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(54) **A CUTTING KNIFE, A METHOD FOR REPLACING A KNIFE TIP OF SAID CUTTING KNIFE, AND A KNIFE TIP REPLACEMENT PART FOR USE IN SAID METHOD**

(57) The disclosure relates to a cutting knife (100) for a cutting shaft (24) in a comminution apparatus (10), said cutting knife (100) being a one-piece element comprising a base part (110) and one or more replaceable knife tip parts (120,120'), wherein each knife tip part is integrally formed with the base part at connection regions (130a,130b) at an outer periphery (104) of the one-piece element and is partly separated from the base part by an associated elongate through-opening (140,140'), said

elongate through-opening: having an elongate extension (141,141') in the main plane (102), being spaced from said outer periphery (104), and being located so as to facilitate replacement of the knife tip part (120) by reducing the cutting required to separate the knife tip part from the base part. The disclosure further relates to a method for replacing a knife tip of such a cutting knife, and a knife tip replacement part for use in said method.

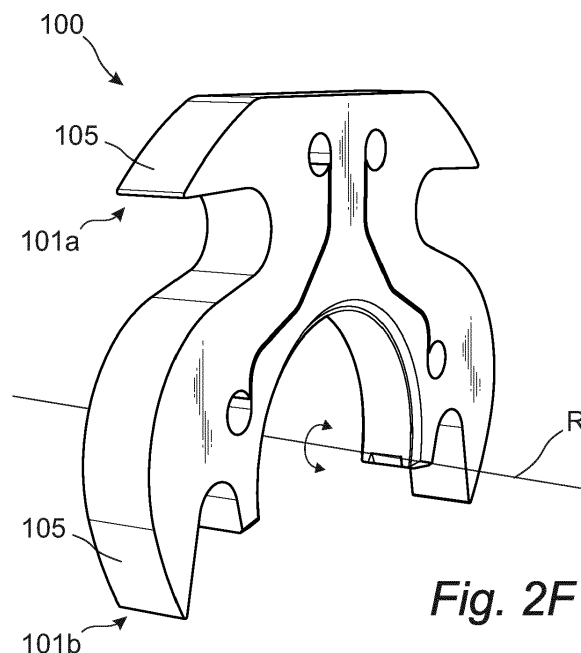


Fig. 2F

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Description

Field of the invention

[0001] The present disclosure relates to a cutting knife for a cutting shaft in a comminution apparatus. The disclosure further relates to a method for replacing a knife tip of such a cutting knife, and a knife tip replacement part for use in said method.

Background art

[0002] Comminution apparatuses, also referred to as shredders, are used for comminuting (by cutting, shredding and shearing) wood, metal parts, rubber and plastic material, garbage and other waste material, material for recycling or material for fuel. Such operation may be performed in connection with incineration, hazardous waste, demolition wood, domestic or industrial waste material, waste-to-energy conversion, recycling, landfills, etc.

[0003] One type of prior-art comminution apparatus comprises one or more rotatable cutting shafts provided with transversely extending cutting knives. One or more sets of transversely extending fixed knife blades define a stationary cutting table for receiving waste material to be comminuted. The counter knives in each set are mutually separated by openings through the cutting table. The rotating knives extend partly down into said openings and co operate with the counter knives for comminuting the waste material. The comminuted waste material falls down through said openings. Prior-art comminution apparatuses of this kind are disclosed in WO 97/10057 and WO 2006/137033.

[0004] Although such prior-art comminution apparatuses are advantageous and effective in many aspects, there is still a need for further improvements, especially with respect to time and cost needed for service and for replacement or substitution of wear parts. An especially exposed region of the apparatus is the rotating cutting knives, especially the cutting surfaces facing the material to be comminuted. For this purpose, it has been proposed in the art to provide rotating cutting knives having replaceable knife tip parts, which comprise the cutting surfaces. These replaceable knife tip parts are carried by a centrally located base part of the cutting knife, wherein the base part is attached to a cutting shaft axle. The purpose of providing replaceable knife tip parts is primarily to facilitate a selective replacement of the parts of the cutting shaft which have been worn out, or in other ways damaged. There may also be other reasons for replacement, such as modification of the cutting properties by changing existing knife tip parts to different knife tip parts more suitable to the material comminuted by the apparatus.

[0005] There are different solutions known in the art. Some rely on providing cutting knives having replaceable knife tip parts which are releasably attached to the central part by means of e.g. a locking elements such as e.g. a screw or bolt. One such example is provided in US patent

6,375,106. Another solution is to provide replaceable knife tip parts which are welded onto the base part. By cutting along the welds, the knife tip parts may be disconnected from the base part, and subsequently replaced by new wear parts which may be fastened to the base part by welding. One such example is provided in US patent application US2004/025609 A1.

[0006] A problem with the solutions of the art is that replacement of the knife tip parts is time-consuming and often also relatively complicated. There is thus a need for an improvement in the art.

Summary

[0007] It is an object to mitigate, alleviate or eliminate one or more of the above-identified deficiencies in the art and disadvantages singly or in any combination and solve at least the above mentioned problem. According to a first aspect there is provided a cutting knife for a cutting shaft in a comminution apparatus, said cutting knife being a one-piece element which extends in a main plane transversely to a rotational axis of the cutting knife and which has an outer periphery in relation to the rotational axis,

said one-piece element comprising a base part and one or more replaceable knife tip parts, wherein said base part is configured to be attached to an axle of said rotatable cutting shaft, and wherein each of said one or more replaceable knife tip parts is suitable for cutting material disposed in the comminution apparatus, and wherein each knife tip part is integrally formed with the base part at connection regions at the outer periphery and is partly separated from the base part by an associated elongate through-opening, said elongate through-opening:

having an elongate extension in the main plane, being spaced from said outer periphery, and being located so as to facilitate replacement of the knife tip part by reducing the cutting required to separate the knife tip part from the base part.

[0008] The cutting knife of the disclosure may be advantageous as it allows for reducing the amount of work needed to replace worn out knife tip parts of a cutting knife of a cutting shaft. Thus, the determining factor will be the relative decrease in the total cutting length that would be obtained by providing the elongate through-opening. By providing an elongate through-opening in the cutting knife, and thereby forming a one-piece element in which the knife tip part is partly separated from the base part but still integrally formed with the base part at the outer periphery, the replaceable knife tip part may be replaced by cutting away significantly less material than would have been required in absence of the elongate through-opening. The elongate through-opening may thus functionally act as a pre-engineered cut. Thus,

in a sense the invention shares structure and function with a perforation. During the replacement procedure, material is cut away at both ends of the elongate extension so as to separate the base part from the replaceable knife tip part. Cutting may be achieved by means of e.g. a flame cutter or a laser cutter. Cutting may alternatively be achieved by means of a milling machine (e.g. a router), where material is removed by advancing a rotary cutter into the material.

[0009] The cutting knife is a result from the inventors' realization that providing an elongate through-opening, which has an inherent apparent disadvantage of introducing a weakening of the structural integrity of the cutting knife, also has the advantage of providing more efficient wear part replacement. Sufficient structural integrity may be maintained for the proposed cutting knife by shaping, and locating, the elongate through-opening of the cutting knife in an appropriate way. Design parameters include at least through-opening position relative to the outer periphery, through-opening shape, through-opening extension relative to dimensions of cutting knife etc. Typically, simulation tools, such as e.g. finite element software tools, are useful for providing optimum through-opening design parameters for a particular embodiment of a cutting knife, and/or for a particular use thereof.

[0010] An additional benefit of the cutting knife is that, when the original replaceable knife tip part is worn out and in need of replacement, there is only limited wear on the inner surfaces of the elongate through-opening. Thus, the base part will have at least a portion of its surface defined by an almost untouched pre-engineered surface (i.e. parts of what was surfaces of the through-opening before cutting). Such a pre-engineered surface provides a smooth and predictable abutment surface enabling a correct positioning of a new wear part, such as a knife tip replacement part of the present disclosure.

[0011] The term "replaceable" should not be construed merely as a name assigned to a part of the cutting knife which is possible to separate from the rest of the cutting knife (indeed, all parts of a cutting knife may be separated from the rest of the cutting knife). Instead, the term should be construed to mean that the cutting knife is configured such that the one or more knife tip parts are replaceable, said configurability being realized by the presence of the elongate through-opening.

[0012] The rotational axis is orthogonal to the main plane. This implies that the cutting knife will rotate in the main plane.

[0013] An essential feature of the invention is that the cutting knife is a one-piece element. This implies that the one or more replaceable knife tip parts are non-releasably attached to the base part. There are thus no releasing means on the cutting knife, such as e.g. a bolt, screw, spring, etc. The only way to separate the one or more replaceable knife tip parts from the base part, is to actively break the chemical bonds of the material, such as by removing parts of the material of the one-piece element by cutting. Typically, the cutting knife is made from metal,

such as steel. The cutting knife may have uniform material properties. For example, the cutting knife may be molded, or formed by cutting, from an element having uniform material properties, so as to obtain its shape. However, the one-piece element must not be construed so narrowly. It is conceivable that the cutting knife is made from two or more separate parts which are non-releasably attached to each other. For example, the one-piece element may be made from a base part which is welded together with one or more replaceable knife tip parts. The cutting knife may be made from steel having different properties, such as e.g. different hardness. In case the base part is attached to the replaceable knife tip parts by welding, it is conceivable that the base part has different properties than the replaceable knife tip parts. For example, the replaceable knife tip parts may have a higher hardness than the base part.

[0014] Finally, it is emphasized that it is conceivable within the scope of the inventive concept to provide a cutting knife which is provided with, in addition to said one or more knife tip parts each being partly separated from the base part by an associated elongate through-opening, one or more additional cutting parts attached to the base part without any through-openings there between. This may for example be necessary where a replaceable knife tip part is relatively small compared to the base part, and thus may need a connection to the base part all along their mutual interface in order for the replaceable knife tip part to withstand stresses during use.

[0015] According to some embodiments, the elongate extension of the elongate through-opening is non-linear in said main plane. The non-linearity may be different for different embodiments of the cutting knife. For example, the elongate extension of the elongate through-opening may have at least one linear portion. In preferred embodiments, the elongate extension of the elongate through-opening has three linear portions aligned after each other and wherein neighboring linear portions are connected to each other by non-linear portions. The non-linearity may facilitate a correct positioning of a knife tip replacement part, which is appropriately shaped to fit to the base part, after the replacement knife tip part has been removed from the base part by cutting.

