other.

[0008] According to a yet further embodiment, a pulley for a wire saw device having a wire forming a wire web is provided. The pulley is rotatable about an axis and includes a pulley tire and a pulley wheel. The tire is essentially ring-shaped about an axis and has a wire guiding portion extending circumferentially about the axis along a radially outer side of the tire for guiding the wire, and a wheel receiving portion extending circumferentially about the tire axis along a radially inner side of the tire. The wheel receiving portion is shaped for receiving the wheel therein by sliding the tire axially in direction of a mounting side onto the wheel. The wheel receiving portion has a forward stopper face facing towards the mounting side for stopping a movement of the tire relative to the wheel in direction to the mounting side and a snap-in profile portion having a backward stopper face facing away from the mounting side for stopping a movement of the tire relative to the wheel in direction away from the mounting side. The wheel is rotatable about the axis and has a tire receiving portion extending circumferentially about the tire axis along a radially outer side of the wheel, the tire receiving portion receiving the tire thereon. The tire receiving portion has a forward stopper counter-face facing away from the mounting side for stopping a movement of the tire relative to the wheel in direction to the mounting side, and a counter snap-in profile portion having a backward stopper counter-face facing towards the mounting side for stopping a movement of the tire relative to the wheel in direction away from the mounting side. The wheel receiving portion of the tire and the tire receiving portion of the wheel are shaped form-fit to each other. Further, at least one of the snap-in profile portion and the counter snap-in profile portion is shaped asymmetrically such as to allow an axial sliding of the tire in direction of the mounting side for mounting the tire on the wheel, while blocking an axial sliding of the tire in direction away from the mounting side.

[0009] According to a yet further embodiment, a wire saw device having a plurality of pulleys according to any embodiment described herein is provided.

[0010] According to a yet further embodiment, a method of assembling a pulley for a wire saw device is provided, wherein the pulley are rotatable about an axis. The method includes:

a) placing a tire and a wheel concentrically about an axis such that the wheel is axially located at a mounting side of the tire, wherein the tire is essentially ring-shaped about an axis and has a wire guiding portion extending circumferentially about the axis along a radially outer side of the tire for guiding the wire, and a wheel receiving portion extending circumferentially about the tire axis along a radially inner side of the tire, the wheel receiving portion having a forward stopper face facing towards the mounting side and a snap-in profile portion having a backward stopper face facing away from the mounting side, and wherein the wheel is rotatable about the axis and has a tire receiving portion extending circumferentially about the tire axis along a radially outer side of the wheel, the tire receiving portion having a forward stopper counter-face facing away from the mounting side, and a counter snap-in profile portion having a backward stopper counter-face facing towards the mounting side;

b) sliding the tire axially in direction of the mounting side onto the wheel, such that the tire receiving portion of the wheel receives the wheel receiving portion of the tire thereon, until the sliding movement of the tire relative to the wheel in direction to the mounting side is stopped by the forward stopper face contacting the forward stopper counter-face; and

c) sliding the snap-in profile portion over the counter snap-in profile portion, whereby the snap-in profile portion snaps in such that a movement of the tire relative to the wheel in direction away from the mounting side is stopped by the backward stopper face contacting the backward stopper counter-face.

[0011] Embodiments are also directed at parts used for carrying out the disclosed assembling method. Furthermore, embodiments according to the invention are also directed at methods by which the described pulley and the described wire saw device operates.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the invention and are described in the following:

FIG. 1 shows a schematic view of a wire saw device according to embodiments described herein;

FIG. 2 shows a schematic view of a yet further wire saw device according to embodiments described herein;

FIG. 3 shows a perspective view of a wire management unit; and

FIGS. 4A and 4B show schematic views of a pulley illustrating embodiments of pulleys according to embodiments described herein; and

FIGS. 5A and 5B show schematic views of a yet further pulleys according to embodiments described herein;

FIGS. 6A to 6H and 7 show cross-sectional views of portions of respective pulleys having a wheel and/or a tire according to embodiments described herein; and

FIG. 8 shows a schematic perspective view of a further pulley having a wheel according to an embodiment described herein.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Reference will now be made in detail to the various embodiments of the invention, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to same components. Generally, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the invention and is not meant as a limitation of the invention. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

[0014] Furthermore, in the following description a wire management unit will be understood as a device handling the supply of wire to a cutting area or working area of a wire saw device, such as a cropper, a squarer, or a wafer cutting wire saw. Typically, the wire saw includes a wire guide for transporting and guiding the wire in a wire moving direction while the wire management unit provides control of the wire tension. Furthermore, the wire provided by the wire management unit forms a wire web in the cutting area. Often, a wire web will be considered as the web formed by a single wire management unit. It should be understood that a wire web may contain more than one working area which is defined as an area in which a

sawing process is performed. Thus, according to some embodiments described herein, a wire web can have multiple areas that are formed by a wire from different wire management units.

[0015] For modern wire saw devices like croppers, squarers, or wire saws, there is the desire to cut the hard material such as semiconductor material, for example silicon, quartz, or the like at high speeds. The wire speed, that is, the speed of the wire moving through the wire saw device, the wire management unit and the material to be sawed, respectively, can be, for example, 10 m/s or higher. Typically, the wire speed can be in a range of 15 to 20 m/s. However, higher wire speeds of 25 m/s or 30 m/s can also be desirable and could be realized under certain conditions.

[0016] For unwinding the wire at the desired wire speed, the spool rotates with a rotation speed of up to several thousands rotations per minute. For example, 1000 to 2000 rpm can be provided for unwinding the wire.

[0017] FIG. 1 shows a wire saw device 100. As can be seen from the pattern of the wire 10 forming the wire web in the wire web compartment 110, the example shown in FIG. 1 illustrates a squarer. The housing of the wire saw device is separated into different areas as indicated by the dotted line. The wire web is formed in the wire web compartment 110. Further, a housing portion 111, which houses further components and equipment of the wire saw device 100 is provided. For example, a wire handling device compartment 112 and an electrical cabinet 114 can be provided. Within the further housing portion 111, tanks 120 and 124 as well as respective pumps 121 and 125 can also be provided.

[0018] According to some embodiments, which can be combined with other embodiments described herein, the first tank 120 can be used for unused cooling fluid, e.g. in the case where the wire saw device is operated with diamond wire, or can be used e.g. for unused (fresh) slurry, in the case where the wire saw device 100 is operated with a wire requiring additional abrasive. The pump 121 pumps the cooling fluid (or slurry, respectively) towards the desired position in the cutting area. This is indicated in FIG. 1 by conduit 122. The used cooling fluid (or slurry) may flow back through conduit 126 and is pumped by pump 125 into the second tank 124. In those cases where cooling fluid or slurry is used, a portion of the used consumable fluid can be re-used if it is reinserted into the tank 120. Thus, according to different embodiments only a portion of the consumable fluid, all of the consumable fluid or none of the consumable fluid may be reused and, thus, be reinserted in tank 120. As one example, an additional valve might be provided in conduit 126 for selectively choosing the

tank into which the used fluid is pumped. According to yet another example, a fluid connection between the tank 124 and 120 can be provided in order to reinsert a portion of the used fluid in tank 120. According to different embodiments, as already described above, the consumable fluid can be cooling fluid or slurry. Generally, if slurry is used, the slurry also takes over the function of cooling the position, at which the wire cuts the material.

[0019] In the wire handling compartment 112 two handling sections for delivering the wire 10 to the cutting area and receiving the wire from the cutting area, respectively, are provided. According to some embodiments, which can be combined with other embodiments described herein, the wire is provided on a spool 132 rotating around the spool axes 132a. The wire is guided over a plurality of rollers 134 into the wire web compartment 110. Further pulleys 134 and 136 guide the wire 10 in the cutting area to form the wire web. Thereby, further pulleys (not shown) are required to guide the wire 10 from one pulley 136 to a further pulley 136. In order to avoid unnecessary complexity, these further pulleys are not shown in FIG. 1. After cutting, the wire is guided by a further pulley 134 towards the wire handling compartment 112 and is therein provided over pulleys 134 on the spool 130 rotating around the spool axes 130a.

[0020] According to yet further embodiments, which can be combined with other embodiments described herein, the wire handling system can be adapted for bi-directional use, such that in one direction the wire is fed from spool 132 to spool 130 and in a further direction, the wire is fed from spool 130 to spool 132. Thereby, according to typical implementations the two units corresponding to spools 130 and 132 include similar components such as pulleys or the like, to have a corresponding wire handling in both sawing directions. The bi-directional use of the wire saw device may be of particular interest if diamond wire is used.

[0021] Typically, the wire is guided from the wire handling compartment to the wire cutting area and back with a wire speed of 10 m/s or higher, typically in a range of 15 to 20 m/s. or even up to 25 m/s or 30 m/s. The material to be cut is positioned on the support 140. The support 140 and the wire web defined by pulleys 136 can be moved relative to each other such that cutting of the material can be conducted. According to one embodiment, the pulleys 136 maintain in a fixed position and the support 314 moves the material to be cut through the wire web while the wire is at a speed of about 10 m/s or higher. For easier understanding, this movement of the support 140 would in FIG. 1 be perpendicular to the plane of the drawing. According to another embodiment, the pulleys 136 and, thus, the web generated by wire 10 is

moved relative to the support 140 to cut the wire through the material. According to yet further embodiment, both the support 140 and the wire web can be both moved with respect to each other.

[0022] As indicated by the dotted lines in FIG. 1 the electrical cabinet 114 may serve to control the operation of the different components. For example, movement of the support 140, operation of the pumps 121 and 125, rotation of the spools 130 and 132 can be controlled. Further, additionally or optionally, the filling level of the tanks 120 and 124 can be measured and respective signals can be fed to the control unit. According to yet further embodiments, other control signals and monitoring signals can be fed to and from the electrical cabinet 114. For example, signals from the motors driving the spools, from a wire tensioner, to a wire tensioner, pressure signals for feeding the consumable fluids like slurry or cooling fluid, or a wire break detection signal can be fed to and from the electrical cabinet. Even though an electrical cabinet 114 integrated in a wire saw device 100 is shown in FIG. 1, it is apparent to a person skilled in the art that an electrical cabinet or a control unit in general can be provided at a different location in the wire saw device, e.g., also external of the wire device, and corresponding control signals from and to the control unit can be provided accordingly.

[0023] A further example of a wire saw device 200 is shown in FIG. 2. As can be seen from the wire web formed by the wire 10 in the wire web compartment 110, the system shown in FIG. 2 can be used to slice wafers, i.e. the system is a wire saw. According to the embodiments illustrated with respect to FIG. 2, two wire handling compartments 212a and 212b are provided. Each of the wire handling units feed the wire 10 towards the wire web and the wire is guided over pulleys 134 to form a wire web. As shown in FIG. 2, the wire web is formed by two adjacent areas wherein wire from each of the wire handling units is used to form one area of the wire web. As described above with respect to FIG. 1, pulleys 134 are provided for guiding the wire. Accordingly, embodiments that have been described with respect to FIG. 1, can correspondingly be formed for the wire saw device of FIG. 2.

[0024] According to different embodiments, a wire saw device can be a cropper, a squarer, a wire saw or a multiple wire saw. Thereby, a cropper is to be understood as a device, which can be used to saw end pieces from bricks or blocks, which have been separated into bricks in a squarer. A squarer is a wire saw that generally saws the silicon ingot into squares of the desired size such that a wire saw or a multiple wire saw can saw wafers from the bricks in a

wafering process. The wire management unit herein is particularly useful for the wire saw device being a squarer, but not limited to a squarer.

[0025] The above-described systems are particularly useful if thin wires or wires with a coating, e.g. a diamond coating, are used. Accordingly, in embodiments which can be combined with other embodiments described herein, the wire handling sections and wire saw devices described herein are adapted for thin wires having a diameter below about 400 μm, such as diameters between about 200 μm and about 400 μm, more particularly between about 200 μm and about 300 μm. However, in other cases embodiments may also have a wire diameter as low as, for example, 100 μm or even 80 μm. Further, the wire handling sections and wire saw devices described herein are adapted for coated wires, for example a wire having a nickel coating with diamond particles embedded therein. Such wires may typically have a diameter of about 300 μm to about 400 μm, e.g. 310 μm to 340 μm. For those wires a twisting of the wire might increase the risk of breaking of the wire or of damaging the coating, so that a twist-free operation is advantageous. By using diamond wire, the throughput may be increased by a factor of 2 or even more. In the case of a squarer, throughput rates of 100MW or even more can be achieved in this manner. When a diamond wire is used, further parts of the wire saw may be adapted to the diamond wire. For example, mechanical parts, electrical parts and/or software may be adapted to the use of diamond wire.

[0026] Typically, embodiments of pulleys described herein are adapted or configured for wire saw devices, they can be used in wire saw devices and/or can be a part of a wire saw device. Besides other aspects that can be used for making the pulley adapted or configured for a wire saw device, the pulley can have a groove structure which is made to guide a wire with a thickness of 400 μm or below, or a thickness of any of the other diameters mentioned above. Thereby, it has to be noted that the groove structure is designed specially for the wire diameter and the cutting process in order to allow for high precision cutting, e.g. with a precision of 250 μm or below, or even of 50 μm or below.

[0027] In the following, yet further embodiments are described, whose elements can be combined with any elements of other embodiments described herein. Within the following description, only those elements will be described, which deviate from those of previous or other embodiments described herein. It is to be understood that components, aspects and details described with respect to other embodiments can as well be applied to those embodiments which do not describe all components, aspects or details.

[0028] FIG. 3 shows a perspective view of a wire management unit according to some embodiments, which can be combined with other embodiments described herein. The embodiment of FIG. 3 includes a spool 312, mounted on spool shaft 310, and the pulleys 320, 330 and 340 are arranged to guide the wire, particularly with a wire tracking system. Examples of a wire tracking system are described in European patent application No. 09153051.9, entitled "Wire saw device and method for operating same" filed February 17, 2009, which is incorporated herein by reference to the extent the applications are not inconsistent with this disclosure. Additionally, a recess 116 can be seen. The recess 116 is provided in the main frame portion. The recess is dimensioned and arranged for accommodating at least partially the first pulley 320. This recess allows the first pulley 320 and, hence, the spool 312 to be arranged closer to the main frame portion while still allowing the first pulley 320 motion track to cover most or all of the wire carrying area 213a. Further, the pulley carrying unit 324 is provided as a retractable or telescopic bar. The retractable or telescopic bar is longitudinally movable along a bar axis parallel to the spool axis. The bar is longitudinally movably mounted to a wall portion of the main frame portion, e.g. a wall portion of the recess 116.