[0016] According to some embodiments, said elongate extension defines:

- at a first connection region: a first minimum distance between a first end of the elongate extension and the outer periphery, and,
- at a second connection region: a second minimum distance between a second end of the elongate extension and the outer periphery, and

wherein the elongate extension is longer than the sum of said first and second minimum distances. The first and second minimum distances correspond to the geometrically minimum cutting distances needed when separat-

ing the one or more replaceable knife tip parts from the base part. As readily realized by the person skilled in the art, the relationship between the first and second minimum distances, and the length of the elongate extension will be related to the cutting time required to separate the one or more replaceable knife tip parts from the base part. However, the person skilled in the art will also realize that the structural integrity of the cutting knife also depends on the aforementioned relationship. For example, if the elongate extension is too long, the one or more replaceable knife tip parts may get torn off the base part as a result from the strong internal forces and moments arising within the cutting knife during comminution.

[0017] It is conceivable to use a longer elongate through-opening. For example, the elongate extension may be 1.5, or even 1.75 times as long as the sum of said first and second minimum distances.

[0018] According to some embodiments, said elongate extension is located such that the one or more replaceable knife tip parts extend so as to constitute at least 70% of the outer periphery of the cutting knife. This may be advantageous as it allows removing relatively large parts of the cutting surface of the cutting knife. For alternative embodiments, the elongate extension is located such that the one or more replaceable knife tip parts extend so as to constitute at least 80%, or 85% or even 90% of the outer periphery of the cutting knife.

[0019] This may be achieved by providing a relatively larger number of relatively small replaceable knife tip parts distributed over the periphery. However, preferably, it is achieved by providing just a few larger replaceable knife tip parts, where each knife tip part extends so as to include a significant portion of the outer periphery of the cutting knife. The elongate extension may for example be located such that the cutting required to separate the associated knife tip part from the base part will have to be separately performed at two substantially opposite ends of the periphery of the cutting knife.

[0020] Expressed in an alternative way, the elongate extension may be arranged in the main plane such that a first line, which connects the rotational axis with the first end of the elongate through-opening, and a second line, which connects the rotational axis with the second end of the elongate through-opening, forms an angle of at least 50 degrees between each other. Said lines may alternatively form an angle between each other being larger than 60 degrees. Said lines may alternatively form an angle between each other being larger than 70 degrees.

[0021] According to some embodiments, said elongate through-opening is at least partly defined by a slit which forms a slit gap between the base part and the associated knife tip part. The slit may be advantageous for several reasons. Firstly, a slit is relatively easy to manufacture using e.g. a flame cutter or a laser cutter. Secondly, the elongate through-opening is narrow enough for preventing waste material from getting stuck in the opening during comminution.

[0022] The slit gap, also referred to as the kerf, may have a gap width of 0.5 - 10 mm. The slit gap width may be substantially constant along the elongate extension. Alternatively, the slit gap width may vary as function of position along the elongate extension. Preferable the slit gap width is less than 6 mm. When using a flame cutter to cut the slit, the slit gap width is typically around 3 mm. When using a laser cutter to cut the slit, the slit gap is usually less than 3 mm, such as e.g. 1 mm, or 0.5 mm.

[0023] According to some embodiments, the elongate through-opening is further defined by one or more stress-relief openings, wherein each opening of said one or more stress-relief openings is defined at an associated end of said elongate extension so as to form a stress-relief opening gap between the base part and the associated knife tip part, wherein the stress-relief opening gap has a gap width being larger than a gap width of a central portion of the elongate through-opening, said one or more stress-relief openings being structured and arranged to spatially distribute internal forces induced in the cutting knife when in use.

[0024] The stress-relief opening gap may have a gap width being ~10 times larger than a gap width of a central portion of the elongate through-opening. Alternatively, the stress-relief opening gap may have a gap width being within a range of 50-150% of a minimum distance between the associated stress-relief opening and the outer periphery. Typically, the stress-relief opening gap is about one order of magnitude smaller than a radius of the cutting knife. Thus, for a cutting knife having a radius of around 450 mm, the stress-relief opening gap may typically be around 45 mm. The center portion of the elongate through-opening may define the slit.

[0025] Thus, the stress-relief openings serve the purpose of improving the structural integrity of the cutting knife, a structural integrity which may in some situations be compromised by the mere existence of the elongate through-opening. It is understood that geometrical shapes and dimensions of said openings may vary dependent on the embodiment of the cutting knife. However, generally, the stress-relief openings will be of most use for embodiments having a relatively narrow elongate through-opening, such as e.g. the embodiment wherein the elongate through-opening is a slit. Without the stress-relief openings disposed at either end of the otherwise narrow elongate through opening (the slit), the internal material stresses may rise to unsafe levels just at the end of the through-opening. By allowing the elongate through-opening to increase its dimensions at either end of the elongate extension, the internal stresses will be distributed over a larger material volume, hence decreasing peak values. The purpose of the stress-relief openings may further be to position the highest level of stress. It is best to avoid high stress level in the area of the weld, simply because high stress levels in such areas may reduce the lifetime of the cutting knife (as determined e.g. by the replaceable knife tip part breaking loose from the base part).

[0026] Thus, according to a preferred embodiment, a center portion of the elongate through-opening is defined by a slit and end portions of the elongate through opening is defined by associated stress-relief openings.

[0027] Although dimensions are disclosed herein, it should be understood that the stress relief openings are not designed based on geometrical concerns. Instead, the design of the stress relief openings will depend on the stress level within the material at the end of the elongate through-opening. The smaller the stress-relief opening the larger the stress peak. The larger the stress-relief opening, the smaller the stress peak.

[0028] According to some embodiments, the one or more stress-relief openings have rounded, preferably circular, cross sections as defined in said main plane. The rounded form effectively prevents the occurrence of sharp corners or edges, which may further aid in minimizing high internal stress peaks in the material.

[0029] According to some embodiments, said one or more replaceable knife tip parts comprises two replaceable knife tip parts being disposed on opposite sides of the base part.

[0030] Each replaceable knife tip part may comprise one or more cutting teeth. Each replaceable knife tip part may comprise two or more cutting teeth. For some embodiments, each knife tip part comprises two cutting teeth. For alternative embodiments, each knife tip part comprises three cutting teeth. Usually, the cutting knife has the same number of cutting teeth on each knife tip part. However, for some embodiments it may differ. For example, one knife tip part may comprise two or even three knife tips, whereas the other knife tip part may comprise only one cutting tooth.

[0031] As previously disclosed, each replaceable knife tip part comprises a respective cutting surface for cutting material disposed in the comminution apparatus. To achieve an improved cutting, the cutting surfaces are typically parts of cutting teeth formed along the periphery of the cutting knife.

[0032] Some comminution apparatuses are based on the cutting shafts rotating in a single rotational direction only. For such comminution apparatuses, the cutting knives may have its cutting teeth directed along substantially the same angle with respect to a radial axis. This implies that such cutting knives has a circular symmetry.

[0033] However, some comminution apparatuses are based on the cutting shafts intermittently changing rotational direction. For such a comminution apparatus, replaceable knife tip parts may be disposed on opposite sides of the base part such that one or more replaceable knife tip parts are configured to cut material for one rotational direction of the rotatable cutting shaft, and one or more other replaceable knife tip parts are configured to cut material for another rotational direction of the rotatable cutting shaft.

[0034] The circular symmetry is often inappropriate for this kind of apparatus. Cutting knives on this kind of comminution apparatuses are instead often symmetric in re-

lation to a radial axis extending outwardly in the main plane from the rotational axis of the cutting knife (although cutting knives may also sometimes be asymmetric along said radial axis, such as e.g. cutting knives having uneven number of cutting teeth on their respective replaceable knife tip parts). This allows for the cutting knife to be effective in cutting independent on the rotational direction of the cutting shaft.

[0035] Preferably, the base part extends radially out from the rotational axis along the radial symmetry axis to form a portion of the outer periphery. This may advantageously provide an increased support for the knife tip parts.

[0036] According to some embodiments, said connecting regions are provided with one or more markings, such as visual indications, providing one or more guides for intended cutting lines for said cutting required to separate said one or more knife tip parts from the base part. The markings may extend between the elongate through-opening and the outer periphery along an extension of the first and second minimum distance, respectively. This has the benefit of minimizing the time needed for cutting. However, for some embodiments, the marking may deviate from the optimum trajectory defined by the respective extension of the first and second minimum distance. A reason for not choosing the optimum trajectory may be to provide a desired shape of the base part. The optimum trajectory as defined by said minimum distances may result in a base part shape difficult to work with when attempting to attach new wear parts, such as a new knife tip replacement part thereto.

[0037] According to some embodiments, the elongate through-opening has an inner surface which includes surface portions extending along the elongate extension, wherein said surface portions are three-dimensionally shaped, as defined in the main plane and along the direction of the rotational axis. This may be an advantage as the three-dimensional surface portions of the inner surface may facilitate easier positioning of a replacement part ones a replaceable knife tip part has been removed. When removing the replaceable knife tip part, the surface portion which extends along the elongate extension on the base part side of the cutting knife will have a three-dimensional interface. If an associated replacement part is shaped in a corresponding way, the replacement part may be easily positioned in a unique position in relation to the base part. Ones correctly positioned, the replacement part may be welded together with the base part.

[0038] According to some embodiments, the elongate through-opening, at each position along the elongate extension of the opening, extends through the cutting knife along a specific direction which forms an angle with the rotational axis, wherein said angle varies as function of position along the elongate extension. This may be beneficial from a manufacturing perspective as it allows for manufacturing a three-dimensional elongate through-opening using a conventional cutting means, such as a flame cutter or laser cutter, which provides cuts being

linear as function of depth. By varying the angle of incidence of the cutting means (flame/laser or the like) as function of position along the elongate extension, a three-dimensional through-opening may be provided.

[0039] According to a second aspect there is provided a rotatable cutting shaft for a comminution apparatus, comprising:

an axle extending along a rotational axis of the rotatable cutting shaft, and a plurality of cutting knives according to any one of claims 1 to 13, said cutting knives being attached to the axle and being mutually spaced along the rotational axis of the cutting shaft.

[0040] According to a third aspect there is provided a comminution apparatus comprising one or more rotatable cutting shafts according to the second aspect.

[0041] According to a fourth aspect there is provided a method for replacing a knife tip of a cutting knife according to the first aspect, said method comprising:

separating a knife tip part of the cutting knife from the base part of the cutting knife by cutting said one-piece element at said connection regions where said knife tip part is integrally formed with the base part, said cutting forming two through-cuts;

removing the separated knife tip part so as to reveal, on the base part, a base part mounting interface, said base part mounting interface presenting two cut surfaces corresponding to said two through-cuts, and one pre-engineered surface forming part of the elongate through-opening;

positioning a knife tip replacement part, which has a replacement part mounting interface, in the same place as the previously removed knife tip part such that the replacement part mounting interface is aligned with the base part mounting interface; and attaching the knife tip replacement part to the base part by welding together the knife tip replacement part with the base part along at least parts of said base part mounting interface and said replacement part mounting interface.

[0042] According to some embodiments, said attaching the knife tip replacement part to the base part is performed by welding together the knife tip replacement part and the base part only at, or along boundaries of, said two cut surfaces of the base part, so as to form one or more new elongate through-openings between the welded-together knife tip replacement part and base part.

[0043] According to some embodiments, the replacement part mounting interface is structured and arranged to fit to the base part mounting interface such that the replacement part mounting interface and the base part mounting interface together define a mutual transition interface between the base part and the knife tip replacement part. Thus, it is understood that the replacement part mounting interface and the base part mounting interface are aligned with each other.

[0044] According to some embodiments, the knife tip

replacement part, at the replacement part mounting interface, presents two or more positioning protrusions adapted to be brought in into abutment with surfaces of the base part along the base part mounting interface when positioning the knife tip replacement part. The protrusions may be advantageous as they allow for an improved positioning of the knife tip replacement part in relation to the base part. The process of separating the replaceable knife tip part from the base part will in many cases result in cut surfaces being located slightly off their intended position, as a result from the cutting process. Such slightly misaligned cut surfaces may effectively prevent an optimal positioning of a knife tip replacement part to the base part, as parts of the cut surfaces of the base part may be protruding too far and thus be in the way. The advantageous protrusions will thus act as a distance means to provide a clearance at each cutting surface. This provides to increase the tolerance for which a manual cutting procedure may be regarded as successful. The positioning protrusions further provides a means of defining a critical volume to be formed at each cutting surface to accommodate a weld. An additional benefit is that when the replaceable knife tip parts of the original cutting knife is worn out and in need of replacement, there will only be limited wear on the inner surfaces of the elongate through-opening. This will further improve the positioning of the knife tip replacement part.

[0045] According to some embodiments, said positioning protrusions are arranged such that they will be in abutment with the pre-engineered surface of the base part. This may be beneficial, as the positioning of the knife tip replacement part can be made independent on the structure and shape of the cutting surfaces of the base part.

[0046] According to a fifth aspect there is provided a knife tip replacement part for use in the method according to the fourth aspect, said knife tip replacement part presenting:

one or more cutting teeth; and a replacement part mounting interface structured and arranged to be aligned with a base part mounting interface of a base part, wherein said replacement part mounting interface comprises:

- two or more positioning protrusions adapted to be in abutment with the pre-engineered surface of the disconnected base part when the knife tip replacement part is correctly positioned in relation to the disconnected base part; and
- two or more attachment portions being adapted to be attached by welding to associated cut surfaces of the base part.

[0047] The knife tip replacement part is thus positioned such that the replacement part mounting interface and the base part mounting interface together define a mutual transition interface between one another when the knife

tip replacement part is correctly positioned in relation to the disconnected base part. The knife tip replacement spare part is advantageous as it provides a replacement part mounting interface which is specifically adapted for being attachable to the base part. Moreover, the positioning protrusions allow for an improved positioning of the knife tip replacement part in relation to the base part, as detailed hereinabove.

[0048] According to some embodiments, the knife tip replacement part presents, at each attachment portion, a respective stress-relief opening structured and arranged to spatially distribute internal stress forces induced in the knife tip replacement part, the base part, and a weld attaching said knife tip replacement part and base part together, when in use.

[0049] According to some embodiments, each stress-relief opening is defined by an inwardly projecting opening which protrudes into the knife tip replacement part next to the respective attachment portion and which opens into the replacement part mounting interface.

[0050] The two or more attachment portions may be provided with tapered side surfaces so as to allow forming a recess between the attachment portion and the cutting surface of the base part when the knife tip replacement part has been correctly positioned in relation to the base part.

[0051] According to a sixth aspect there is provided a method for manufacturing a cutting knife according to the first aspect from a precursor one-piece element which extends in the main plane and which has an outer periphery in relation to a rotational axis of said precursor one-piece element, the method comprising: cutting through the precursor one-piece element so as to create, for each replaceable knife tip part of the cutting knife, an elongate through-opening, wherein said elongate through-opening has an elongate extension in the main plane, is spaced from said outer periphery, and is located so as to facilitate replacement of the knife tip part by reducing the cutting required to separate the knife tip part from the base part.

[0052] The precursor one-piece element may be a steel element. The precursor one-piece element may be a cutting knife of the prior art. This implies that the precursor element may have the contours of a cutting knife, such as an inner and an outer periphery. It is, however, conceivable that also other parts of the cutting knife are manufactured in the cutting machine. For example, the cutting machine may cut also the boundaries of the cutting knife defining the outer and inner peripheries. Thus, the precursor one-piece element could, for some embodiments, be a e.g. rectangular slab of material, such as e.g. a steel plate. The cutting machine will then cut both the contours of the cutting knife defining the outer and inner peripheries, and the elongate through openings.

[0053] According to some embodiments, the precursor one-piece element is a steel element, and the cutting of said elongate through-opening is achieved using a flame cutter.

[0054] Alternatively, the cutting knife may be manufactured by a molding method. Such a method may comprise:

5 providing a mold having an interior shape being defined equal to an exterior shape of the cutting knife, as defined by surfaces of the cutting knife, including surfaces of the elongate through-openings, providing heated liquid metal to the mold, and hardening/solidifying the metal within the mold by allowing the metal to cool.

[0055] As readily appreciated by the person skilled in the art, the molding method will differ from the cutting method, in that the elongate through-openings are formed together with the formation of the rest of the cutting knife. Expressed in other words, the molding method will produce the cutting knife in essentially one step.

[0056] The person skilled in the art of manufacturing cutting knives will appreciate the advantages and disadvantages with the proposed methods, and thus realize that they may both be suitable for manufacturing the cutting knife of the inventive concept, dependent on the specific embodiment.

[0057] As apparent to the person skilled in the art, the aspects disclosed hereinabove may be regarded as belonging to a single inventive concept. The cutting knife defined in the first aspect is specifically prepared for being equipped with the knife tip replacement part defined in the fifth aspect using the replacement method defined in the fourth aspect. This means that effects and features of said first, fourth and fifth aspects will be largely analogous. Furthermore, effects and features of the second and third aspects are largely analogous to those described above in connection with the first aspect. Embodiments mentioned in relation to the first aspect are largely compatible with the second aspect and third aspects. It is further noted that the inventive concepts relate to all possible combinations of features unless explicitly stated otherwise.

[0058] A further scope of applicability of the present invention will become apparent from the detailed description given below. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the scope of the invention will become apparent to those skilled in the art from this detailed description.

[0059] Hence, it is to be understood that this invention is not limited to the particular component parts of the device described or steps of the methods described as such device and method may vary. It is also to be understood that the terminology used herein is for purpose of describing particular embodiments only, and is not intended to be limiting. It must be noted that, as used in the specification and the appended claim, the articles "a", "an", "the", and "said" are intended to mean that there

are one or more of the elements unless the context clearly dictates otherwise. Thus, for example, reference to "a unit" or "the unit" may include several devices, and the like. Furthermore, the words "comprising", "including", "containing" and similar wordings does not exclude other elements or steps.

Brief descriptions of the drawings

[0060] The invention will by way of example be described in more detail with reference to the appended [schematic] drawings, which shows presently preferred embodiments of the invention.

Figure 1A is a perspective view of a comminution apparatus according to an embodiment of the present disclosure.

Figure 1B is a perspective view of a cutting module of the comminution apparatus of Fig. 1A.

Figure 2A is a front view of a cutting knife according to an example embodiment of the present disclosure.

Figure 2B is a top view of the cutting knife of Fig. 2A.

Figure 2C is a side view of the cutting knife of Fig. 2A.

Figure 2D is a cross sectional view in the main plane of the cutting knife of Fig. 2A.

Figure 2E and F are perspective views of the cutting knife of Fig. 2A.

Figure 2G is a magnification of parts of an elongate through-opening of the cutting knife, as illustrated in Fig. 2E.

Figure 3A is a front view of a knife tip replacement part according to an example embodiment of the present disclosure.

Figure 3B is a top view of the knife tip replacement part of Fig. 3A.

Figure 3C is a side view of the knife tip replacement part of Fig. 3A.

Figure 3D is a cross sectional view in the main plane of the knife tip replacement part of Fig. 3A.

Figure 3E is a perspective views of the knife tip replacement part of Fig. 3A.

Figure 4A is a front view of the cutting knife of Fig. 2A, here further illustrating markings.

Figure 4B is a perspective view of the cutting knife of Fig. 4A during a separation of a worn-out replaceable knife tip part from the base part using a flame cutter.

Figure 4C is a perspective view of the base part of the cutting knife of Fig. 4A after removal of the separated replaceable knife tip part.

Figure 4D is a perspective view of a cutting knife comprising the base part from the cutting knife of Fig. 4A, and attached knife tip replacement parts of Figs 3A-E.

Figure 5A is a perspective view of a precursor one-piece element.

Figure 5B is a perspective view of the precursor one-piece element of Fig 5A during a cutting of an elon-

gate through-opening by a flame cutter.

Figure 5C is a perspective view of the precursor one-piece element of Fig 5A after both elongate through-openings has been cut by the flame cutter.

Figure 6 is a perspective view of a cutting knife according to an alternative example embodiment of the present disclosure.

Figure 7 is a perspective view of a knife tip replacement part according to an alternative example embodiment of the present disclosure. The knife tip replacement part of Fig. 7 is suitable for use on the base part of the cutting knife of Fig. 6, once its original knife tip parts has been removed.

Figure 8 is a side view of a cutting knife according to an alternative example embodiment of the present disclosure.