[0029] Further, in the embodiment of FIG. 3 the main frame portion includes a mounting member 314, to which the second and third pulley 330, 340 are mounted. The mounting member 314, being part of the main frame portion, is rigidly connected to the chassis of the wire saw device. While other designs of the mounting member are possible in the specific embodiment of FIG. 3, the mounting member is a bar, more specifically an L-shaped bar with a first leg 114a extending to a side surface of the main frame portion (i.e. extending parallel to the x axis), and with a second leg 114b forming an essentially right angle with the first leg and extending to a top surface of the main frame portion (i.e. extending parallel to the z axis). Independently from the shown embodiment, it is a general aspect that the first pulley 320 and the second pulley 330 (and, if present, optionally also other pulleys such as a third and/or fourth pulley) are mounted on a common mounting member, especially on a one-piece mounting member.

[0030] Further, a fourth pulley 350 is shown. The fourth pulley 350 receives the wire from the third pulley and redirects the wire by a fourth redirection angle. The fourth pulley 350 is rotatably mounted to the frame for rotation around a fourth pulley axis. Here, the fourth redirection angle is about 90°. In other embodiments, the fourth redirection angle may be between 60° and 120°. The fourth pulley axis is essentially parallel to the spool axis. Further,

the fourth pulley axis is essentially perpendicular to the first pulley axis, the second pulley axis, and the third pulley axis. In other embodiments, the fourth pulley axis may be essentially parallel to at least one of these axes.

[0031] The embodiment of FIG. 3 further includes a wire tensioner for controlling the tension of the wire. The wire tensioner includes a fifth pulley 360 rotatably mounted to the frame for rotation around a fifth pulley axis 362 and a sixth pulley 370 rotatably mounted to a movable element 374 for rotation around a sixth pulley axis 372. The movable element 374 is movably mounted on the main frame portion. The movement of the movable element 374 may be controlled by a motor, or the movable element 374 may be pre-biased e.g. by a spring, for controlling the wire tension. In FIG. 3, the movable element 374 is shown as a pre-biased swivel lever. The wire tensioner receives the wire 10 from the fourth pulley 350 and provides the wire 10 to the wire web (to the right of the wire management unit shown in FIG. 3). More precisely, the fifth pulley 360 receives the wire 10 from the fourth pulley 350 and deflects the wire by a fifth deflection angle, and then the sixth pulley 360 receives the wire 10 from the fourth pulley 350 and deflects the wire by a sixth deflection angle.

[0032] With the x-y-z reference frame defined above, it is a general aspect, illustrated in the embodiment of FIG. 3, that at least one condition (and in some embodiments, even all conditions) selected from the following list is satisfied:

- the wire tensioner is on a side of the spool 312 essentially opposite of the first pulley 320;
- the wire between the fourth pulley and the wire tensioner, more specifically between the fourth and the fifth pulley, extends primarily along the z axis;
- the wire between the fifth pulley and the sixth pulley extends primarily along the y axis;
- the wire leaves the sixth pulley essentially parallel to the y axis;
- the fifth and sixth pulley having respective axes each extending essentially in the x direction;
- the fifth redirection angle is in the range of about 60° to 90°, especially in the range of about 80° to 90°; and/or
- the sixth redirection angle is about 180°.

[0033] Generally, in embodiments which may be combined with other embodiments herein, the pulleys have at least one and in embodiments all of the following radiuses: The spool shaft 310 has a diameter of about 150 mm. The first pulley 320 and the second pulley 330 have a diameter of between 100 mm and 150 mm, especially of 112 mm (here, the diameter means the diameter observed by the wire, i.e. diameter within the wire guiding groove). The third

pulley 340 has a diameter of between 140 and 170 mm, especially of 158 mm. The fourth pulley 350 has a diameter similar to the first pulley 320. The fifth pulley 360 and the sixth pulley 370 have a diameter similar to the third pulley 340.

[0034] Continuing the description of FIG. 3, besides the wire handling section 300, which in the following will also be called primary wire handling section 300, the wire management unit of FIG. 3 also has a secondary wire handling section 300b. Here, the terms "primary" and "secondary" are introduced for ease of identification, and do not imply and hierarchical or functional order of the wire handling sections, spools etc. The secondary wire handling section 300b is constructed similarly to the primary wire handling section 300 and has corresponding elements to the elements of the primary wire handling section 300. The elements of the secondary wire handling section 300b are denoted as "secondary" elements and assigned reference signs 310b, 312b etc. corresponding to the corresponding "primary" elements 310, 312 etc. of the primary wire handling section 300. Thus, the secondary wire handling unit 300b has e.g. a secondary spool shaft 310b for a spool 312b, a secondary first pulley 320b, a secondary second pulley 330b etc. The secondary first pulley 320b is rotatably mounted to a secondary pulley carrying unit 324b for rotation around a secondary first pulley axis 322b, the secondary pulley carrying unit being longitudinally movable along a secondary pulley motion track. The primary and the secondary wire handling sections 300, 300b are placed in y direction adjacent to each other. As a general aspect illustrated by, but independent of the shown embodiment, the primary and the secondary wire handling sections 300, 300b may be placed on a common wall portion of the main frame portion. Further, the primary and the secondary wire handling sections 300, 300b may be placed in a common compartment of the wire saw device. Further, it can be seen that in FIG. 3, the primary spool 312 is of a different type than the secondary spool 312b (as can be seen from the absence of slits in the front flange of the secondary spool 312b).

[0035] Generally, the secondary wire handling section 300b is formed in the same manner as the wire handling section 300 according to any embodiment described herein. The description of elements of the primary wire handling section 300 is therefore also applicable to the corresponding elements of the secondary wire handling section 300b.

[0036] In an example mode of operation, henceforth called primary-to-secondary-spool sawing, the primary wire handling section provides wire from the primary first spool 312 to the web 10, so that the wire can be used for sawing in the web. Then, the secondary wire handling section 300b receives the wire 10 from the web. Thereby, the wire 10 is transported

from the web to the secondary wire tensioner, more precisely to the secondary sixth pulley 370b and then to the secondary fifth pulley 360b, from there to the secondary fourth pulley 350b, from there to the secondary third pulley 340b, from there to the secondary second pulley 330b, from there to the secondary first pulley 320b, and from there finally is wound onto the spool 312b. Further, a controller controls the motion of the secondary first pulley 320b along the secondary pulley motion track so that the wire is wound in a controlled manner onto the wire carrying area of the secondary spool 312b.

[0037] For receiving the wire, a secondary first pulley controller includes a wire winding pattern and is programmed to determine a desired wire winding position for winding the wire on the wire carrying area of the secondary spool, and transmits a moving command to the secondary first pulley moving device 324b for causing the secondary first pulley moving device 324b to move the secondary first pulley 320b to the desired wire winding position.

[0038] The secondary second pulley 330b redirects the wire by about 180°, and the secondary first pulley redirects the wire by about 90°. Due to the large secondary second pulley 330b redirection angle, sharp tensions and vibrations during winding of the wire are avoided, as explained above, so that the wire can be securely wound with reduced risk of wire damage. Therefore, the secondary second pulley 330b may redirect the wire by not less than 60°, and the secondary first pulley redirects the wire by not more than 120°.

[0039] Generally, the spools in which new wire is provided are of a different type (say, a first spool type) than the spools onto which the used wire is wound (say, a second spool type). For example, the spools in which new wire is provided may be disposable spools from a wire manufacturer. Such spools may, on the other hand, be unsuitable for receiving used wire because they sometimes do not withstand the high wire tension of the used wire. In order to support these different spool types during primary-to-secondary-spool sawing, the primary spool shaft (i.e. the spool shaft of the primary wire handling section) may be adapted for carrying a spool of the first type, and the secondary spool shaft (i.e. the spool shaft of the secondary wire handling section) is adapted for carrying a spool of the second type, i.e. the second type being different from the first type.

[0040] Also, in some embodiments, which can be combined with any other embodiments herein, the wire management section may support bidirectional sawing. Herein, bidirectional sawing is understood to be a sawing process during which first the wire is transported from the primary spool to the secondary spool, and thereafter is transported back from the

secondary spool to the primary spool, and again from the primary spool to the secondary spool etc. Thus, for bidirectional sawing the (primary) spool 312 is adapted for providing wire to the wire web and is also adapted for receiving used wire from the wire web. Likewise, a secondary spool 312b may be adapted for providing wire to the wire web and is also adapted for receiving used wire from the wire web.

[0041] For the bidirectional sawing, a controller is adapted for sending actuating commands to the primary spool shaft and to the secondary spool shaft, the actuating commands causing, in a first step, the first spool shaft to unwind wire to the second spool, and causing, in a second step, the second spool shaft to unwind wire to the first spool.

[0042] The above-described arrangements of the pulleys are particularly useful if thin wires or wires with a coating, e.g. a diamond coating, are used. Accordingly, in embodiments, which can be combined other embodiments described herein, the wire handling sections and wire saw devices described herein are adapted for thin wires having a diameter below about 400 μm, such as diameters between about 200 μm and about 400 μm, more particularly between about 200 μm and about 300 μm. However, in other cases embodiments may also have a wire diameter as low as for example 100 μm or even 80 μm. Further the wire handling sections and wire saw devices described herein are adapted for coated wires, for example a wire having a nickel coating with diamond particles embedded therein. Such wires may typically have a diameter of about 300 μm to about 400 μm, e.g. 310 μm to 340 μm. For those wires a twisting of the wire might increase the risk of breaking of the wire or of damaging the coating, so that a twist-free operation is advantageous. By using diamond wire, the throughput may be increased by a factor of 2 or even more. In the case of a squarer, throughput rates of 100MW or even more can be achieved in this manner.

[0043] When a diamond wire is used, further parts of the wire saw may be adapted to the diamond wire. For example, mechanical parts, electrical parts and / or software may be adapted to the use of diamond wire.

[0044] As described above, a plurality of pulleys are used in wire saw devices described herein. Thereby, it has to be taken into account that there is the desire for higher cutting speeds and, thereby, higher wire speeds, a desire for thinner wires or different types of wires, such as diamond wires, and improved device control at the facility of the customer. During sawing operation the pulleys generally rotate fast around their respective axes. According to some embodiments, the pulleys are adapted for wire saw devices by being capable of rotation

speeds of 2000 rpm and more, or even 3000 rpm or more, e.g., 2000 rpm to 4000 rpm. For example, during an emergency stop the wire saw device needs to be stopped as fast as possible. Thereby, however, the inertia of the pulleys, that is the moment of inertia of the pulleys, result in the pulleys rotation not to stop immediately. This further pulley rotation may result in a harmful tension on the wire such that wire breakage may occur.

[0045] Further, according to some embodiments, which can be combined with other embodiments described herein, such a wire breakage can be detected as follows. The wire is biased to the potential having an absolute value of about 20 V to 120 V, such as 30 V to 60 V. Thereby, a voltage between the wire and remaining wire saw device components such as the housing, the mainframe, the police, housing portions, or doors of cabinets, and the like is generated. For example, these further components can be on ground potential. If the wire breaks, the loose end of the wire touches one of the components of the wire saw device. The voltage between the wire and the wire saw device results in a current. Accordingly, a wire breakage detection system can monitor the existence of such a current and detect the breakage of the wire if such a current is detected.

[0046] As a yet further aspect, the increasing cutting speeds and the use of thin wires according to embodiments described herein and different types of wires, such as diamond wires, result in an increased desire to avoid even small vibrations in the wire saw device. On the one hand, this can be done by improved wire handling units. Examples of a wire handling unit are described e.g. in the patent application PCT/EP2009/062149 entitled "WIRE HANDLING UNIT, WIRE SAW DEVICE AND METHOD FOR OPERATING SAME", which is incorporated herein by reference to the extent the applications are not inconsistent with this disclosure.. On the other hand the tendency of pulleys and other means for guiding the wire through the wire saw device to bend or to be instable should be reduced.

[0047] Common pulleys for guiding the wire through the wire saw device are made out of metal, for example aluminum, so that they provide conductivity for a wire break detection system. Aluminum pulleys have a comparably low mass as compared to other metal pulleys. The still further increasing demand for faster cutting, thinner wires, faster wire break detection and new types of wires, for example diamond wires, bring the desire for even further improvements. According to embodiments described herein, pulleys are made of an electrically conductive plastic material. Thereby, the mass and, thus, the moment of inertia can be further reduced, electrical conductivity for wire breakage detection can be provided and a deformation of the wire during maintenance and/or operation can also be reduced.

Accordingly, a lower moment of inertia and smoother spinning can be provided while being capable of having a wire break detection current flowing through the pulley.

[0048] FIGS. 4A and 4B illustrate some embodiments of pulleys according to embodiments described herein. The pulley 400 has a wheel portion 410 and a tire portion 450, which is provided radially outward of the wheel portion 410. Thereby, the wheel portion or at least 80% of the wheel portion is made of a material consisting essentially of electrically conductive plastic material. According to yet further embodiments, which can be combined with other embodiments described herein, the tire can be a separate component, which is detachably connectable to the wheel portion.

[0049] As shown in FIG. 4A openings 412 can be provided in the wheel portion 410 such that for example a spoke structure is provided in the wheel portion. This can further decrease the weight and thus the moment of inertia of the pulley 400. The wheel portion 410 may further have a bearing receiving portion 414. Thereby, the bearing receiving portion 414 is adapted for receiving a bearing that can be used at 2000 rpm and more, or even 3000 rpm or more, e.g., 2000 rpm to 4000 rpm. A tire 450, which is made of an insulating material, is provided radially outward of the wheel portion 410. Typically, the tire, which provides a wire carrying portion of pulley 400, includes one or more grooves for guiding the wire. Since the tire 450 is electrically insulating, the wire 10, which is biased to a potential, is electrically insulated from the wheel portion 410. If the wire is biased by a power supply 470, as shown in FIG. 4A, and the loose end of the wire 10 touches the pulley at the wheel portion 410 after breakage, which is indicated in FIG. 4A, a current can be detected by a measurement device 472.

[0050] A cross-sectional view illustrating yet further embodiments of the pulley 400 is shown in FIG. 4B. In FIG. 4B the wheel portion 410 is configured to rotate around the axis 410a. The wheel portion has a tire carrying or tire receiving portion 420. The functionality and possible shapes of the tire receiving portion 420 are described in more detail below, with reference to Figs 6A to 6H. The tire 450 is mounted on the wheel portion 410, that is radially outward of the wheel portion. As shown in FIG. 4B a groove 452 is provided in the wire guiding portion (tire 450) such that the wire is guided on the pulley 400. Groove 452 defines, as indicated in FIG. 4B, a plane 482 which is indicated by dotted lines. The wire is guided in plane 482 during rotation of the pulley. According to some embodiments, which can be combined with other embodiments described herein, the wheel portion has protrusions 422 or recesses (not shown) such that the pulley 410 is fully balanced with respect to plane 482 in which the wire is guided. For example, the protrusion 422 can compensate for the tire

receiving portion 420. The center of mass can be located in the wire guiding plain 482. In FIG. 4B this is indicated by arrow 480 symbolizing a weighing scale. Since the center of mass is in the wire guiding plain 482 the pulley 400, which would be supported on a pivot point 480 as shown in FIG. 4B, is balanced.

[0051] In light of the above, smooth spinning can be further improved and the probability for vibrations can also be reduced. The manufacturing of the pulley from plastic material such as plastic material being formed in a mold, allows for optimized design and balance of the pulley without significantly increasing the manufacturing costs.

[0052] According to embodiments, which can be combined with other embodiments described herein, the pulley includes electrically conductive plastic material. For example, the pulley includes a wheel portion with electrically conductive plastic material or a wheel portion made out of electrically conductive plastic material. Thereby, according to some optional embodiments, the conductive plastic material has a density of 2.57 g/cm^3 or less, for example of 2.00 g/cm^3 or less. According to yet further optional modification. The density can be 1.5 g/cm^3 or less, for example from 1.0 g/cm^3 to 1.5 g/cm^3. According to yet further embodiments, which can be combined with other embodiments described herein, the plastic material is a synthetic polymeric material including electrically conductive fibers. For example, the polymeric material can be polyamid and/or the electrically conductive fibers can be carbon fibers.

[0053] Thereby, the carbon fibers also increase the stiffness of the pulley or the wheel portion, respectively. For example, the bending moment at the periphery of the wheel portion can be reduces as compared to a bending moment of a corresponding alumiun pulley. Further damages to the wheel and a resulting loss of balance of the wheel with respect to the wire guiding plane can be reduced by a yield strength of 200 to 600 MPa, for example 300 to 500 MPa.

[0054] The material properties of the electrically conductive plastic material allow for a further reduction of the weight by providing a wheel portion with spokes or wheel portion openings for reducing the overall weight of the pulley. According to different embodiments, for example, 3 to 10, typically 6 to 8 openings can be provided in the wheel portion. Thereby, according to yet further optional embodiments, the moment of inertia can be $5.0*10^{-4}$ kg*m^2 or less, for example $3.5*10^{-4}$ kg*m^2 or less, such as for example from $1*10^{-4}$ kg*m^2 to $3.5*10^{-4}$ kg*m^2. This may, according to yet further embodiments and in pulley diameter ranges

configured for wire saw devices, be also described as the weight per diameter being 730 g/m or less, typically 500 g/m or less, more typically from 300 to 500 g/m.

[0055] In light of the above, the weight of the pulleys can, for example be reduced by 5% to 75% as compared to aluminum pulleys. For example, a pulley having having dimensions suitable for guiding wire saw wire and a weight of about 50 g to 130 g can be obtained. For example, the pulley shown in Fig. 8 and having dimensions suitable for guiding wire saw wire has a weight of about 70 g. In contrast, previous pulleys typically have a weight of 140 g or more. Further, the electrically conductiveness is given by electrically conductive fibers such as carbon fibers which are embedded in the plastic material. For example carbon fiber charged polyamide can be used. The improved possibility to manufacture an essentially perfectly balanced pulley, that is the pulley which has the center of mass in the wire guiding plane, can further be used for smoother spinning and reduction of vibrations. This property can further be improved by a reduction of bending and deformation during maintenance, for example when forcing the tire on the wheel portion or damages by dropping the pulley or the like.

[0056] As described above the pulleys according to embodiments described herein are adapted or configured for use in a wire saw device. Thereby, one or more of the following properties can be provided: the pulley is adapted for rotation of at least 2000 rpm or even at least 3000 rpm; the pulley includes a bearing receiving portion for receiving a bearing which is adapted for rotation with at least 2000 rpm or even at least 3000 rpm; the wheel portion of the pulley has a tire receiving portion for receiving the tire with a groove structure for guiding the wire; the pulley includes a groove structure with grooves adapted for wires having a diameter of 400 μm or less; a tire with one or more grooves is provided, wherein one of the grooves, typically a center groove, defines a wire guiding plane; the wire is balanced, that is as the center of mass in the wire guiding plane; the wheel portion of the pulley has a diameter in the range of 70 to 300 mm, for example 100 to 200 mm, or the like.

[0057] FIGS. 5A and 5B illustrate yet further embodiments of pulleys according to embodiments described herein. The pulley 500 has a wheel portion 410 and a tire portion 450, which is provided radially outward of the wheel portion 410. Thereby, the wheel portion or at least 80% of the wheel portion is made of a material consisting essentially of electrically conductive plastic material. The electrically conductive plastic material is considered to be a material which comprises, besides the plastic itself (organic amorphous solid, in particular based on polymers), a material which gives conductive properties to the plastic, in particular

electrically conductive fibers such as carbon fibers. The content of carbon fibers in the plastic itself may be between 1 % and 50%, in particular between 20 % and 45 %.

[0058] As shown in FIG. 5A and already described with respect to FIGS. 4, openings 412, typically 6 to 8 openings, can be provided in the wheel portion 410 such that for example a spoke structure is provided. This can further decrease the weight and thus the moment of inertia of the pulley 500. The wheel portion 410 may further have a bearing receiving portion 414. Thereby, the bearing receiving portion 414 is adapted for receiving a bearing that can be used at rotation speeds of 2000 rpm and above, or even 3000 rpm or more, e.g., 2000 rpm to 4000 rpm. A tire 450, which is made of an insulating material, is provided radially outward of the wheel portion 410 on a tire receiving portion 420. The functionality and possible shapes of the tire receiving portion 420 are described in more detail below, with reference to Figs 6A to 6H. Typically, the tire, which can provide a wire guiding portion of pulley 400, includes one or more grooves, typically one groove, for guiding the wire.

[0059] A cross-sectional side view illustrating yet further embodiments of the pulley 500 is shown in FIG. 5B. The wheel portion 410 has a tire carrying portion 420. The tire 450 is mounted on the wheel portion 410, that is, adjacent to the wheel portion. As shown in FIG. 5B a groove 452 is provided in the wire guiding portion of the pulley. Groove 452 defines, as indicated in FIG. 5B, a plane 482. The wire is guided in plane 482 during rotation of the pulley. According to some embodiments, which can be combined with other embodiments described herein, the wheel portion has protrusions 422 or recesses (not shown) such that the pulley 410 is fully balanced with respect to plane 482 in which the wire is guided. For example, the protrusion 422 can compensate for the tire receiving portion 420 such that the center of mass is located in the wire guiding plain 482.

[0060] According to yet further embodiments, which can be combined with other embodiments described herein, a pulley can have a fixation opening for fixing the wire to a bearing. Thereby, as a further option alignment openings, such as openings 416 or 416' can be provided. As shown in FIGS. 5A and 5B, the edges of the openings 412, the edges of the tire receiving portions and other structures, for example protrusion and recess in the pulley can be rounded or have rounded edges with a radius of curvature of several mm, e.g., at least 1 mm or 2 mm to 5 mm. This may further reduce the weight and might improve the pulley behavior during fast spinning. Additionally, slurry, cooling fluid, or other solid particles from the process can not sediment at the pulleys as compared to a corresponding shape having sharp edges.

[0061] According to yet further embodiments, which can be combined with other embodiments described herein, the plastic material included in the pulley can be resistant to polyethylene glycol, water based coolants adapted for sawing in a wire saw device, e.g. with diamond wire, and/or combinations thereof.

[0062] Each of FIGS. 6A to 6H shows a cross-sectional view of a respective portion of a wheel 410 and a tire 450 of a respective pulley 601 to 608. Therein, the cross-sectional plane corresponds to the plane of FIGS. 4B and 5B and contains the axis. While FIGS. 6A to 6H and 7 relate to various embodiments, the same reference numbers are used for corresponding parts, even though their shape and detailed function may differ somewhat. In FIGS. 6A to 6H, only the interfacing portion between the wheel 410 and a tire 450 is shown, while other parts of the wheel and tire are not shown. These other parts may be formed as in any other embodiment shown herein, e.g. as in the embodiments of FIG. 4B, FIG. 5B or FIG. 8.

[0063] In FIG. 6A, a portion of a pulley 601 including a wheel 410 and a tire 450 is shown. The tire 450 has a wheel receiving portion 460, and the wheel 410 has a tire receiving portion 420. The tire receiving portion 420 and the wheel receiving portion 460 extend circumferentially about an axis (horizontal axis in the cross-sectional plane below the elements of FIG. 6A, analogous to the axis 410a of FIG. 4B). The wheel receiving portion 420 extends along a radially inner side of the tire 410 (i.e. a side of the tire located towards the axis), while the tire receiving portion 460 extends along a radially outer side of the wheel 450 (i.e. a side of the wheel located away from the axis).

[0064] The wheel receiving portion 460 and the tire receiving portion 420 are shaped form-fit to each other and engage each other, whereby the tire is fixed firmly on the wheel. The wheel 410, has received the tire 450 (more precisely, the tire receiving portion 420 has received the wheel receiving portion 460) by sliding the tire 450 axially, i.e. horizontally, in direction of a mounting side 405 onto the wheel 410. In FIGS. 6A to 6H and 7, the tire 450 has been visibly slid axially from left to right onto the wheel 410, therefore in these Figures the mounting side 405 is on the right side of the tire 450 and of the wheel 410. Independently of the shown embodiment, the mounting side is a side in an axial direction of the wheel / tire / pulley. Generally, the mounting side is defined by the shape of the wheel and / or the tire.

[0065] The wheel receiving portion 460 has a support surface 468 facing towards the axis for supporting the tire 450 on the wheel 410. Here, the support surface 468 is parallel to the axis (i.e. horizontal). More generally, facing towards the (horizontal) axis means that the support

surface faces more towards the axis than towards any other orthogonal direction, i.e. that the support surface is inclined by less than 45° with respect to the axis. Correspondingly, the tire receiving portion 420 has a support counter-surface 428 facing away from the axis (which, likewise, implies that the support counter-surface 428 is inclined by less than 45° with respect to the axis), for supporting the tire 450 on the wheel 410.

[0066] The wheel receiving portion 460 further has a forward stopper face 462 facing towards the mounting side 405, i.e. primarily to the right in FIG. 6A (implying that the forward stopper face 462 is inclined by more than 45°, namely between 45° and 135° with respect to the axis). Likewise, the tire receiving portion 420 has a forward stopper counter-face 422 facing away from the mounting side 405. The forward stopper face 462 and the forward stopper counter-face 422 abut each other, thereby stopping a movement of the tire 450 relative to the wheel 410 in direction to the mounting side 405, i.e. to the right.

[0067] The forward stopper face 462 is located at the mounting side 405 with respect to the remaining parts of the wheel receiving portion 460, in particular at the mounting side 405 with respect to the snap-in portion 464. Likewise, the forward stopper counter-face 422 is located at the mounting side 405 with respect to the remaining parts of the tire receiving portion 420, in particular at the mounting side 405 with respect to the counter snap-in portion 424.

[0068] The wheel receiving portion 460 further has a snap-in profile portion 464. The snap-in profile portion 464 has a backward stopper face 465 facing away from the mounting side 405, i.e. primarily to the left. Likewise, the tire receiving portion 420 has a corresponding counter snap-in profile portion 424 having a backward stopper counter-face 425 facing towards the mounting side 405, i.e. primarily to the right.

[0069] The snap-in profile portion 464 and the counter snap-in profile portion 424 are shaped such that when the tire 450 is slid axially in direction of the mounting side 405 onto the wheel 410, a lateral snap-in motion between the backward stopper face 465 and the backward stopper counter-face 425 takes place, resulting in the backward stopper face 465 and the backward stopper counter-face 425 abutting each other for stopping a movement of the tire 450 relative to the wheel 420 in a backward direction (direction away from the mounting side 405, i.e. to the left). Generally and independently of the shown embodiment, a snap-in portion or snap-in profile portion is defined by being shaped such that it causes a (primarily lateral) snap-in motion between the backward stopper face and the backward stopper counter-face

when the tire is slid axially in direction of the mounting side 405 onto the wheel. Generally, the snap-in portion is resilient and in this case carries out the snap-in motion itself. The snap-in portion 464 shown in Fig. 6A is resilient, and hence carries out the snap-in motion. For example, the entire wheel can be made of a material with at least slightly resilient properties, whereby also the snap-in portion 464 is resilient. According to an aspect which can be combined with any embodiment, the material of the tire 450 is softer and / or more resilient than the material of the tire receiving portion 420.

[0070] The snap-in profile portion 464 further has, on its mounting (right) side, a slanted ramp surface 466. The ramp surface 466 is inclined with respect to the axis in direction towards the mounting side 405, at an angle between 3° and 45° (excluding 45°). Likewise, the counter snap-in profile portion 464 has a slanted ramp counter-surface 466, which is likewise inclined with respect to the axis, in direction away from the mounting side 405 (i.e. being oriented a little towards the left, although still facing primarily away from the axis). The slanted ramp surface 466 and the backward stopper face 465 of the snap-in profile portion 464 are shaped asymmetrically in the sense of a left-right asymmetry, i.e. asymmetrically with respect to a center plane normal to the axis. Likewise, the counter snap-in profile portion 464 is shaped asymmetrically. The ramp surface 466 or the asymmetry have the advantage that at assembly of the pulley, the ramp surface 466 allows the snap-in portion 464 to be slid over the tire receiving portion 420 in the direction of the mounting side 405 with low resistance, while allowing a lateral deformation which precedes the snap-in motion.