Figure 9 is a side view of a cutting knife according to an alternative example embodiment of the present disclosure.

Figure 10 is a side view of a cutting knife according to an alternative example embodiment of the present disclosure.

Figure 11 is a side view of a cutting knife according to an alternative example embodiment of the present disclosure.

Detailed description

[0061] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which currently preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness, and fully convey the scope of the invention to the skilled person.

[0062] Figure 1A illustrate a comminution apparatus 10 of a kind suitable for being equipped with cutting knives according to the inventive concept. The comminution apparatus 10 has to its purpose to comminute waste material (not shown), such as domestic or industrial waste material, bulk objects or the like, by a cutting/shredding operation. The shredding capacity may differ substantially and as an example it may lie in the range of 5 to 200 tons of waste material per hour.

[0063] The illustrated apparatus 10 is intended for stationary use and is mounted on a stationary chassis 12. Other embodiments may be mobile where the chassis 12 may be replaced with some other supporting structure. The apparatus 10 comprises a cutting module 14 which is positioned on and supported by the chassis 12, a drive module 16 which is positioned on and supported by the chassis 12 next to the cutting module 14, and a top module 18 which is arranged on top of the cutting module 14. The top module 18 may optionally extend horizontally over the drive module 16 as in the illustrated embodiment. The cutting module 14 is detachably connected to the

chassis 12.

[0064] The apparatus 10 may also comprise a feed hopper 20 mounted on the top module 18. In simpler embodiments, the hopper 20 may be integrally formed with the top module 18 but it is advantageously designed as a separate, detachably connected unit which may be customized for each user and adapted to the waste type, etc.

[0065] Figure 1B illustrates the cutting module 14 in isolated view. The cutting module 14 comprises two rotational cutting shafts 24 which are arranged to cut waste material input into the hopper 20. Each rotational cutting shaft 24 comprises an axle 25 extending along a rotational axis S of the rotatable cutting shaft 24, and a plurality of cutting knives 100, said cutting knives 100 being attached to the axle 25 and being mutually spaced along the rotational axis S of the cutting shaft 24. The cutting knives 100 will be further described below, and it should be noted that they are only schematically represented in Figs 1A and B (e.g. the elongate through-openings are not shown). As the cutting shaft 24 rotates in relation to the stationary part of the cutting module 14, the waste material will be compressed towards stationary cutting surfaces 26. The stationary cutting surfaces 26 are mutually distributed along each side of each rotational axis 24 such that each of the plurality of cutting knives may rotate freely in gaps formed between each stationary cutting surface 26. As readily appreciated by the person skilled in the art, a rotation of the cutting knives in relation to the stationary cutting surfaces 26 in such a fashion will achieve the function of cutting the waste material by shear forces applied to the waste material. Cut waste material may then leave the cutting module 14 at a bottom thereof.

[0066] The cutting knife 100 will now be described in detail with reference to Figs 2A-G. The cutting knife 100 is a one-piece element, which implies that the cutting knife does not have parts which are releasably attached to each other. However, the cutting knife 100 may consist of different parts which are attached to each other in a non-releasable way, such as e.g. by welding. The cutting knife 100 extends in a main plane 102 (see Fig. 2B) which is transverse to a rotational axis R of the cutting knife. The rotational axis R is orthogonal to the main plane 102. The cutting knife 100 will thus rotate in the main plane 102. When attaching the cutting knife 100 to the axle 25 of the rotational cutting shaft 24, the rotational axis R of the cutting knife 100 will be parallel, and coaxial with, the rotational axis S of the cutting shaft 24. The cutting knife 100 further has an outer periphery 104 in relation to the rotational axis R (marked as thick black line in Fig. 2A). The example embodiment, the cutting knife 100, has a radius of 445 mm and a thickness of 80 mm. The thickness may differ between embodiments. Typically, the thickness is in the range 45 - 80 mm. However, the inventive concept should not be construed to any such limitation. Both larger cutting knives, and smaller cutting knives are conceivable within the scope of the claims.

[0067] As illustrated in Figs 2A-G, the one-piece element comprises a base part 110 and two replaceable knife tip parts 120, 120' being disposed on opposite sides of the base part 110. The base part 110 is configured to be attached to an axle 25 of the rotatable cutting shaft 24. For this purpose, the base part 110 comprises an attachment portion 112, at which the cutting knife 100 is attachable to the axle 25. It is to be understood that such attachment can be made in many different ways, for example by welding or by a fastening means such as e.g. screws or bolts. The attachment portion 112 extends over an inner periphery 103 of the cutting knife 100. The inner periphery 103 connects to the outer periphery 104 so as to, together, constitute the entire periphery of the cutting knife 100 in the extension in the main plane 102. The replaceable knife tip parts 120, 120' are suitable for cutting material disposed in the comminution apparatus 10. For this purpose, each replaceable knife tip part 120, 120' comprises a respective pair of cutting teeth 101a, 101b, 101a', 101b'. The cutting teeth 101a, 101b, 101a', 101b' are shaped so as to form tips having a tip angle typically between 30 and 40 degrees. The cutting teeth 101a, 101b, 101a', 101b' serve the purpose of penetrating the material to be comminuted.

[0068] As illustrated in Figs 2A-G, the cutting knife 100 has two elongate through-openings 140, 140' which have elongate extensions 141, 141' (marked by dashed thick lines in Fig. 2A) in the main plane 102, and are spaced from the outer periphery 104 of the cutting knife 100. The elongate through-openings 140, 140' mark, and define, a transition interface between the base part and each replaceable knife tip part 120, 120'. Thus, each knife tip part 120, 120' is partly separated from the base part 110 by a respective associated elongate through-opening 140, 140'. Importantly, each knife tip part 120, 120' is integrally formed with the base part 110 at connection regions 130a, 130b at the outer periphery 104. As will be further described later, the elongate through openings 140, 140' are located so as to facilitate replacement of the knife tip part 120 by reducing the cutting required to separate the knife tip part from the base part 110.

[0069] As previously mentioned, the cutting knife 100 is a one-piece element, and the base part 110 and the knife tip parts 120, 120' are integrally formed together at the connection regions 130a, 130b. Thus, the only way to separate a knife tip part 120, 120' from the base part is to actively break the chemical bonds of the material (for the example embodiment, this is achieved by cutting). Thus, the base part 110 and knife tip parts 120, 120' are un-releasably attached to each other.

[0070] The cutting knife 100 is made from metal, preferably steel. One example of a suitable steel type is Hardox 500 having a hardness of 450-540 HBW and a typical yield strength of 1400 MPa. As illustrated in Fig. 2A, the elongate extension 121, 121' defines, at the first connection region 130a, 130a', a first minimum distance 132a between a first end 142a, 142a' of the elongate extension 141, 141' and the outer periphery 104. Similarly, the elongate extension 121, 121' defines, at the second connection region 130b, 130b', a second minimum distance 132b between a second end 142b, 142b' of the elongate extension 141, 141' and the outer periphery 104.

gate extension 121,121' defines, at the second connection region 130b,130b', a second minimum distance 132b,132b' between a second end 142b,142b' of the elongate extension 141,141' and the outer periphery 104. As readily understood by the person skilled in the art, the relationship between the first 132a,132a' and second 132b,132b' minimum distances, on one hand, and the length of the elongate extension 141,141' on the other hand, will influence the structural integrity of the cutting knife 100. If the elongate extension 141,141' exceeds a critical length, the replaceable knife tip part 120,120' may risk breaking loose from the base part 110 during use. At the same time, the purpose of the elongate through opening 140,140' is to reduce the cutting needed for separating the replacement knife tip part 120,120' from the base part 110, and thus, from that perspective, the elongate extension 141,141' should be as long as possible without jeopardizing structural integrity. The elongate extension 141,141' may be at least longer than the sum of said first 132a,132a' and second 132b,132b' minimum distances. In the embodiment of Fig 2A-G, the elongate extension 141,141' is 1.75 times longer than the sum of said first 132a,132a' and second 132b,132b' minimum distances.

[0071] As illustrated in Fig. 2A, the elongate through-opening 140,140' has a relatively long elongate extension 141,141'. Specifically, the elongate extension 141,141' is located such that the one or more replaceable knife tip parts 120,120' extend so as to constitute at least 90% of the outer periphery 104 of the cutting knife 100. This may be advantageous as it allows removing relatively large parts of the cutting surface of the cutting knife.

[0072] As evident from Figs 2A-G, the cutting knife 100 is symmetrical. This means that the replaceable knife tip part 120 with its associated elongate through-opening 140 is a mirrored equivalent of the replaceable knife tip part 120' with its associated the elongate through-opening 140'. Thus the features described with reference to one of the knife tip parts/through-openings will apply equally well to the other. Therefore, in what follows, the description will be made with reference to the replaceable knife tip part 120 with its associated elongate through-opening 140 only.

[0073] The relative position of the elongate through-openings may also be expressed in terms on an angle. Describing the elongate through-opening 140, only, and with reference to Fig. 2, the elongate extension 141 is arranged in the main plane 102 such that a first line L1, which connects the rotational axis R with the first end 142a of the elongate through-opening 140, and a second line L2, which connects the rotational axis R with the second end 142b of the elongate through-opening 140, forms an angle K of 50 degrees between each other.

[0074] As can be seen in Figs 2A-G, the elongate extension 141 of the elongate through-opening 140 is non-linear in the main plane 102. Specifically, the elongate extension 141 of the elongate through-opening 140 has three linear portions 141a-c aligned after each other and

wherein neighboring linear portions are connected to each other by non-linear portions 141d-f.

[0075] Moreover, the elongate through-opening 140 is partly defined by a slit 143 which forms a slit gap 144 between the base part 110 and the associated knife tip part 120. The slit gap 144 has a gap width W1 (kerf) which may be typically 0.5 - 10 mm. For the example embodiment, the gap width W1 is ~3 mm as a result from it being formed by flame cutting.