[0071] Further, in FIG. 6A, the backward stopper face 465 is adjacent to the support surface 468. Likewise, the backward stopper counter-face 425 is adjacent to the support surface 428. Due to this arrangement, the tire is fixated on the wheel even more stably.

[0072] The tire 450 is essentially ring-shaped about the axis, and the wheel 410 is essentially cylinder-shaped and rotatable about the axis. The portions 420 and 460 may be essentially rotationally symmetrical about the axis, but not necessarily so. Alternatively, portions such as shown in FIG. 6A may extend only along certain angular regions about the axis.

[0073] FIG. 6B shows portions of a pulley 602 according to a further embodiment. In the following, only differences with respect to FIG. 6A will be described. Unless explicitly mentioned otherwise or in contradiction with the respective description or drawing, the description of FIG. 6A will also apply to the embodiments of FIG. 6B to 6H.

[0074] In FIG. 6B, in addition to the (first) support surface 468, a further (second) support surface 469 is provided. The support surface 469 is adjacent to the ramp surface 466. Hence, the snap-in profile portion 464 is located between the first and second support surface 468, 469. Likewise, the wheel receiving portion 420 includes, besides the (first) support counter-surface 428, also a second support counter-surface 429. The support counter-surface 429 is adjacent to the ramp counter-surface 466, such that the counter snap-in profile portion 464 is located between the first and second support counter-face. Hence, horizontal and vertical loads on the tire 450 are distributed and counter-acted even more evenly.

[0075] Further, in FIG. 6B, at the forward stopper face 462 a step-like structure is provided, such that above the (first) forward stopper face 462, a second forward stopper face is formed, separated from the first forward stopper face 462 by a step surface facing towards the axis. Likewise, above the (first) forward stopper counter-face 422, a second forward stopper counter-face is formed, separated from the first forward stopper counter-face 422 by a step surface facing away from the axis.

[0076] Further, the support surface 468 includes a slanted support surface portion 468a slightly inclined in direction towards the mounting side with respect to the axis. Thus, at the slanted support surface portion 468a the support surface 468 recedes towards the axis. The inclination may be between 3° and 45° with respect to the axis. The slanted support surface portion 468a is located at the left of the snap-in profile portion 464, i.e. on a side away from the mounting side. Likewise, the support counter-surface 420 includes a slanted support counter-face portion 428a inclined in direction away from the mounting side with respect to the axis, the slanted support counter-face portion being located on the left (side away from the mounting side) of the counter snap-in profile portion. The slanted portions 428a and 468a allow for easier mounting, because the tire is guided even more naturally onto the wheel. One may suspect that the slanted portions 428a and 468a contribute to the tire being ejected from the wheel more easily under the influence of lateral forces. However, the snap-in effect described above fixates the tire 250 so tightly on the wheel 210 that the risk of ejection is sufficiently reduced.

[0077] FIG. 6C shows portions of a pulley 603 according to a further embodiment. A difference with respect to the embodiment of FIG. 6A is that while the snap-in portion 464 has a slanted ramp surface 466 as described above with respect to Fig. 6A, the corresponding surface of the counter snap-in profile portion 424 is not slanted, but parallel to the axis.

[0078] FIG. 6D shows portions of a pulley 604 according to a further embodiment. A difference with respect to the embodiment of FIG. 6B is that the snap-in portion 464 and the corresponding counter snap-in portion 424 are arranged adjacent to the forward stopper plane 462 and forward counter-stopper plane 422, respectively. Further, the snap-in portion 464 and the corresponding counter snap-in portion 424 do not have a slanted ramp surface, but instead a surface portion parallel to the axis. Further, the slanted support counter-face portion 428a is adjacent to the backward stopper counter-plane 425, thus providing a ramp for the snap-in portion 464. When sliding the tire 450 onto the wheel 410 in the mounting direction, the snap-in portion 464 compresses easily due to this ramp, and then snaps in into place. Correspondingly, the slanted support face portion 468a is adjacent to the backward stopper plane 465.

[0079] In a variation of the embodiment of FIG. 6D, the snap-in portion 464 has a slanted ramp surface, and the counter snap-in portion 424 has a corresponding slanted ramp counter-surface, as shown e.g. in Fig. 6B. In a further variation of the embodiment of FIG. 6D, the ramp portion provided by the slanted support counter-face portion 428a may be resilient, e.g. mounted on a biasing member such as a spring, biasing the ramp portion away from the axis. Then, less or no resilient deformation of the snap-in portion 464 is required when mounting the pulley. Other embodiments may be varied in a similar manner.

[0080] FIGS. 6E and 6F show portions of a respective pulley 605 and 606 according to further embodiments. A difference with respect to the embodiment of FIG. 6A is that the backward stopper plane 465 and the backward stopper counter-plane 425 are inclined at an angle different from 90° with respect to the axis. In the pulley 605 of FIG. 6E, their inclination angle is about 100°, thus providing an especially stable and durable interlocking of the tire 250 on the wheel 210 at the cost of the mounting being more difficult. In FIG. 6F, their inclination angle is about 75°, thus providing an especially easy mounting at the cost of less stable interlocking of the tire 250 on the wheel 210.

[0081] Generally, the backward stopper face 465 should be inclined by an angle between 45° and 135° with respect to the axis, i.e. facing in the direction away from the mounting side. It is especially advantageous that the inclination is between 45° and 100°, and in particular by an essentially right angle, e.g. 90° ± 5°, with respect to the axis. The right angle provides a good balance between ease of mounting and durability of interlocking. Analogous considerations and inclination angles apply for the backward stopper counter-face 425.

[0082] In a further variation of any of the shown embodiments, the forward stopper face 462 and / or the forward stopper counter-face 422 may be inclined at an angle different from 90°. Here, the forward stopper face 462 should be inclined at an angle of between 45° and 135° with respect to the axis, i.e. facing in the direction of the mounting side. It is especially advantageous that the inclination is between 75° and 115°, and in particular at an essentially right angle, e.g. 90° ± 5°, with respect to the axis. Analogous considerations and inclination angles apply for the forward stopper counter-face 422.

[0083] FIG. 6G shows portions of a further pulley 607. Therein, the wheel receiving portion 460 of the tire 450 is shaped according to an embodiment of the invention in such a manner that advantages of the snap-in effect can be realized even for a very simple wheel 410. Here, as a difference with respect to the wheel receiving portion of FIG. 6A, the snap-in portion 464 is located at the mounting side with respect to the remaining parts of the wheel receiving portion 460, in particular with respect to the forward stopper face 462. In view of this location of the snap-in portion 464, no counter snap-in portion is required at the wheel 410.

[0084] FIG. 6H shows portions of a further pulley 608. Therein, the tire receiving portion 420 of the wheel 410 is shaped according to an embodiment of the invention in such a manner that advantages of the snap-in effect can be realized even for a very simple tire 450. Here, the counter snap-in portion 424 (between forward stopper counter-face 422 and backward stopper counter-face 425) essentially spans the entire receiving length for the tire 410. Hence, the wheel receiving portion of the tire 450 snaps in, with its entire width, at mounting the tire 450 on the wheel 410. Further, a slanted counter-surface portion 428a is provided. The counter-surface 428a faces away from the axis and is adjacent to the backward stopper counter-plane 425.

[0085] FIG. 7 shows portions of a further pulley 700. The cross-section is in a similar cross-sectional plane as the pulley 601 of FIG. 6A. The pulley 700 has a wheel 410 with a tire receiving portion 420, and a tire 450 with a wheel receiving portion 460. The tire receiving portion 420 and the wheel receiving portion 460 are shaped similar to the respective portions shown in FIG. 6A, and the description of FIG. 6A applies to the pulley 700 as well. Further, the wheel has a tapered portion with slanted wheel surface portion 419. Due to the tapered portion, an axially inner wheel portion 411 is thinner (in an axial direction) than the tire receiving portion 420. This allows a pulley with relatively low inertia and, hence, momentum, while still having a relatively large and therefore stable tire receiving portion 420.

[0086] Further, the tire receiving portion 420 of the wheel 410, and more specifically the forward stopper counter-face 422, includes a protrusion 423 facing away from the mounting side 405. The wheel receiving portion 460 of the tire 450, and more specifically the forward stopper face 462, includes a corresponding cavity 463 which recedes from the forward stopper face 462 and faces towards the mounting side 405. The protrusion 423 and the cavity 463 do not extend rotationally symmetrically about the axis, but only cover a limited angle about the axis, e.g. less than 20°, e.g. between 1° and 20° or 10°. The cavity 463 and the protrusion 423 engage each other, and thereby block a relative rotation between the tire 450 and the wheel 410 about the axis. The wheel 410 may include one or more protrusions 423 circumferentially distributed along its tire receiving portion 420, and correspondingly the tire 450 may include one or more cavities 463 circumferentially distributed along its wheel receiving portion 460.

[0087] Further, the tire 450 includes an RFID chip. The RFID chip is arranged in an axially extending slot 454. Here, the slot 454 faces away from the mounting side 405, but the slot may alternatively also be arranged e.g. facing the mounting side 405. The slot 454 only covers a limited angle about the axis, and may be at a common angular position with the cavity 463, or at a different angular position.

[0088] As a variation of the embodiment of FIG. 7, the tire 450 and the wheel 410 may be shaped rotationally asymmetrically with respect to the axis in any other manner such as to block a relative rotation between the tire 450 and the wheel 410. For example, the wheel 410 may have a cavity and the tire may have a protrusion. Also, an angular portion of the wheel receiving portion 460 may be formed as an axially extending slot, and a corresponding angular portion of the tire receiving portion 420 may be formed as axially extending key, or vice versa.

[0089] The tires 450 of any of FIGS. 6A to 6H and 7 further have a wire guiding portion extending circumferentially about the axis along a radially outer side of the tire for guiding the wire of the wire saw device. This wire guiding portion is not shown in these FIGS, but may be similar to the wire guiding portion 452 shown in FIG. 4B or FIG. 5B. As a further general aspect applicable for any embodiment shown herein, the pulley tire 450 may be integrally made of one piece.

[0090] FIG. 8 is a perspective view of a further pulley 800 being an embodiment of the invention. The pulley includes a wheel 410 and a tire 450. The tire 450 and the tire receiving portion of the wheel 410 may be in accordance with any other embodiment shown herein, e.g.

with the embodiments shown in FIGS. 6A to 6H and 7. In the following, only the wheel 410 is described in some more detail.

[0091] The wheel 410 has a tapered portion with a slanted wheel surface portion 419, such that an axially inner wheel portion is axially thinner than the tire receiving portion 420, as described in conjunction with FIGS. 5A, 5B, and 7.

[0092] Further, at the axially thin wheel portion, the wheel includes a plurality of spoke portions 417. These spoke portions 417 are Y-shaped, with the base leg of the Y being oriented towards the axis, and the upper arms of the Y being oriented away from the axis and towards the tire receiving portion 420. Due to the spoke portions 417, a plurality of openings 412 extending through the wheel in an axial direction are created. Due to these openings, an unwanted deposition of slurry on the wheel 410 is reduced. To this purpose, it is especially advantageous that in a cross-sectional center plane normal to the axis (e.g. the wire guiding plane), the surface covered by the openings is at least 20%, or even at least a third, or even at least 50% of the surface covered by solid material of the wheel 410. Fig. 8 illustrates a general aspect independent of the shown embodiment, namely that the wheel 410 has two differently shaped kinds of openings (here: one kind between two arms of a Y-shaped spoke portion 417, and another kind between two neighboring Y-shaped spoke portions). These openings are arranged alternately, and / or with their centers radially displaced with respect to each other. In particular, at a radially outer side of the wheel more openings are provided than at a radially inner side. As a further general aspect, the openings are non-circular.

[0093] The wheel 410 further includes slanted surface portions 417a at the spokes and 419. These surface portions 417a and 419 are adjacent to the openings 412 and slanted towards the openings 412. These slanted surface portions 417a and 419 further help to reduce an unwanted deposition of slurry on the wheel 410, as described with respect to FIGS. 5A and 5B.

[0094] The wheel 450 further includes an optional bearing receiving portion 414. These and other elements may be formed in analogy to corresponding elements of the embodiments shown in FIGS. 4A and 5A. Also, as described with reference to FIGS. 4A and 5A, the pulley wheel may include an electrically conductive material, especially an electrically conductive plastic material, especially a synthetic polymeric material such as a polyamide. The pulley wheel may include electrically conductive fibers such as carbon fibers, and / or any other material described in conjunction with the wires of FIG. 4A, 4B and 5A, 5B. The wheel 450

may further include optional alignment openings, similar to the alignment openings 416 shown in Fig. 5A (not shown in Fig. 8). Further, as a variation of the embodiment of Fig. 8, there may be any number of Y-spokes 419, e.g. 6, 8 or 10 Y-spokes arranged at equal angular spacing about the wheel axis, instead of the 4 spokes 419 shown in Fig. 8

[0095] In the following, some general aspects of the embodiments described herein will be summarized. Each of these general aspects can be combined with any other general aspect, within any embodiment described herein, to generate yet another embodiment.

[0096] According to one embodiment, a pulley configured for a wire saw device having a wire forming a wire web is provided. The pulley includes a wheel portion around the pulley axis, wherein the wheel portion includes electrically conductive plastic material, and a wire guiding portion radially outward of the wheel portion having a groove structure for guiding the wire.

[0097] According to one optional aspect, which can be provided for pulleys for wire saw devices, and wire saw devices described herein, the conductive plastic material can have a density of 2.00 g/cm^3 or less, typically 1.5 g/cm^3 or less, more typically from 1.0 g/cm^3 to 1.5 g/cm^3. Accordingly, as a further alternative or optional aspects the moment of inertia can be $5.0*10^{-4}$ $kg*m^2$ or less, typically $3.5*10^{-4}$ $kg*m^2$ or less; and/or the weight per diameter can be 730 g/m or less, typically 500 g/m or less, more typically from 300 to 500 g/m.. As described above, this can result in a reduced wire breakage probability, especially during stop or emergency stop of the wire saw device, during which the inertia of pulleys might generate additional tension on a wire. These and other aspects might particularly useful for diamond wire or thin wires as described herein, wherein wire breakage needs to be effectively reduced.