[0076] The elongate through-opening 140 is further defined by stress-relief openings 145a,145b defined at associated ends 144a,144b of the elongate extension 142. Each stress-relief opening 144a,144b form an associated stress-relief opening gap 146a,146b between the base part 110 and the associated knife tip part 120. The stress-relief opening gaps 146a,1496 has gap widths W2a,W2b being larger than a gap width W1 of a center portion 147 (in the example, the center portion is the slit 143) of the elongate through-opening 140. The stress-relief openings 145a,145b are structured and arranged to spatially distribute internal forces induced in the cutting knife 100 when in use. As discussed earlier, the structural integrity of the cutting knife 100 is of importance. When providing a relatively narrow elongate through-opening 140, such as e.g. a slit 143, zones of peak stress will be located at each end of the slit. By allowing the elongate through opening 140 to be wider at each end 142a, 142b of the elongate extension 141, the stresses will be spatially distributed in the material, resulting in lowered peak stresses. The stress-relief openings 145a,145b have rounded, preferably circular, cross sections 148a,148b as defined in said main plane 102. The stress-relief openings 145a,145b may be 30-80 mm in diameter. For the example embodiment, the stress-relief openings 145a,145b are ~45 mm in diameter, which is slightly above one order of magnitude larger than the slit gap of ~3 mm.

[0077] Figure 2G is a magnification of the dotted area of Fig. 2E, illustrating the second end 142b of the elongate through-opening 140. Fig. 2G illustrates more clearly the inner surfaces 149 of the elongate through opening 140 and how the stress-relief opening 145b are located in relation to the slit 143. As can be seen, the slit defines inner surface portions 149a and 149b. The inner surface portion 149a forms a part of the replaceable knife tip part 120, whereas the surface portion 149b forms a part of the base part 110. the slit 143 mouths into the stress-relief opening 145b substantially tangentially to the near-circular cross section of the opening 145b.

[0078] As mentioned earlier, the purpose of providing the elongate through-opening 140 is to reduce the cutting required to separate the replaceable knife tip part 120 from the base part 110. As said separation is performed in order to replace worn-out parts (i.e. the knife tip parts 120), there will be required substitute parts to be attached in their place. Forming a part of the same inventive concept, a knife tip replacement part 1000 will now be described with reference to Figs 3A-E. The knife tip replace-

ment part 1000 extends in a main plane 1020 (see Fig. 3C). The knife tip replacement part 1000 presents one or more cutting teeth 1010a, 1010b, and a replacement part mounting interface 1052 structured and arranged to be aligned with a base part mounting interface 152 of a base part 110. The extension of the replacement part mounting interface 1052 is indicated in Fig. 3A by a dashed line. The extension of the base part mounting interface 152 is best illustrated in Fig. 4C, which will be described later). The replacement part mounting interface 1052 comprises three positioning protrusions 1060a, 1060b, 1060c adapted to be in abutment with a pre-engineered surface 156 of the disconnected base part 110 when the knife tip replacement part 1000 is correctly positioned in relation to the disconnected base part 110. As readily realized by the person skilled in the art, the pre-engineered surface 156 is for this embodiment the same as the surface portion 149a previously discussed with reference to Fig. 2G.

[0079] The replacement part mounting interface 1052 further comprises two or more attachment portions 1070a, 1070b being adapted to be attached by welding to associated cut surfaces 154a, 154b of the base part 110 (see Fig. 4D).

[0080] Thus, the replacement part mounting interface 1052 is geometrically shaped to fit, at least adequately, to the base part mounting interface 152 of a base part 110. The one or more positioning protrusions 1060a, 1060b, 1060c will, when being in abutment with the base part 110, distance the pre-engineered surface 156 of the knife tip replacement part 1000 with mounting interface surfaces 1053a, 1053b of the knife tip replacement part 1000. The advantageous protrusions will thus act as a distance means to provide a clearance between each of the two attachment portions 1070a, 1070b and associated cut surfaces 154a, 154b of the base part 110. This provides to increase the tolerance for which a manual cutting procedure may be regarded as successful. It also provides a means of allowing a critical volume to be shaped at each cutting surface to accommodate a weld 190a, 190b (see Fig. 4D).

[0081] The latter aspect is further improved by the shape of the attachment portions 1070a, 1070b. As illustrated in Figs 3A-E, the attachment portions 1070a, 1070b presents tapered side faces 1071 which connects to main attachment surfaces 1072. When the knife tip replacement part 1000 is correctly positioned in relation to the base part 110, the tapered side surfaces 1071 will, together with parts of the cut surfaces 154a, 154b of the base part 110, form a recess for accommodating the weld 190a, 190b. This will provide a stronger weld, and hence a stronger attachment between the knife tip replacement part 1000 and the base portion 110.

[0082] The knife tip replacement part 1000 presents, at each attachment portion 1070a, 1070b, a respective stress-relief opening 1080a, 1080b structured and arranged to spatially distribute internal stress forces induced in the knife tip replacement part 1000, the base

part 110, and the weld 190a, 190b attaching said knife tip replacement part 1000 and base part 110 together, when in use. Thus, the purpose for the stress relief openings 1070a, 1070b of the knife tip replacement part 1000 is similar to the purpose of the stress-relief openings 145a, 145b of the cutting knife 100. As illustrated in Figs 3A-E, each stress-relief opening 1080a, 1080b is defined by an inwardly projecting opening which protrudes into the knife tip replacement part 1000 next to the respective attachment portion 1070a, 1070b and which opens into the replacement part mounting interface 1052.

[0083] A method for replacing a knife tip part 120 of a cutting knife will now be disclosed with reference to Figs 4A-D. The method will be described using the cutting knife 100, but the method is equally applicable for other embodiments of the cutting knife (these will be described later). Starting off with a cutting knife 100, as illustrated in Fig. 4A, the method comprises separating a knife tip part 120 of the cutting knife from the base part 110 of the cutting knife by cutting said one-piece element at the connection regions 130a, 130b where said knife tip part 120 is integrally formed with the base part 110. In the example of Fig. 4A, the cutting is not performed along the minimum distances 132a, 132b illustrated in Fig. 2A. Instead, the cutting is performed along markings 134a, 134b which are located at the respective connection region 130a, 130b but slightly offset to the position of the associated minimum distance 132a, 132b. The markings 134a, 134b serve as visual indications and provide one or more guides for intended cutting lines for the cutting process. The cutting process results in the formation of two through-cuts 150a, 150b, as illustrated in Fig. 4B, where through-cut 150a is completed and through-cut 150b is just partly completed.

[0084] The method further comprises removing the separated knife tip part 120 so as to reveal, on the base part 120, a base part mounting interface 152. This is illustrated in Fig. 4C. The base part mounting interface 152 presents two cut surfaces 154a, 154b which corresponds to the two through-cuts 150a, 150b, and one pre-engineered surface 156 which forms part of (what was previously) the elongate through-opening 140 (or more specifically: the inner surface portion 149a of the elongate through-opening 140).

[0085] The method further comprises positioning a knife tip replacement part 1000, which has a replacement part mounting interface 1052, in the same place as the previously removed knife tip part 120 such that the replacement part mounting interface 1052 is aligned with the base part mounting interface 152. This is illustrated in Fig. 4D.

[0086] The method further comprises attaching the knife tip replacement part 1000 to the base part 110 by welding together the knife tip replacement part 120 with the base part 110 along at least parts of said base part mounting interface 152 and said replacement part mounting interface 1052. Specifically, as can be seen in Fig. 4D, the knife tip replacement part 1000 is welded to the

base part 110 only at, or along boundaries of, said two cut surfaces 154a,154b of the base part, so as to form one or more new elongate through-openings 160a,160b between the welded-together knife tip replacement part 1000 and base part 110. The replacement part mounting interface 1052 is structured and arranged to fit to the base part mounting interface 152 such that the replacement part mounting interface 1052 and the base part mounting interface 152 together define a mutual transition interface between the base part 110 and the knife tip replacement part 120. This is an alternative way of expressing that the two parts 110,120 fit well together geometrically, an aspect that has been mentioned earlier.

[0087] The knife tip replacement part 1000 further presents, at the replacement part mounting interface 1052, two or more positioning protrusions 1060a,1060b,1060c adapted to be brought into abutment with surfaces of the base part 110 along the base part mounting interface 152 when positioning the knife tip replacement part 1000. The positioning protrusions 1060a,1060b,1060c are arranged such that they will be in abutment with the pre-engineered surface 156 of the base part 110.

[0088] A method for manufacturing a cutting knife will now be described with reference to Figs 5A-C. The previously described cutting knife 100 will be used as an example in the description. As realized by the person skilled in the art, the method is equally applicable for any other cutting knife falling within the scope of the claims.

[0089] Figure 5A illustrates a precursor one-piece element 100P which extends in the main plane 102 and which has an outer periphery 104P in relation to a rotational axis P of the precursor one-piece element 100P. The precursor one-piece element 100P lacks the elongate through-openings of the inventive cutting knife, and could therefore be e.g. a cutting knife of the prior art. The method comprises cutting through the precursor one-piece element 100P so as to create, for each replaceable knife tip part 120,120' of the cutting knife, an elongate through-opening 140,140'. This is illustrated in Fig 5B. The cutting is typically carried out using a cutting machine. The cutting is in the example carried out using a flame cutter 80. However, it is also conceivable to use other cutting means, such as e.g. a laser cutter, or a milling machine, such as a CNC router, where material is removed by advancing a rotary cutter into the material. As will be readily understood by now, the elongate through-opening 140 has an elongate extension 141 in the main plane 102, is spaced from said outer periphery 104P, and is located so as to facilitate replacement of the knife tip part 120,120' by reducing the cutting required to separate the knife tip part 120,120' from the base part 110. Once two elongate through-openings 140,140' has been cut, the characteristic features of the cutting knife 100 has been obtained, as illustrated in Fig 5C.

[0090] The precursor one-piece element 100P is typically a steel element. It is conceivable that also parts of the precursor one-piece element 100P is manufactured

in the cutting machine. For example, the cutting machine may cut also the boundaries of the cutting knife defining the outer 104 and inner 103 peripheries. Thus, the precursor one-piece element 100P could, alternatively, have a shape different from the shape of a cutting knife. Such a shape could be for example a rectangular shape. The cutting machine will then cut both the contours of the cutting knife defining the outer and inner peripheries, and the elongate through openings 140,140'.

[0091] It is also conceivable to manufacture the cutting knife of the inventive concept by molding or casting techniques. This way, cutting may not be required at all. Instead, each cutting knife is molded into its final shape fully featured with one or more through-openings.

[0092] An alternative embodiment of a cutting knife and associated cutting tip replacement part will now be described with reference to Figs 6 and 7. Figure 6 illustrates the cutting knife 200. The cutting knife 200 has all features in common with the cutting knife 100, except for the geometry of the two elongate through-openings 240,240'. As can be seen in Fig. 6, the elongate through-opening 240 has an inner surface 249 which includes surface portions 249a,249b extending along the elongate extension 241, wherein said surface portions 249a,249b are three-dimensionally shaped as defined in the main plane 102 and along a direction of the rotational axis R. Specifically, the elongate through-opening 240, at each position along the elongate extension 241 of the opening, extends through the cutting knife 200 along a specific direction A which forms an angle B with the rotational axis R, wherein said angle B varies as function of position along the elongate extension 241.

[0093] Figure 7 illustrates the associated knife tip replacement part 2000. The knife tip replacement part 2000 have all features in common with the previously described knife tip replacement part 1000, except for the replacement part mounting interface (not shown), which is defined, in part, by mounting interface surface 2053. The mounting interface surface 2053 is shaped so as to align with the three-dimensional surface portions 249a,249b extending along the elongate extension 241 of the cutting knife 2000. As readily realized by the person skilled in the art, an advantage with the three-dimensional surface is to improve positioning of the knife tip replacement part 2000 with respect to the base part 210 of the cutting knife 200 during replacement of the knife tips. Also, the knife tip replacement part 2000 differs from the knife tip replacement part 1000 in that the knife tip replacement part 2000 only has two positioning protrusions 2060a,2060b.

[0094] Figure 8 to 11 illustrates some alternative embodiments of the cutting knife according to the inventive concept. As each of these alternative embodiments share most features with the cutting knife 100, already described in detail, the further example embodiments will only be described in brief.

[0095] Figure 8 illustrates the cutting knife 300, which differs from the cutting knife 100 in that each elongate

through-opening 340,340' connects with a further elongate through-opening 340A,340A' at a center portion thereof. The purpose of the further elongate through-opening 340A,340A' is to replace cutting teeth individually. By providing suitable knife tip replacement parts, the four teeth may be individually replaced, by cutting along the illustrated dashed lines in Fig. 8.

[0096] Figure 9 illustrates the cutting knife 400, which differs from the cutting knife 300 in that it comprises four elongate through-openings 440a,440b,440a',440b'. As for the cutting knife 400, the four teeth may be individually replaced with suitable knife tip replacement parts, as illustrated using the dashed lines in Fig. 9.

[0097] Figure 10 illustrates the cutting knife 500, which differs from the cutting knife 100 in that each elongate through-opening 540,540' has an essentially constant gap width along the elongate extension. Specifically, the elongate through-openings 540,540' has a gap width being similar to the gap width W2a,W2b of the stress-relief openings 145a,145b of the cutting knife 100. As understood by the person skilled in the art, the stress-relieving functionality will thus be achieved in spite of stress-relieving openings not being defined per se.

[0098] Figure 11 illustrates the cutting knife 600, which differs from the cutting knife 400 in that each elongate through-opening 640a,640b,640a',640b' are further defined by one or more stress-relief openings 645a,645b,645c, 645a',645b',645c', which are defining narrow slits extending out from the elongate through-opening at an acute angle.

[0099] The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims. Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

Claims

1. A cutting knife (100) for a cutting shaft (24) in a comminution apparatus (10), said cutting knife (100) being a one-piece element which extends in a main plane (102) transversely to a rotational axis (R) of the cutting knife and which has an outer periphery (104) in relation to the rotational axis (R), said one-piece element comprising a base part (110) and one or more replaceable knife tip parts (120,120'), wherein said base part (110) is configured to be attached to an axle (52) of said rotatable cutting shaft (24), and wherein each of said one or more replaceable knife tip parts (120,120') is suitable for cutting material disposed in the comminution apparatus (10), and

wherein each knife tip part is integrally formed with the base part at connection regions (130a,130b) at the outer periphery (104) and is partly separated from the base part by an associated elongate through-opening (140,140'), said elongate through-opening:

having an elongate extension (141,141') in the main plane (102), being spaced from said outer periphery (104), and being located so as to facilitate replacement of the knife tip part (120) by reducing the cutting required to separate the knife tip part from the base part (110).

2. The cutting knife (100) according to claim 1, wherein the cutting knife has uniform material properties.

3. The cutting knife (100) according to claim 1 or 2, wherein the cutting knife is made from metal.

4. The cutting knife (100) according to any one of claim 1 to 3, wherein the elongate extension (141,141') of the elongate through-opening (140,140') is non-linear in said main plane (102).

5. The cutting knife (100) according to any one of claim 1 to 4, wherein said elongate extension (121) defines:

- at a first connection region (130a): a first minimum distance (132a) between a first end (142a) of the elongate extension (141) and the outer periphery (104), and,
- at a second connection region (130b): a second minimum distance (132b) between a second end (142b) of the elongate extension (141) and the outer periphery (104), and

wherein the elongate extension (141) is longer than the sum of said first (132a) and second (132b) minimum distances.

6. The cutting knife (100) according to any one of claim 1 to 5, wherein said elongate extension (141) is located such that the one or more replaceable knife tip parts (120,120') extend so as to constitute at least 70% of the outer periphery (104) of the cutting knife.

7. The cutting knife (100) according to any one of claim 1 to 6, wherein said elongate through-opening (140) is at least partly defined by a slit (143) which forms a slit gap (144) between the base part (110) and the associated knife tip part (120)

8. The cutting knife (100) according to claim 7, wherein the slit gap (144) has a gap width (W1) of 0.5 - 10 mm.

9. The cutting knife (100) according to any one of claim 1 to 8, wherein said elongate through-opening (140) is further defined by one or more stress-relief openings (145a,145b), wherein each opening of said one or more stress-relief openings (145a,145b) is defined at an associated end (142a,142b) of said elongate extension (141) so as to form a stress-relief opening gap (146a,146b) between the base part (110) and the associated knife tip part (120), wherein the stress-relief opening gap (146a,146b) has a gap width (W2a,W2b) being larger than a gap width (W1) of a center portion (147) of the elongate through-opening (140), said one or more stress-relief openings (145a,145b) being structured and arranged to spatially distribute internal forces induced in the cutting knife when in use.
10. The cutting knife (100) according to claim 9, wherein the one or more stress-relief openings (145a,145b) have rounded, preferably circular, cross sections (148a,148b) as defined in said main plane (102).
11. The cutting knife (100) according to any one of claim 1 to 10, wherein said one or more replaceable knife tip parts comprises two replaceable knife tip parts (120,120') being disposed on opposite sides of the base part (110).
12. The cutting knife (100) according to any one of claim 1 to 11, wherein said connection regions (130a,130b) being provided with one or more markings (134a,134b), such as visual indications, providing one or more guides for intended cutting lines for said cutting required to separate said one or more knife tip parts (120,120') from the base part (110).
13. The cutting knife (200) according to any one of claim 1 to 12, wherein the elongate through-opening (240) has an inner surface (249) which includes surface portions (249a,249b) extending along the elongate extension (241), wherein said surface portions (249a,249b) are three-dimensionally shaped, as defined in the main plane (102) and along a direction of the rotational axis (R).
14. The cutting knife (200) according to claim 13, wherein the elongate through-opening (240), at each position along the elongate extension (241) of the opening, extends through the cutting knife along a specific direction (A) which forms an angle (B) with the rotational axis (R), wherein said angle (B) varies as function of position along the elongate extension (241).
15. A rotatable cutting shaft (24) for a comminution apparatus (10), comprising:
an axle (25) extending along a rotational axis (S) of the rotatable cutting shaft (24), and a plurality of cutting knives (100) according to any one of claim 1 to 14, said cutting knives being attached to the axle (25) and being mutually spaced along the rotational axis of the cutting shaft (24).
16. A comminution apparatus (10) comprising one or more rotatable cutting shafts (24) according to claim 15.
17. A method for replacing a knife tip part (120) of a cutting knife (100) according to any one of claim 1 to 14, said method comprising:
separating a knife tip part (120) of the cutting knife from the base part (110) of the cutting knife by cutting said one-piece element at said connection regions (130a,130b) where said knife tip part is integrally formed with the base part, said cutting forming two through-cuts (150a,150b), removing the separated knife tip part (120) so as to reveal, on the base part (120), a base part mounting interface (152), said base part mounting interface presenting two cut surfaces (154a,154b) corresponding to said two through-cuts (152a,152b), and one pre-engineered surface (156) forming part of the elongate through-opening (140);
positioning a knife tip replacement part (1000), which has a replacement part mounting interface (1052), in the same place as the previously removed knife tip part (120) such that the replacement part mounting interface (1052) is aligned with the base part mounting interface (152); and
attaching the knife tip replacement part (1000) to the base part (110) by welding together the knife tip replacement part with the base part along at least parts of said base part mounting interface (152) and said replacement part mounting interface (1052).
18. The method according to claim 17, wherein said attaching the knife tip replacement part (1000) to the base part (110) is performed by welding together the knife tip replacement part (1000) and the base part (110) only at, or along boundaries of, said two cut surfaces (154a,154b) of the base part, so as to form one or more new elongate through-openings (160a,160b) between the welded-together knife tip replacement part (1000) and base part (110).
19. The method according to claim 17 or 18, wherein the replacement part mounting interface (1052) is structured and arranged to fit to the base part mounting interface (152) such that the replacement part mounting interface (1052) and the base part mounting interface (152) together define a mutual transition interface between the base part and the knife tip replacement part.