[0098] Thereby, for some embodiments, which can be combined with other embodiments described herein, a wire saw device and/or a pulley for a wire saw device can be adapted for diamond wire, and methods of operating can be performed with diamond wire. This can, for example, be done by adapting the groove structure with an appropriate pitch of grooves, a different depth of grooves and/or a different shape of grooves. By using diamond wire, typically the cutting speed can be increased, e.g., by a factor of 2, the energy consumption of the wire saw device can be reduced and, further, as yet another example, the costs of squaring silicon ingots or wafering silicon can be significantly reduced.

[0099] According to yet further optional aspects, which can be combined with embodiments described herein, the yield strength of the pulley can be 400 MPa or more; and/or the bending moment can be reduced as compared to a corresponding aluminum pulley. According to yet further alternative or additional implementations, the plastic material can be a synthetic polymeric material including electrically conductive fibers, e.g. the polymeric material can be a polyamide, the pulley can include carbon fibers; and/or the plastic material can be chemical stable with respect to polyethylene glycol, water based coolant liquids adapted for a wire saw device, and mixtures thereof.

[00100] According to yet another optional aspect, which can be provided for embodiments described herein, the wire guiding portion can include a tire, can be provided as a tire or with a tire respectively. Typically, the wire guiding portion can be separate from the wheel portion. For example a tire can be provided on the wheel portion. According to yet further embodiments, which can be combined with other embodiments described herein, the groove structure can be one or more circumferential grooves, wherein one of the grooves or the one groove defines a wire guiding plane. Thereby, for example, the center of mass of the pulley can be located within the wire guiding plane

[00101] According to a yet further embodiment, a wire saw device with a pulley according to any of the embodiments described above is provided. Thereby, as one optional aspect, essentially all pulleys have essentially the same moment of inertia. For example, the moment of inertia of the pulleys does not deviate from each other more than 10 % or more than 5 %. Typically, according to different implementations, the wire saw device can be an element selected from the group consisting of: a wire saw, a multiple wire saw, a squarer, and a cropper. According to yet further embodiments, which can be combined with other embodiments described herein, the wire saw device can further include a main body of the wire saw device, a voltage supply adapted for biasing the wire on an electrical potential and an electrical conductive path from the wheel portion of the pulley to the main body.

[00102] According to a yet further embodiment, a method of operating a wire saw device having a wire forming a wire web is provided. The method includes providing a plurality of pulley having a wheel portion around the pulley axis, wherein the wheel portion includes electrically conductive plastic material, biasing the wire on an electrical potential, and monitoring existence of an electrical current in the wire saw device during contact of the wire with the wheel portion. Thereby, the pulley can according to different implementation be provided according to any of the embodiments described herein. According to a yet further

aspect, which can be combined with embodiments described herein, the method can further include moving the wire towards and from the wire web, wherein the wire is guided by the plurality of pulleys, stopping movement of the wire in the wire saw device upon a signal that existence of the electrical current has been detected.

[00103] According to a further aspect, a wire management unit can include a first pulley wire tracking system allowing actuation of a first pulley moving device in response to a detected wire position. According to a further aspect, the first pulley wire tracking system includes: a first pulley moving device being at least one element selected from the group of a linear actuator, a linear motor, a pneumatic cylinder, and a motor with a worm drive; a wire position detection device adapted for detecting the wire position along the direction of the motion path; a first pulley position controller being operatively connected to the wire position detection device for receiving the detected wire position, and being adapted for determining a target position, and being operatively connected to the first pulley moving device for transmitting a moving command causing the first pulley moving device to move the first pulley to the target position.

[00104] According to a further aspect, the wire management unit is adapted for the wire being a diamond wire, i.e. including diamonds. According to a further aspect, a main frame portion is rigid, and rigidly connectable or connected or integral with the chassis of the wire saw device.

[00105] According to a further aspect, a spool is adapted for providing wire to the wire web and is also adapted for receiving used wire from the wire web. According to a further aspect, the spool has a wire carrying area, and the first pulley position controller includes a wire winding pattern and is programmed for determining a target position, and being operatively connected to the first pulley moving device for transmitting a moving command thereto for causing the first pulley moving device to move the first pulley to the target position. According to a further aspect, the wire handling section is a primary wire handling section, the wire management unit further including a secondary wire handling section. According to a further aspect, the primary wire handling section has a spool shaft that is adapted for carrying a spool of first type, and the secondary wire handling section has a spool shaft that is adapted for carrying a spool of second type.

[00106] According to a further aspect, a wire saw device is provided, the wire saw including a wire management unit according to any one of the embodiments described herein,

wherein the main frame portion is rigidly connected to a chassis of the wire saw device. According to a further aspect, the wire saw device is an element selected from the group consisting of a wire saw, a multiple wire saw, a squarer, and a cropper. The present pulleys, wire management units and wire handling units can be particularly useful for a squarer.

[00107] According to a further aspect, a pulley tire configured for a pulley of or for a wire saw device having a wire forming a wire web is provided, the pulley including a wheel and the tire. The tire is essentially ring-shaped about an axis and has: a wire guiding portion extending circumferentially about the axis along a radially outer side of the tire for guiding the wire; and a wheel receiving portion extending circumferentially about the tire axis along a radially inner side of the tire, the wheel receiving portion being shaped for receiving the wheel therein by sliding the tire axially in direction of a mounting side onto the wheel. The wheel receiving portion has a support surface facing towards the axis (herein, a surface facing towards the axis implies that this surface is inclined by less than 45° with respect to the axis) for supporting the tire on the wheel; a forward stopper face facing towards the mounting side (herein, a face facing towards the mounting side, the mounting side defining an axial direction, implies that the face is inclined more than 45° with respect to the axis, in direction towards the mounting side) for stopping a movement of the tire relative to the wheel in direction to the mounting side, and a snap-in profile portion having a backward stopper face, the backward stopper face being adjacent to the support surface and facing away from the mounting side (herein, a face facing away from the mounting side, the mounting side defining an axial direction, implies that the face is inclined more than 45° with respect to the axis, in direction away from the mounting side) for stopping a movement of the tire relative to the wheel in direction away from the mounting side.

[00108] Herein, the inclination of a face with respect to the axis is defined as the angle between the axis and a tangential of the face in a cross-sectional side plane containing the axis, i.e. a tangential cutting the axis (unless the angle is 0°, in which case the tangential is parallel to the axis). The angle is defined as an absolute value, i.e. there are only non-negative angles according to this definition. Hence, e.g. an angle of 0° means a cylindrical face, and an angle of 90° means a face normal to the axis. For curved faces, any suitable tangential of the face may be used to define the inclination of the face.

[00109] According to a further aspect, the pulley tire is integrally made of one piece. According to a further aspect, the snap-in profile portion is resilient. According to a further aspect, at least one of the forward stopper face and the backward stopper face is inclined at an

angle of between 45° and 100°, in particular at an essentially right angle (essentially means, in particular, up to a tolerance of ± 5°), with respect to the axis. According to a further aspect, the snap-in profile portion further has a slanted ramp surface inclined between 3° and 45° in direction towards the mounting side with respect to the axis. According to a further aspect, the support surface is a first support surface, the wheel receiving portion further including a second support surface, wherein the second support surface optionally is adjacent to the ramp surface such that the snap-in profile portion is located between the first and second support surface. In particular, the snap-in profile portion may protrude from these support surfaces towards the axis. According to a further aspect, the support surface includes a slanted support surface portion inclined in direction inclined between 3° and 45° in direction towards the mounting side with respect to the axis, the slanted support surface portion being located, relative to the snap-in profile portion, on a side away from the mounting side. According to a further aspect, the snap-in profile portion is shaped asymmetrically with respect to a plane normal to the axis. In particular, the normal plane may be a center plane of the snap-in profile portion. According to a further aspect, the wheel receiving portion is shaped rotationally asymmetrically with respect to the axis such as to block a relative rotation between the tire and the wheel when the tire is mounted on the wheel. According to a further aspect, the wheel receiving portion includes a cavity covering an angle of less than 20°, in particular less than 10°, about the axis, for blocking the relative rotation between the tire and the wheel. In particular, the cavity may face the mounting side for engagement with a corresponding protrusion of the wheel. The cavity may, in particular, recede from the forward stopper face. According to a further aspect, the wire guiding portion has a groove structure. The wire guiding portion may thus have one or more circumferential grooves for receiving the wire therein, wherein one groove defines a wire guiding plane. In particular, the one or more grooves may be V-shaped.

[00110] According to a further aspect, a pulley wheel for a pulley of a wire saw device having a wire forming a wire web is provided, the pulley including the wheel and a tire. The wheel is rotatable about an axis and has: a tire receiving portion extending circumferentially about the tire axis along a radially outer side of the wheel, the tire receiving portion being shaped for receiving the tire thereon by sliding the tire axially in direction of a mounting side [relative to the wheel] onto the wheel, the tire receiving portion having a support counter-surface facing away from the axis (i.e. inclined by less than 45° with respect to the axis, see above) for supporting the tire on the wheel; a forward stopper counter-face facing away from the mounting side (i.e. inclined more than 45° with respect to the axis, in direction towards

the mounting side, see above) for stopping a movement of the tire relative to the wheel in direction to the mounting side, and a counter snap-in profile portion having a backward stopper counter-face, the backward stopper counter-face being adjacent to the support surface and facing towards the mounting side (i.e. inclined more than 45° with respect to the axis, in direction away from the mounting side, see above) for stopping a movement of the tire relative to the wheel in direction away from the mounting side.

[00111] According to a further aspect, at least one of the forward stopper counter-face and the backward stopper counter-face is inclined with respect to the axis at an angle of between 45° and 100°, in particular at an essentially right angle (i.e. up to a tolerance of ± 5°). According to a further aspect, the counter snap-in profile portion further has a slanted ramp counter-surface inclined between 3° and 45° in direction away from the mounting side with respect to the axis. According to a further aspect, the support counter-surface is a first support counter-surface, the wheel receiving portion further including a second support counter-surface, wherein the second support counter-surface optionally is adjacent to the ramp counter-surface such that the counter snap-in profile portion is located between the first and second support counter-face. In particular, the counter snap-in profile portion may recede towards the axis. According to a further aspect, the support counter-surface includes a slanted support counter-face portion inclined between 3° and 45° in direction away from the mounting side with respect to the axis, the slanted support counter-face portion being located, relative to the counter snap-in profile portion, on a side away from the mounting side. According to a further aspect, the counter snap-in profile portion is shaped asymmetrically with respect to a plane normal to the axis. In particular, the normal plane may be a center plane of the snap-in profile portion.

[00112] According to a further aspect, the pulley wheel has a plurality of openings extending through the wheel in an axial direction, wherein in a cross-sectional center plane normal to the axis, the surface covered by the openings is at least 20% (or even at least 40% or even 50%) of the surface covered by solid material of the wheel. According to a further aspect, a wheel surface portion adjacent to the openings is slanted towards the openings, or even more than 50% of the entire wheel surface adjacent to any opening is slanted towards the openings. According to a further aspect, the wheel includes spoke portions, especially Y-shaped spoke portions, i.e. spoke portions having a respective stem portion bifurcating into two respective arm portions. The stem portion may extend in a radial direction of the wheel. According to a further aspect, the pulley wheel includes an electrically conductive material,

especially an electrically conductive plastic material. According to a further aspect, the plastic material is a synthetic polymeric material, such as a polyamide, including electrically conductive fibers, such as carbon fibers. According to a further aspect, the tire receiving portion is shaped rotationally asymmetrically with respect to the axis such as to block a relative rotation between the tire and the wheel. According to a further aspect, the tire receiving portion includes a protrusion covering an angle of less than 20°, in particular less than 10°, about the axis, for blocking a relative rotation between the tire and the wheel. In particular, the protrusion may face away from the mounting side for engagement with a corresponding cavity of the tire. The protrusion may, in particular, protrudes from the forward stopper counter-face.

[00113] According to a further aspect, a pulley for a wire saw device having a wire forming a wire web, the pulley being rotatable about an axis and including a pulley tire according to any aspect described herein, and a pulley wheel, especially one according to any aspect described herein, wherein the wheel receiving portion of the tire and the tire receiving portion of the wheel are shaped form-fit to each other.

[00114] According to a further aspect, a pulley for a wire saw device having a wire forming a wire web is provided, the pulley being rotatable about an axis and including a pulley tire and a pulley wheel. The tire is essentially ring-shaped about an axis and has a wire guiding portion extending circumferentially about the axis along a radially outer side of the tire for guiding the wire, and a wheel receiving portion extending circumferentially about the tire axis along a radially inner side of the tire, the wheel receiving portion being shaped for receiving the wheel therein by sliding the tire axially in direction of a mounting side onto the wheel, the wheel receiving portion having a forward stopper face facing towards the mounting side for stopping a movement of the tire relative to the wheel in direction to the mounting side and a snap-in profile portion having a backward stopper face facing away from the mounting side for stopping a movement of the tire relative to the wheel in direction away from the mounting side. The wheel is rotatable about the axis and has a tire receiving portion extending circumferentially about the tire axis along a radially outer side of the wheel, the tire receiving portion receiving or being shaped for receiving the tire thereon. The tire receiving portion has a forward stopper counter-face facing away from the mounting side for stopping a movement of the tire relative to the wheel in direction to the mounting side, and a counter snap-in profile portion having a backward stopper counter-face facing towards the mounting side for stopping a movement of the tire relative to the wheel in direction away from the mounting

side. The wheel receiving portion of the tire and the tire receiving portion of the wheel are shaped form-fit to each other. At least one of the snap-in profile portion and the counter snap-in profile portion is shaped asymmetrically, especially with respect to a center plane of the respective snap-in profile or counter-profile portion normal to the axis, such as to allow an axial sliding of the tire in direction of the mounting side (relative to the wheel) for mounting the tire on the wheel, while blocking an axial sliding of the tire in direction away from the mounting side. In particular, the asymmetry is such that it allows an axial sliding of the snap-in profile portion against the counter snap-in profile portion in direction of the mounting side, and blocks an axial sliding of the snap-in profile portion against the counter snap-in profile portion away from the mounting side by an engagement of the backward stopper face against the backward stopper counter-face. The tire and / or the wheel, in particular the snap-in profile portion and/or the counter snap-in profile portion may be shaped as described in any other part of this document.

[00115] According to a further aspect, a wire saw device having a plurality of pulleys as described in any other part of this document is provided. In particular, essentially all pulleys of the plurality of pulleys may have essentially the same moment of inertia.

[00116] According to a further aspect, a method of assembling a pulley for a wire saw device having a wire forming a wire web, the pulley being rotatable about an axis, the method including:

a) placing a tire and a wheel concentrically about an axis such that the wheel is axially located at a mounting side of the tire, wherein the tire is essentially ring-shaped about an axis and has a wire guiding portion extending circumferentially about the axis along a radially outer side of the tire for guiding the wire, and a wheel receiving portion extending circumferentially about the tire axis along a radially inner side of the tire, the wheel receiving portion having a forward stopper face facing towards the mounting side and a snap-in profile portion having a backward stopper face facing away from the mounting side, and wherein the wheel is rotatable about the axis and has a tire receiving portion extending circumferentially about the tire axis along a radially outer side of the wheel, the tire receiving portion having a forward stopper counter-face facing away from the mounting side, and a counter snap-in profile portion having a backward stopper counter-face facing towards the mounting side;

b) sliding the tire axially in direction of the mounting side onto the wheel, such that the tire receiving portion of the wheel receives the wheel receiving portion of the tire thereon, until

the sliding movement of the tire relative to the wheel in direction to the mounting side is stopped by the forward stopper face contacting the forward stopper counter-face; and

c) sliding the snap-in profile portion over the counter snap-in profile portion, whereby the snap-in profile portion snaps in such that a movement of the tire relative to the wheel in direction away from the mounting side is stopped by the backward stopper face contacting the backward stopper counter-face.

[00117] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. A pulley tire (450) for a pulley (400) of a wire saw device (100; 200), the pulley comprising a wheel (410) and the tire (450), the tire having an axis (410a) and comprising:

a wire guiding portion (452) extending circumferentially about the axis (410a) along a radially outer side of the tire; and

a wheel receiving portion (460) extending circumferentially about the tire axis (410a) along a radially inner side of the tire, the wheel receiving portion being shaped for receiving the wheel (410) therein by sliding the tire axially in direction of a mounting side (405) onto the wheel, the wheel receiving portion having

- a forward stopper face (462) facing towards the mounting side (405), and

- a snap-in profile portion (464) having a backward stopper face (465), the backward stopper face (465) facing away from the mounting side (405).

2. The pulley tire (450) according to any one of the preceding claims, being integrally made of one piece.

3. The pulley tire (450) according to any one of the preceding claims, wherein the snap-in profile portion (464) is resilient.

4. The pulley tire (450) according to any one of the preceding claims, wherein at least one of the forward stopper face (462) and the backward stopper face (465) is inclined at an angle of between 45° and 100°, in particular at an essentially right angle , with respect to the axis.

5. The pulley tire (450) according to any one of the preceding claims, wherein the snap-in profile portion (464) further has a slanted ramp surface (466) inclined between 3° and 45° in direction towards the mounting side with respect to the axis.

6. The pulley tire (450) according to any one of the preceding claims, wherein the wheel receiving portion (460) further has a support surface (468) facing towards the axis for

supporting the tire on the wheel, and wherein the snap-in profile portion (464) is adjacent to the support surface (468).

7. The pulley tire (450) according to any one of the preceding claims, wherein the support surface (468) comprises a slanted support surface portion (468a) inclined in direction inclined between 3° and 45° in direction towards the mounting side with respect to the axis, the slanted support surface portion being located, relative to the snap-in profile portion, on a side away from the mounting side.

8. The pulley tire (450) according to any one of the preceding claims, wherein the snap-in profile portion (464) is shaped asymmetrically with respect to a plane normal to the axis .

9. The pulley tire (450) according to any one of the preceding claims, wherein the wheel receiving portion is shaped rotationally asymmetrically with respect to the axis such as to block a relative rotation between the tire and the wheel when the tire is mounted on the wheel.

10. The pulley tire (450) according to claim 9, wherein the wheel receiving portion comprises a cavity covering an angle of less than 20°, in particular less than 10°, about the axis, for blocking the relative rotation between the tire and the wheel.

11. A pulley wheel (410) for a pulley (400) of a wire saw device (100; 200), the pulley comprising the wheel (410) and a tire (450), the wheel being rotatable about an axis (410a) and comprising:

a tire receiving portion (420) extending circumferentially about the tire axis (410a) along a radially outer side of the wheel, the tire receiving portion being shaped for receiving the tire (450) thereon by sliding the tire axially in direction of a mounting side (405) onto the wheel, the tire receiving portion having

- a forward stopper counter-face (422) facing away from the mounting side (405), and

- a counter snap-in profile portion (424) having a backward stopper counter-face (425), the backward stopper counter-face (425) facing towards the mounting side (405).

12. The pulley wheel (410) according to claim 11, wherein at least one of the forward stopper counter-face (422) and the backward stopper counter-face (425) is inclined with respect to the axis at an angle of between 45° and 100°, in particular at an essentially right angle .

13. The pulley wheel (410) according to any one of the claims 11 to 12, wherein the counter snap-in profile portion (464) further has a slanted ramp counter-surface (466) inclined between 3° and 45° in direction away from the mounting side with respect to the axis.

14. The pulley wheel (410) according to any one of the claims 11 to 13, wherein the tire receiving portion (420) further has a support counter-surface (428) facing away from the axis for supporting the tire on the wheel, and wherein the counter snap-in profile portion (424) is adjacent to the support counter-surface (428).

15. The pulley wheel (410) according to any one of the claims 11 to 14, wherein the support counter-surface comprises a slanted support counter-face portion inclined between 3° and 45° in direction away from the mounting side with respect to the axis, the slanted support counter-face portion being located, relative to the counter snap-in profile portion, on a side away from the mounting side.

16. The pulley wheel (410) according to any one of the claims 11 to 15, wherein the counter snap-in profile portion (464) is shaped asymmetrically with respect to a plane normal to the axis.

17. The pulley wheel (410) according to any one of the claims 11 to 16, having a plurality of openings extending through the wheel in an axial direction, wherein in a cross-sectional center plane normal to the axis, the surface covered by the openings is at least 20% of the surface covered by solid material of the wheel.

18. The pulley wheel (410) according to any one of the claims 11 to 17, wherein the pulley wheel comprises an electrically conductive material, especially an electrically conductive plastic material.

19. The pulley wheel (410) according to claim 18, wherein the plastic material is a synthetic polymeric material, such as a polyamide, including electrically conductive fibers, such as carbon fibers.

20. The pulley wheel (410) according to any one of the claims 11 to 19, wherein the tire receiving portion is shaped rotationally asymmetrically with respect to the axis such as to block a relative rotation between the tire and the wheel.

21. The pulley wheel (410) according to claim 20, wherein the tire receiving portion comprises a protrusion covering an angle of less than 20°, in particular less than 10°, about the axis, for blocking a relative rotation between the tire and the wheel.

22. A pulley (400) for a wire saw device (100; 200), the pulley being rotatable about an axis (410a) and comprising

a pulley tire according to any one of claims 1 to 10, and

a pulley wheel (410), especially one according to any one of claims 11 to 21, wherein the wheel receiving portion (460) of the tire (450) and a tire receiving portion (420) of the wheel (410) are shaped form-fit to each other.

23. A pulley (400) for a wire saw device (100; 200) having a wire (10) forming a wire web, the pulley being rotatable about an axis (410a) and comprising a pulley tire and a pulley wheel (410), wherein:

the tire (450) is essentially ring-shaped about an axis (410a) and has a wire guiding portion (452) extending circumferentially about the axis (410a) along a radially outer side of the tire for guiding the wire (10), and a wheel receiving portion (460) extending circumferentially about the tire axis (410a) along a radially inner side of the tire, the wheel receiving portion being shaped for receiving the wheel (410) therein by sliding the tire axially in direction of a mounting side (405) onto the wheel, the wheel receiving portion having
- a forward stopper face (462) facing towards the mounting side (405) for stopping a movement of the tire relative to the wheel in direction to the mounting side and
- a snap-in profile portion (464) having a backward stopper face (465) facing away from the mounting side (405) for stopping a movement of the tire (450) relative to the wheel (420) in direction away from the mounting side, and wherein

the wheel (410) is rotatable about the axis (410a) and has a tire receiving portion (420) extending circumferentially about the tire axis (410a) along a radially outer side of the wheel, the tire receiving portion receiving the tire (450) thereon, the tire receiving portion having
- a forward stopper counter-face (422) facing away from the mounting side (405) for stopping a movement of the tire relative to the wheel in direction to the mounting side, and
- a counter snap-in profile portion (424) having a backward stopper counter-face (425) facing towards the mounting side (405) for stopping a movement of the tire (450) relative to the wheel (420) in direction away from the mounting side, and wherein

the wheel receiving portion (460) of the tire (450) and the tire receiving portion (420) of the wheel (410) are shaped form-fit to each other, and wherein

at least one of the snap-in profile portion and the counter snap-in profile portion is shaped asymmetrically such as to allow an axial sliding of the tire in direction of the mounting side (405) for mounting the tire on the wheel, while blocking an axial sliding of the tire in direction away from the mounting side (405).

24. A wire saw device (100; 200) having a wire (10) forming a wire web, the wire saw device comprising a plurality of pulleys according to any one of claims 22 to 23, wherein in particular essentially all pulleys of the plurality of pulleys have essentially the same moment of inertia.

25. A method of assembling a pulley for a wire saw device (100; 200), the pulley being rotatable about an axis (410a), the method comprising:

a) placing a tire (450) and a wheel (410) concentrically about an axis (410a) such that the wheel is axially located at a mounting side of the tire, wherein

the tire (450) is essentially ring-shaped about an axis (410a) and has a wire guiding portion (452) extending circumferentially about the axis (410a) along a radially outer side of the tire for guiding the wire (10), and a wheel receiving portion (460) extending circumferentially about the tire axis (410a) along a radially inner side of the tire, the wheel receiving portion having
- a forward stopper face (462) facing towards the mounting side (405) and

- a snap-in profile portion (464) having a backward stopper face (465) facing away from the mounting side (405), and wherein

the wheel (410) is rotatable about the axis (410a) and has a tire receiving portion (420) extending circumferentially about the tire axis (410a) along a radially outer side of the wheel, the tire receiving portion having
- a forward stopper counter-face (422) facing away from the mounting side (405), and
- a counter snap-in profile portion (424) having a backward stopper counter-face (425) facing towards the mounting side (405);

b) sliding the tire axially in direction of the mounting side (405) onto the wheel, such that the tire receiving portion of the wheel receives the wheel receiving portion of the tire thereon, until the sliding movement of the tire relative to the wheel in direction to the mounting side is stopped by the forward stopper face (462) contacting the forward stopper counter-face (422); and

c) sliding the snap-in profile portion (464) over the counter snap-in profile portion (424), whereby the snap-in profile portion (464) snaps in such that a movement of the tire relative to the wheel in direction away from the mounting side is stopped by the backward stopper face (462) contacting the backward stopper counter-face (422).

FIG 1

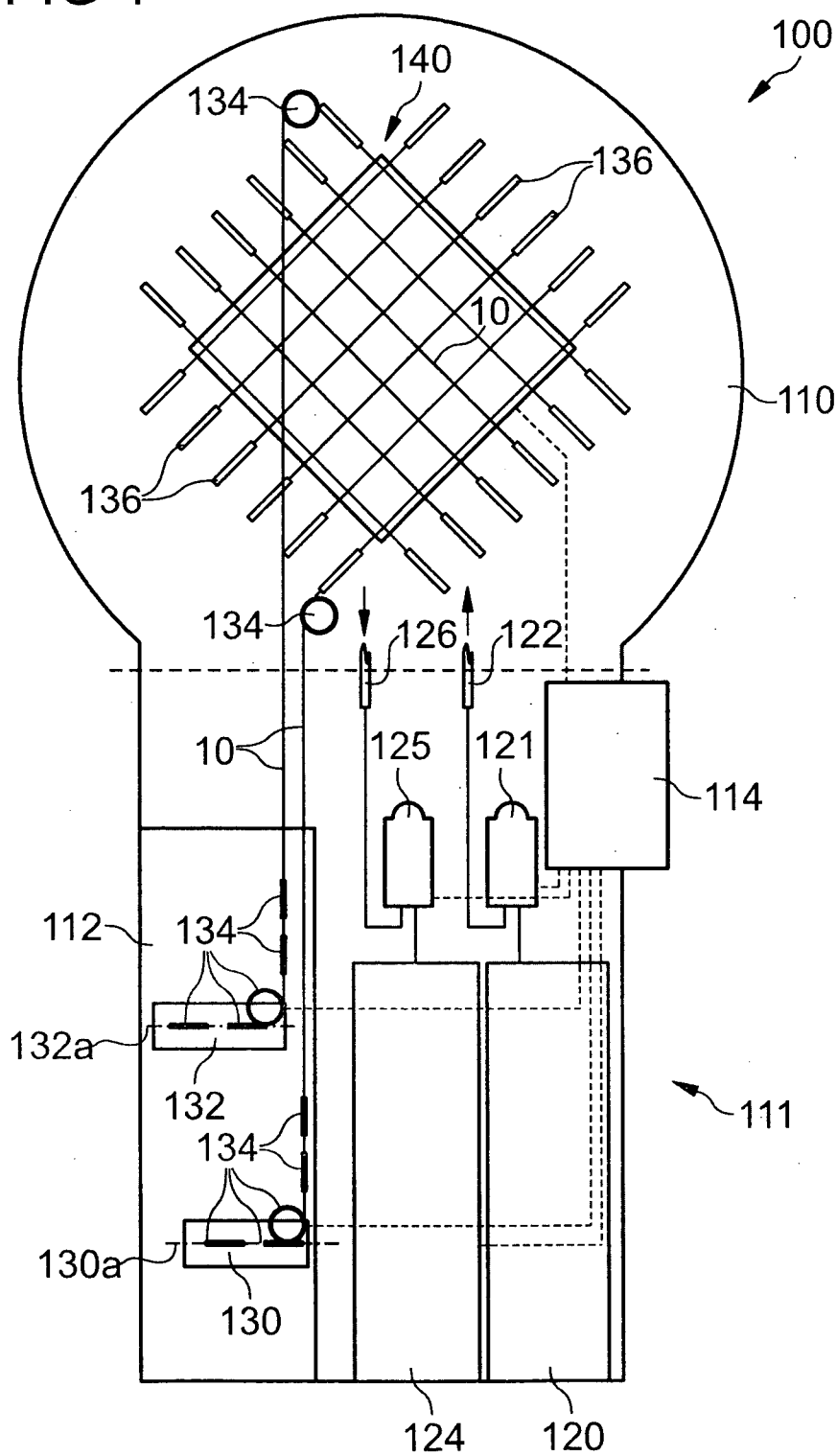

100
140
134
136
10
110
136
134
126
122
10
125
121
114
112
134
132a
132
134
111
130a
130
124
120