20. The method according to any one of claim 17 to 19, wherein the knife tip replacement part (1000), at the replacement part mounting interface (1052), presents two or more positioning protrusions (1060a, 1060b, 1060c) adapted to be brought into abutment with surfaces of the base part (110) along the base part mounting interface (152) when positioning the knife tip replacement part (1000). 5
21. The method according to claim 20, wherein said positioning protrusions (1060a, 1060b, 1060c) are arranged such that they will be in abutment with the pre-engineered surface (156) of the base part (110). 10
22. A knife tip replacement part (1000) for use in the method according to any one of claim 17 to 21, said knife tip replacement part presenting: 15
- one or more cutting teeth (1010a, 1010b); and a replacement part mounting interface (1052) structured and arranged to be aligned with a base part mounting interface (152) of a base part (110), 20
- wherein said replacement part mounting interface (1052) comprises: 25
- two or more positioning protrusions (1060a, 1060b, 1060c) adapted to be in abutment with the pre-engineered surface (156) of the disconnected base part (110) when the knife tip replacement part (1000) is correctly positioned in relation to the disconnected base part (110); and 30
 - two or more attachment portions (1070a, 1070b) being adapted to be attached by welding to associated cut surfaces (154a, 154b) of the base part (110). 35
23. The knife tip replacement part according to claim 22, wherein the knife tip replacement part (1000) presents, at each attachment portion (1070a, 1070b), a respective stress-relief opening (1080a, 1080b) structured and arranged to spatially distribute internal stress forces induced in the knife tip replacement part (1000), the base part (110), and a weld (190a, 190b) attaching said knife tip replacement part and base part together, when in use. 40 45
24. The knife tip replacement part according to claim 23, wherein each stress-relief opening (1080a, 1080b) is defined by an inwardly projecting opening which protrudes into the knife tip replacement part (1000) next to the respective attachment portion (1070a, 1070b) and which opens into the replacement part mounting interface (1052). 50 55
25. A method for manufacturing a cutting knife (100) according to any one of claim 1 to 14 from a precursor one-piece element (100P) which extends in the main plane (102) and which has an outer periphery (104P) in relation to a rotational axis (P) of said precursor one-piece element (100P), the method comprising: cutting through the precursor one-piece element (100P) so as to create, for each replaceable knife tip part (120, 120') of the cutting knife, an elongate through-opening (140, 140'), wherein said elongate through-opening has an elongate extension (141, 141') in the main plane (102), is spaced from said outer periphery (104P), and is located so as to facilitate replacement of the knife tip part (120, 120') by reducing the cutting required to separate the knife tip part (120, 120') from the base part (110).
26. The method according to claim 25, wherein the precursor one-piece element (100P) is a steel element, and the cutting of said elongate through-opening (140, 140') is achieved using a flame cutter (80).