FIG 2

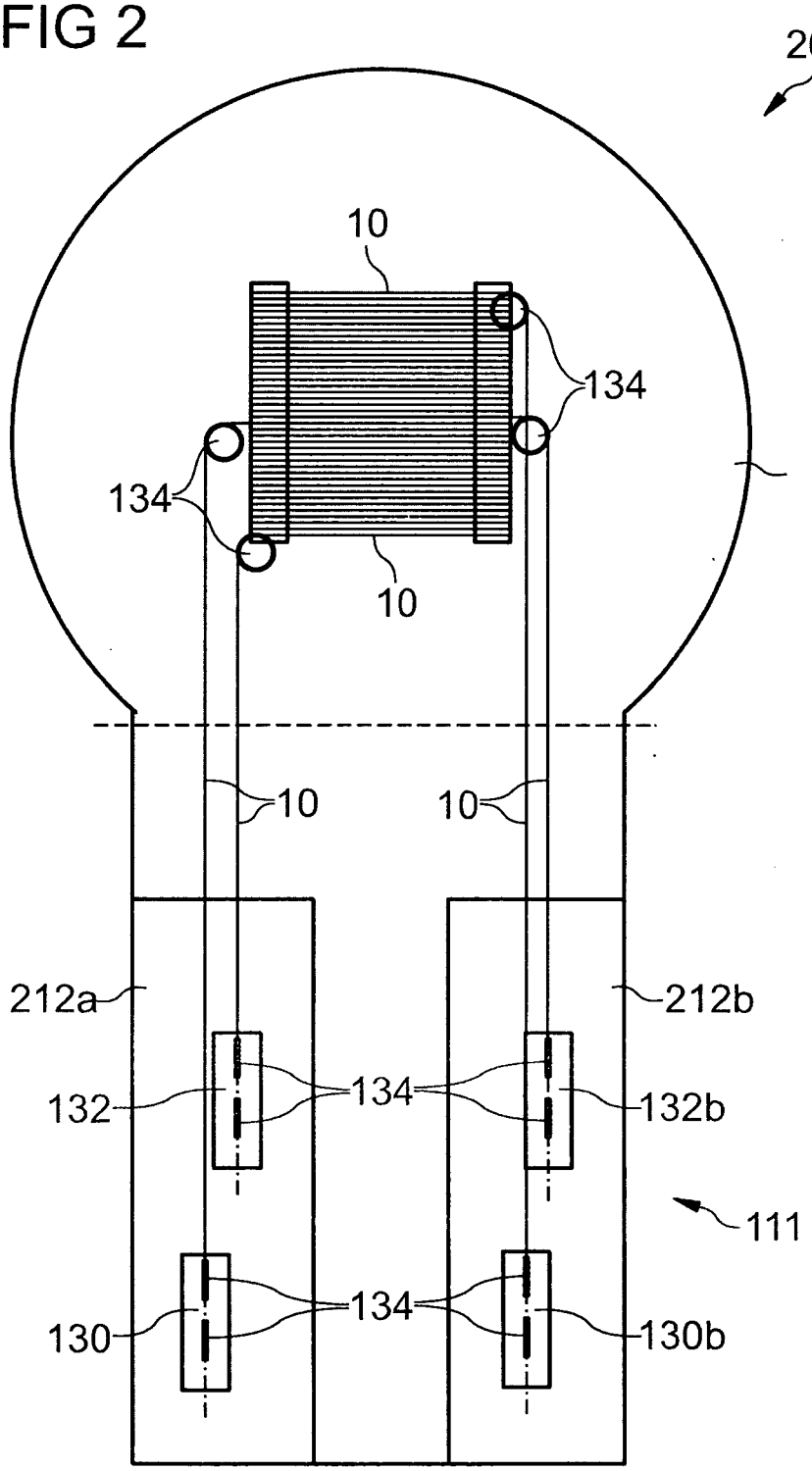


FIG 3

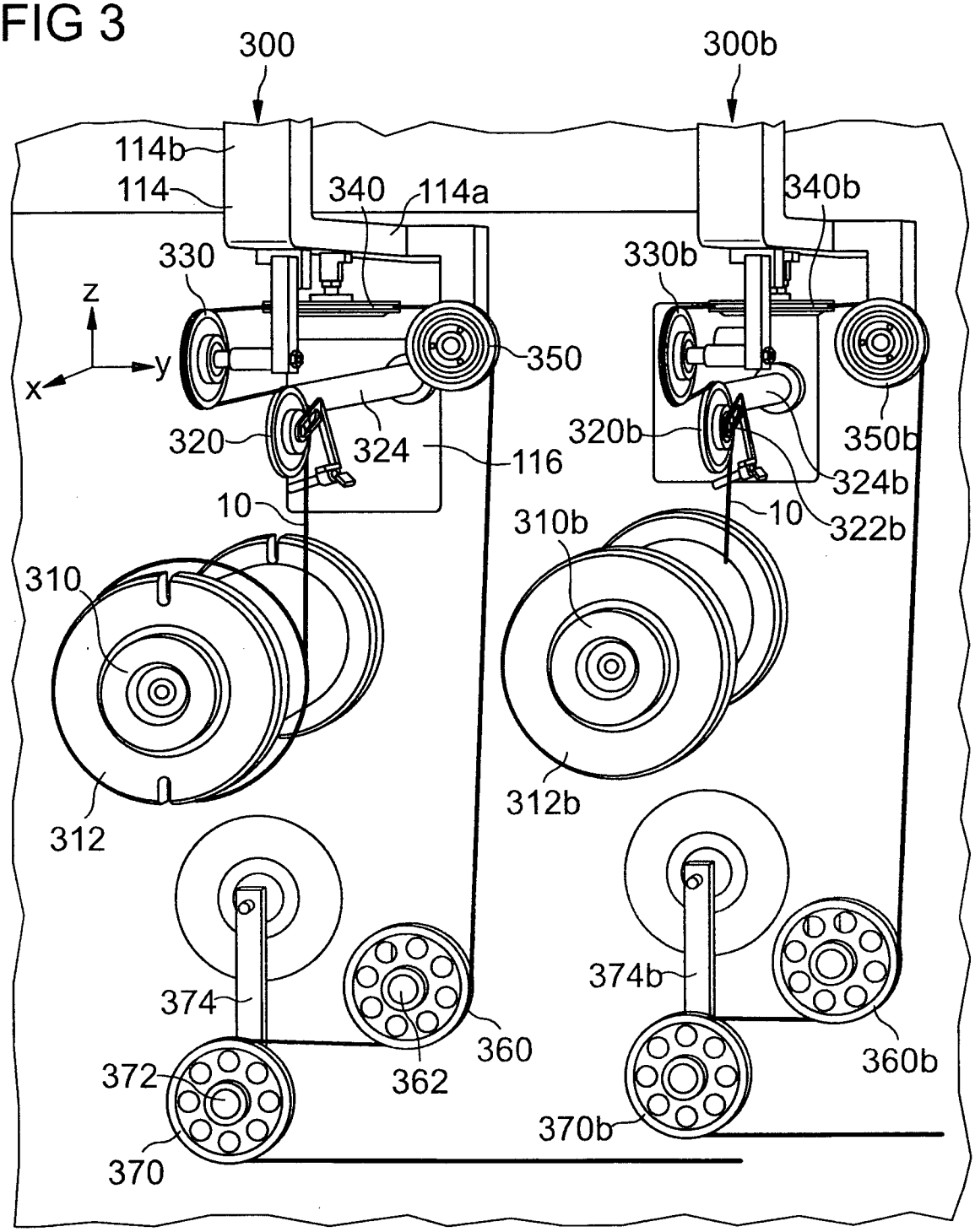

300
300b
114b
114
340
114a
340b
330
330b
z
y
x
350
320
324
116
320b
350b
324b
10
322b
310b
310
312b
312
374
374b
360
362
360b
372
370b
370

FIG 4A

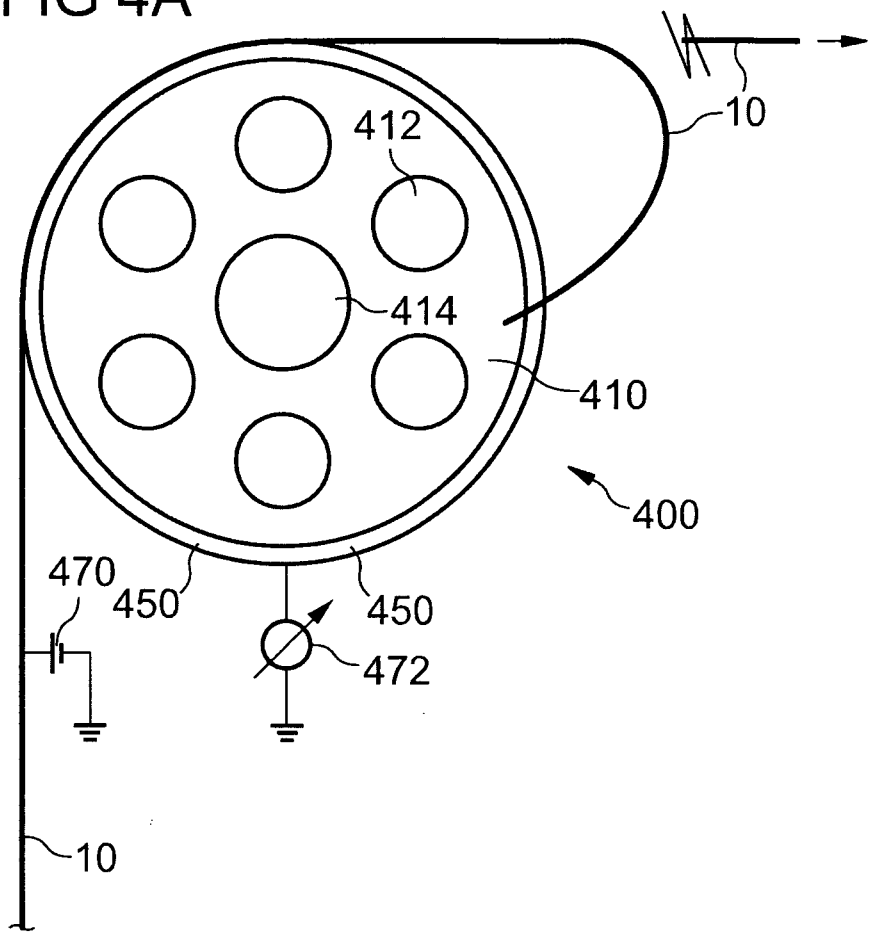

10
412
414
410
400
470
450
450
472
10

FIG 4B

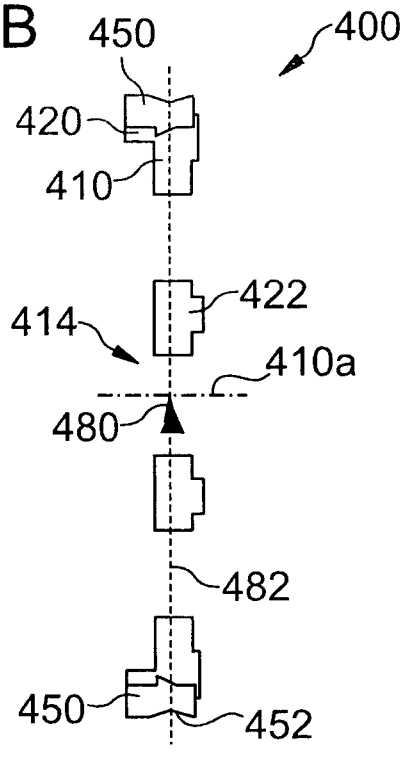

450
400
420
410
422
414
410a
480
482
450
452

FIG 5A

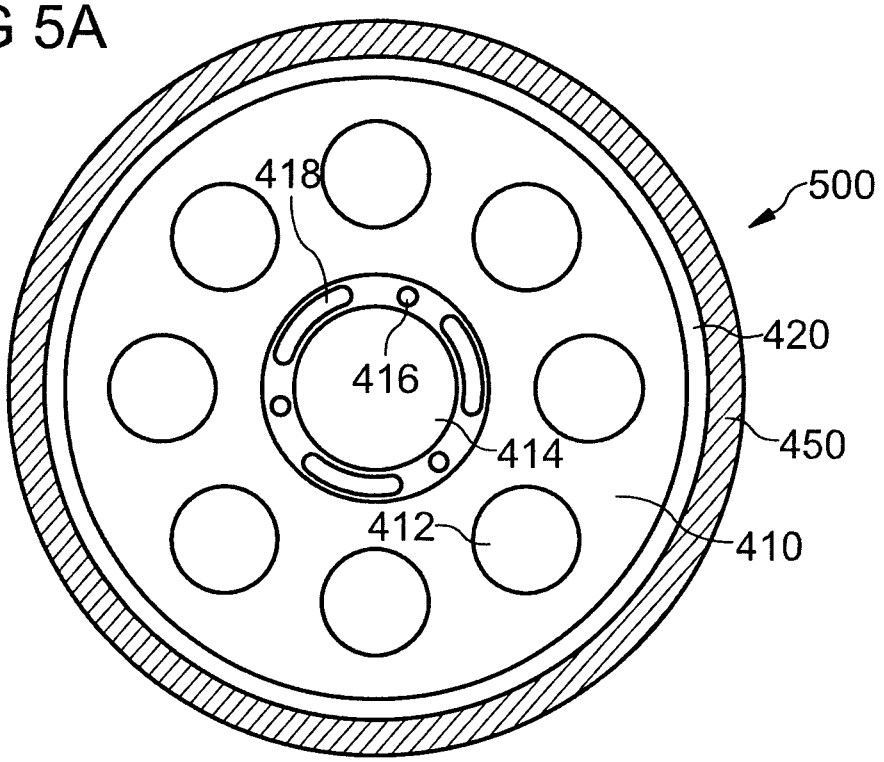
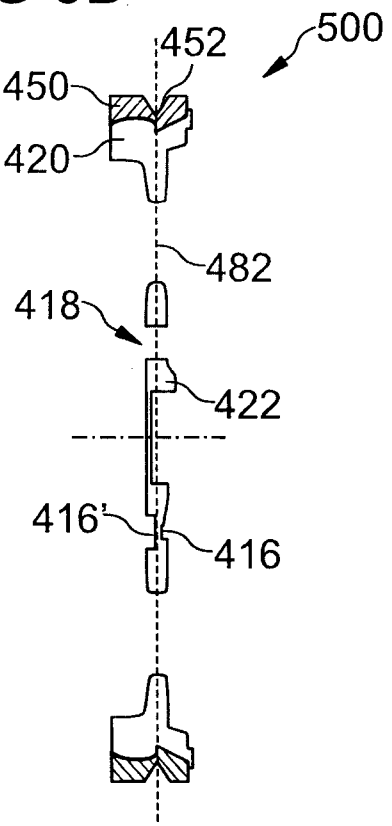

418
500
420
416
450
414
412
410

FIG 5B


500
452
450
420
482
418
422
416'
416

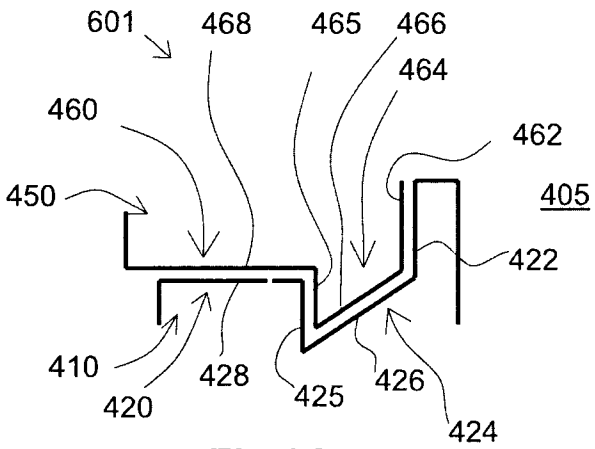


Fig.6A

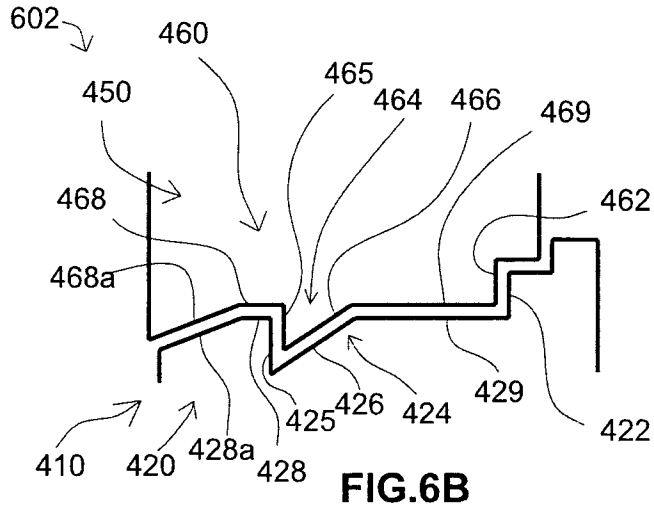


FIG.6B

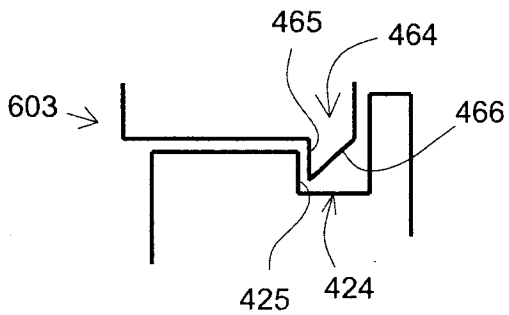


FIG.6C

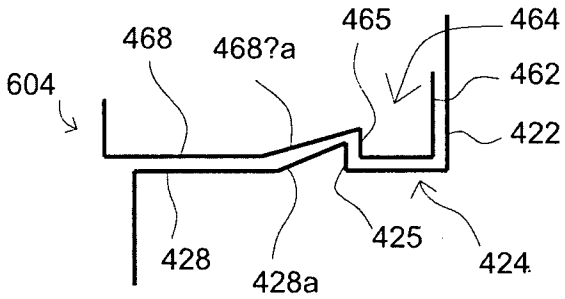


FIG.6D

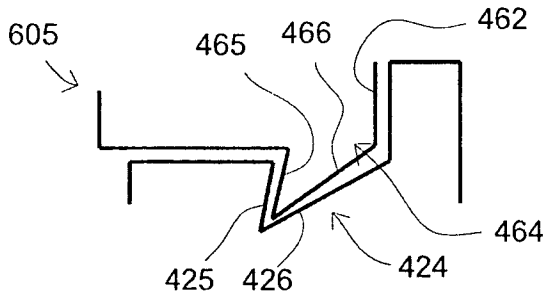


FIG.6E

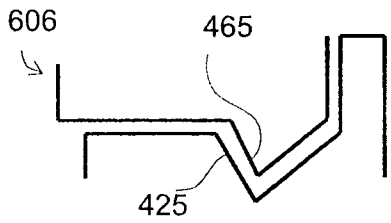


FIG.6F

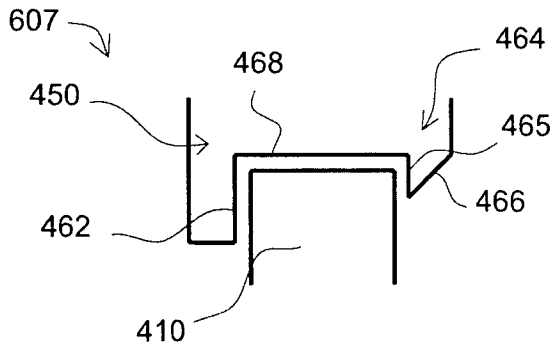


FIG.6G

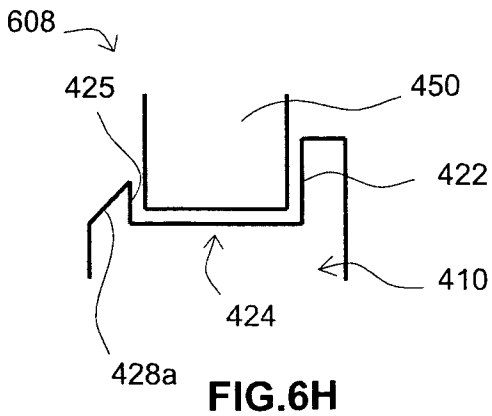


FIG.6H

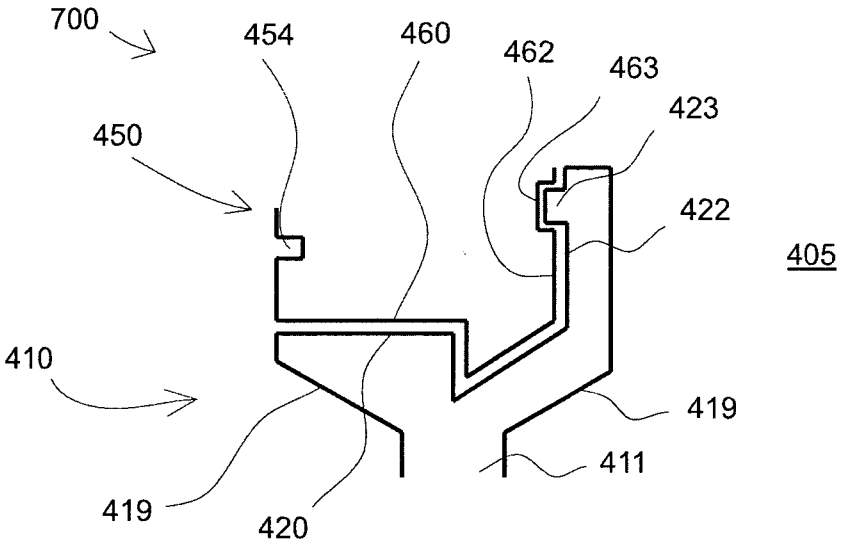

700
454
460
462
463
423
450
422
405
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419
411
419
420

Fig.7

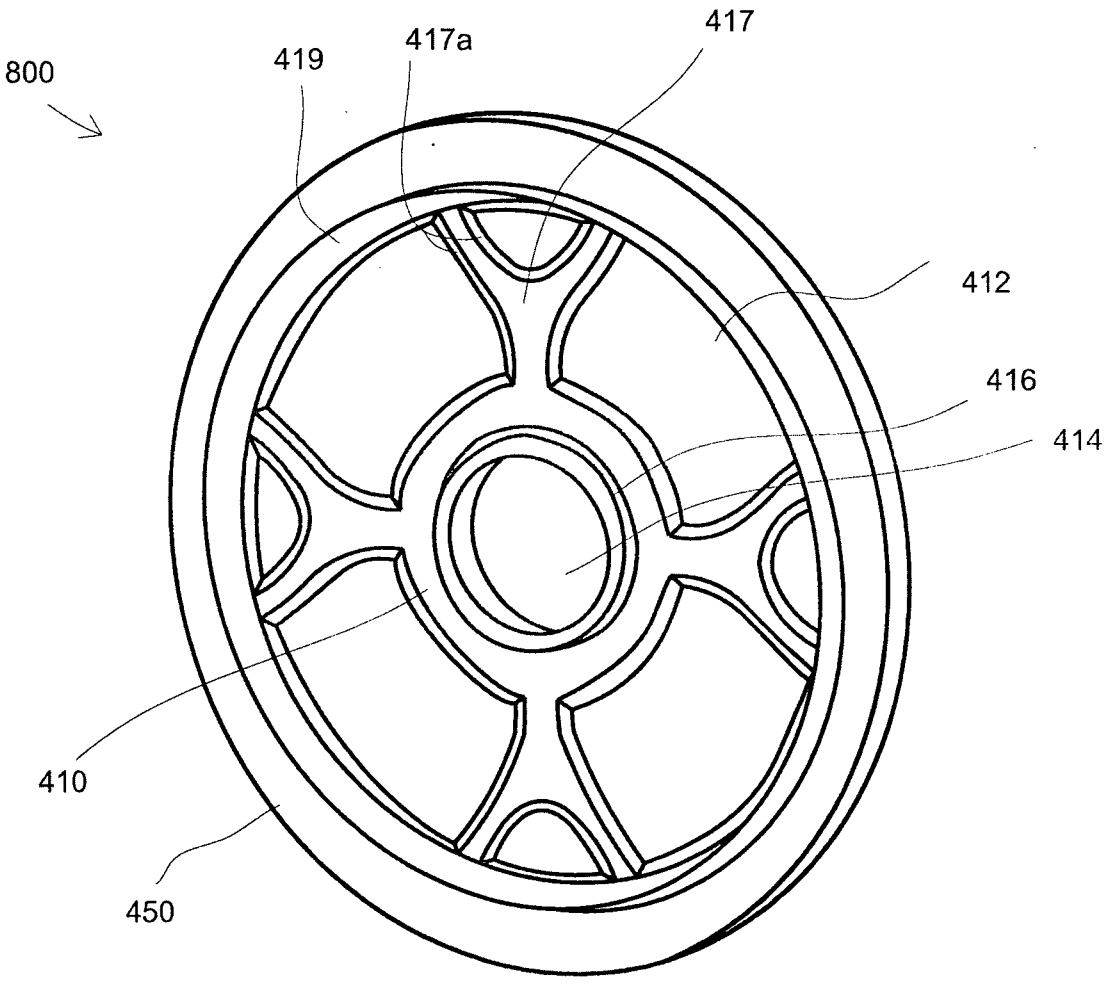

800
419
417a
417
412
416
414
410
450

Fig.8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2010/000089

A. CLASSIFICATION OF SUBJECT MATTER

B65H 57/14(2006.01)i, F16H 7/08(2006.01)i, B28D 1/08(2006.01)i

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)

B65H, F16H, B28D

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: "pulley", "wheel", "tire", "wre", "guide", "axis", "saw", "face", "stopper", "mounting", "receiving", and "sliding"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2000-044123 A (NITTO KAKO KK.) 15 February 2000 See claim 1; figures 1-7.	1-25
A	JP 11-071062 A (CLABER SPA) 16 March 1999 See claims 1-4; figures 1-5.	1-25
A	JP 09-176269 A (BRIDGESTONE CORP.) 08 July 1997 See claims 1-9; figures 1-2.	1-25
A	KR 20-0376216 Y1 (CHO, T.S. et al.) 11 March 2005 See claims 1-11; figures 1-17.	1-25
A	JP 2006-207083 A (MURATA MACH. LTD.) 10 August 2006 See claims 1-3; figures 1-7.	1-25

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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	Date of mailing of the international search report
27 SEPTEMBER 2010 (27.09.2010)	**28 SEPTEMBER 2010 (28.09.2010)**

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Authorized officer

KIM Sung Ho

Telephone No. 82-42-481-8438

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IB2010/000089

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2000-044123 A	15.02.2000	JP 2960058 B2	06.10.1999
JP 11-071062 A	16.03.1999	DE 69803017 D1	31.01.2002
		DE 69803017 T2	27.06.2002
		EP 0896947 A1	17.02.1999
		EP 0896947 B1	19.12.2001
		ES 2169473 T3	01.07.2002
		IT MI970502U1	07.01.1999
		IT MI970502V0	07.07.1997
		IT 237643 Y1	13.09.2000
		US 5975459 A1	02.11.1999
JP 09-176269 A	08.07.1997	JP 3539027 B2	14.06.2004
KR 20-0376216 Y1	11.03.2005	None	
JP 2006-207083 A	10.08.2006	None	