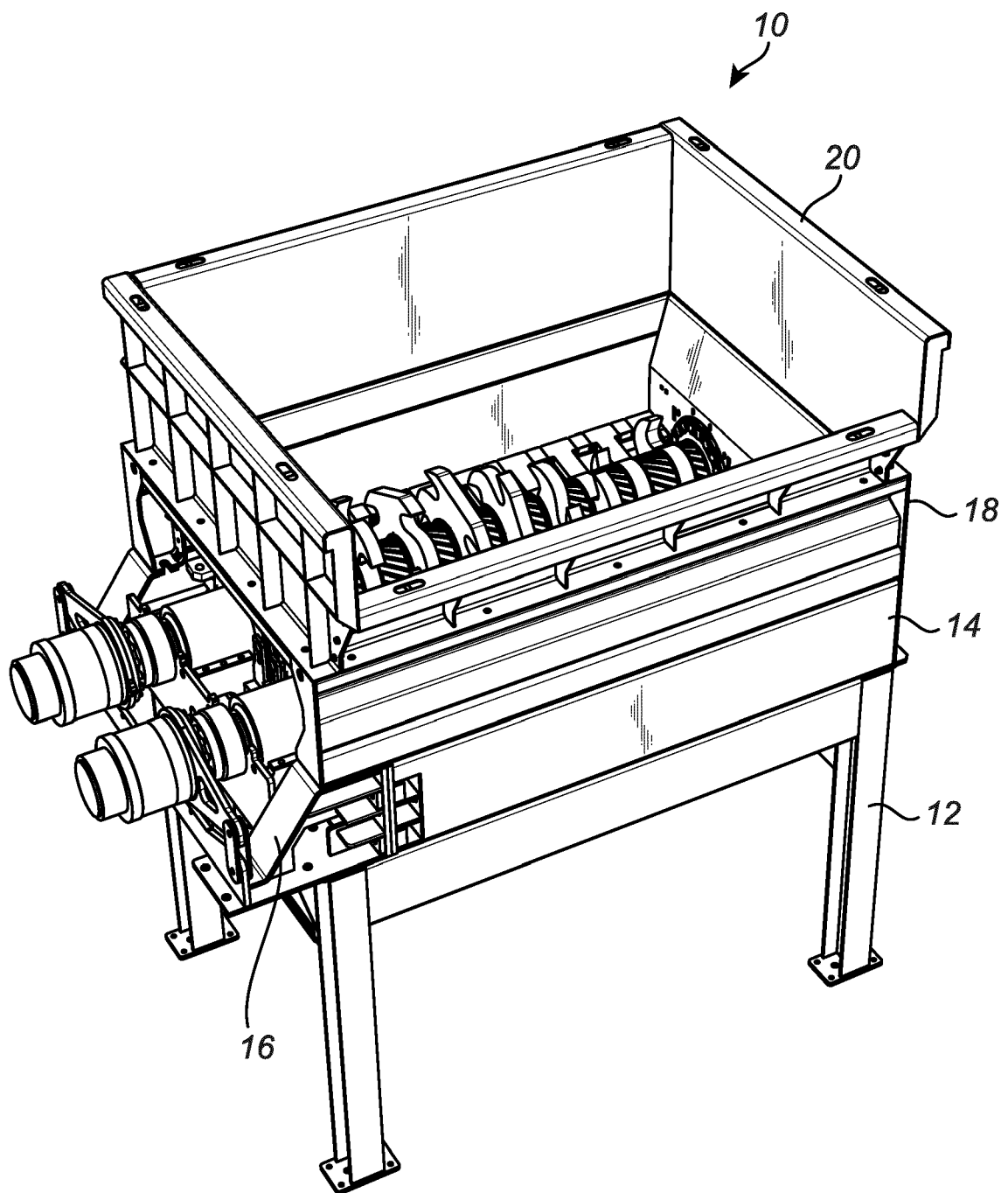


Fig. 1A

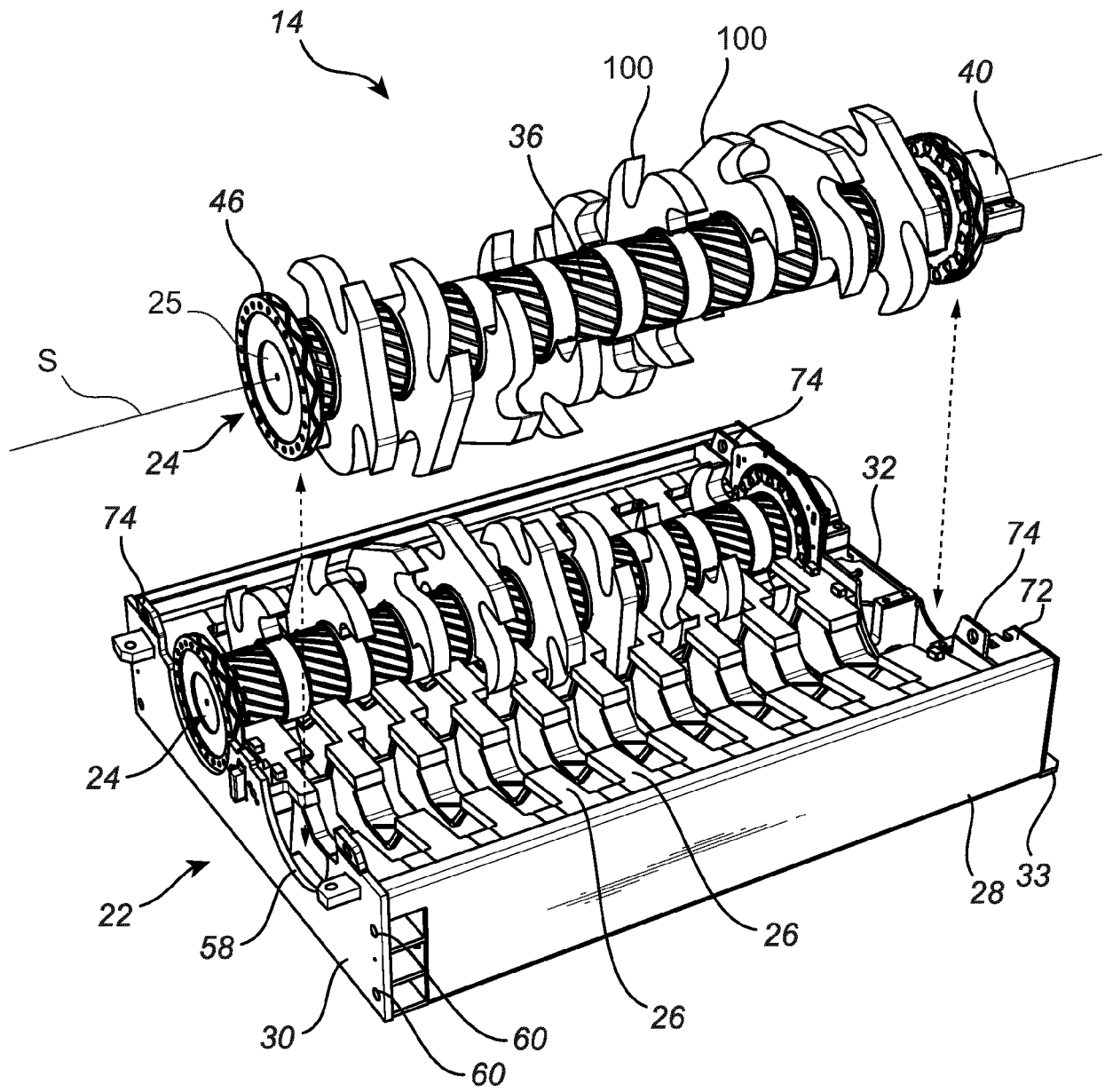
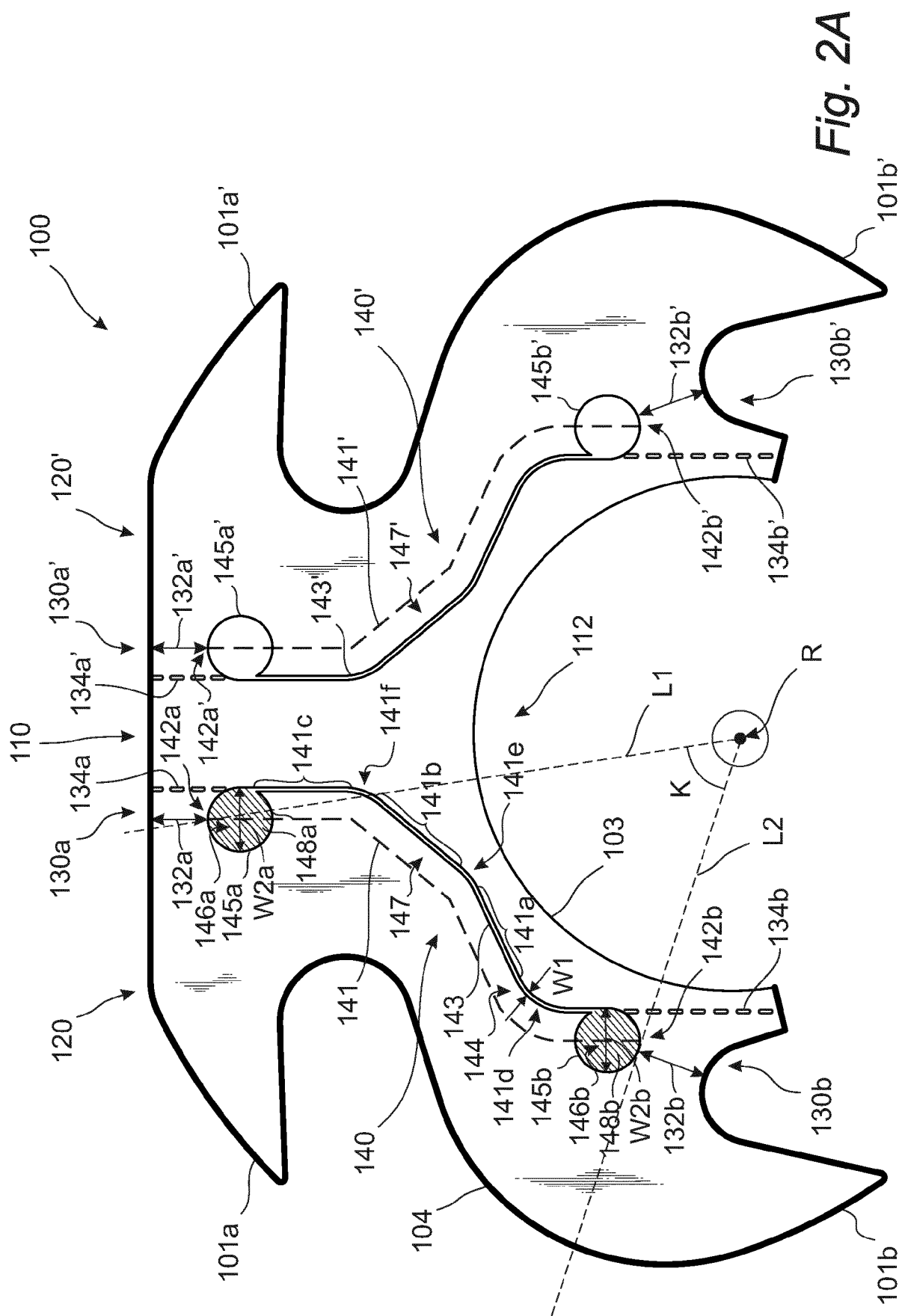
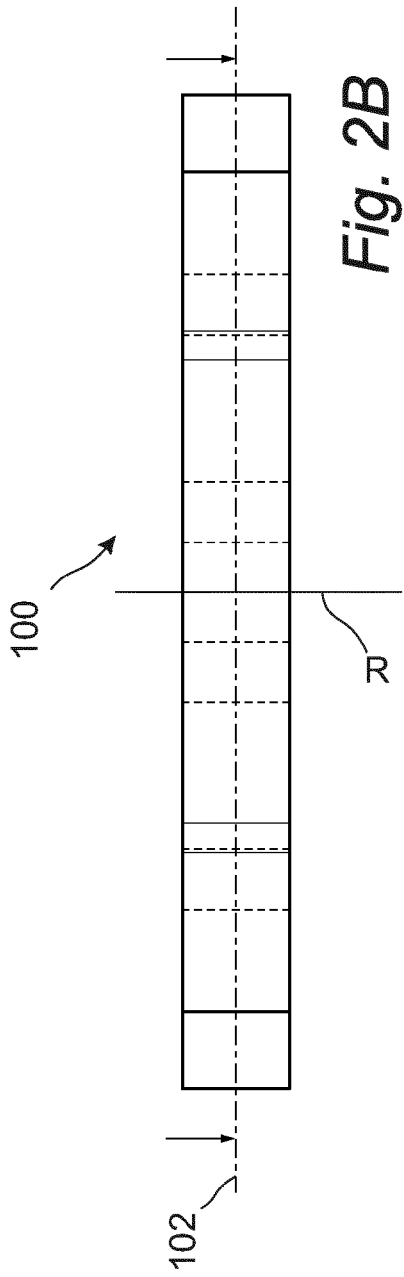


Fig. 1B





100

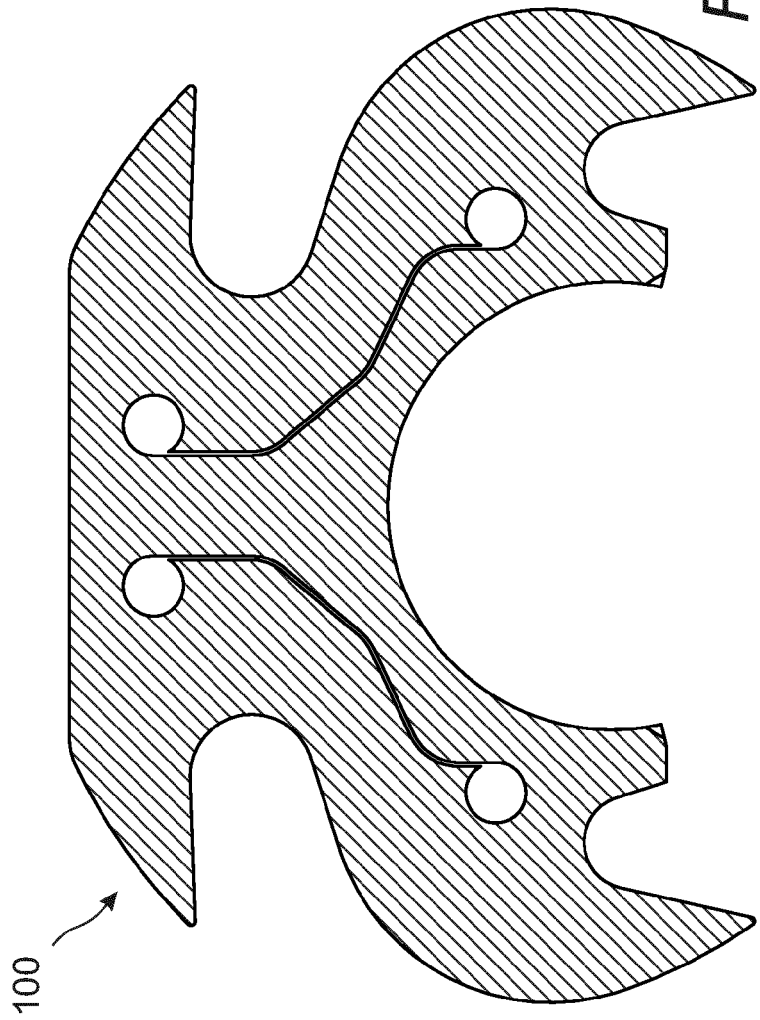


Fig. 2C



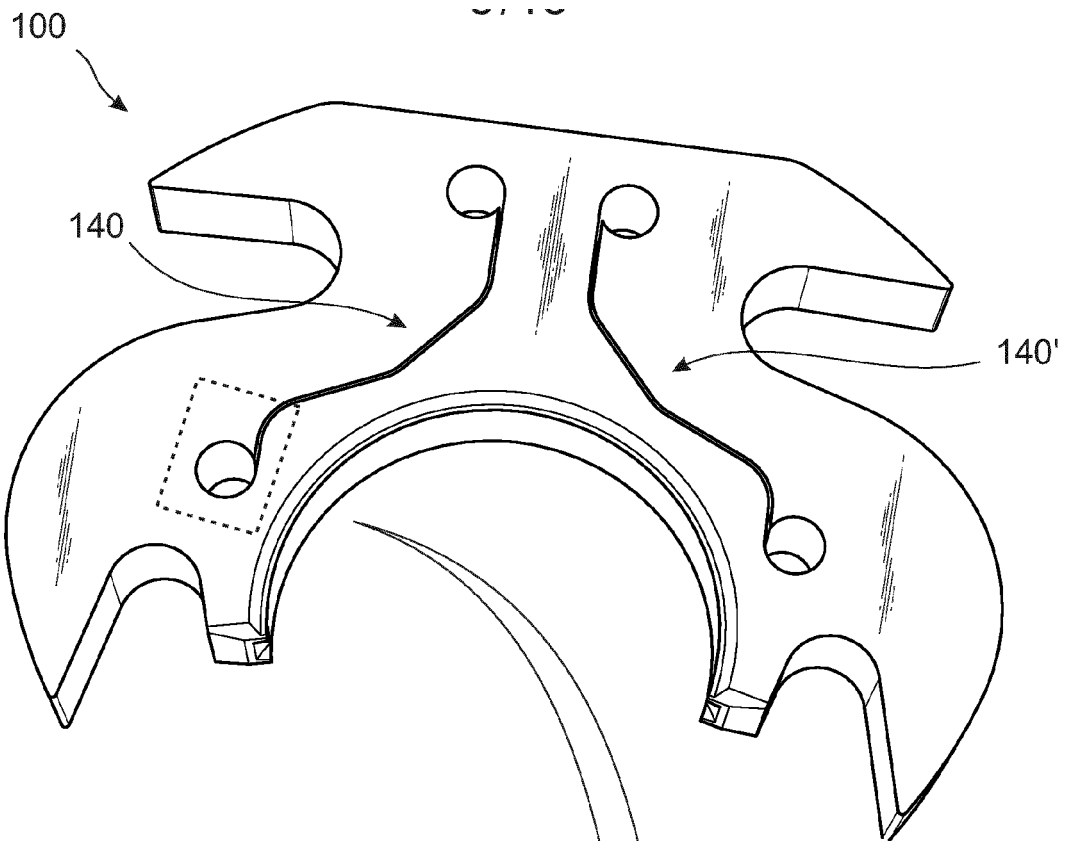


Fig. 2E

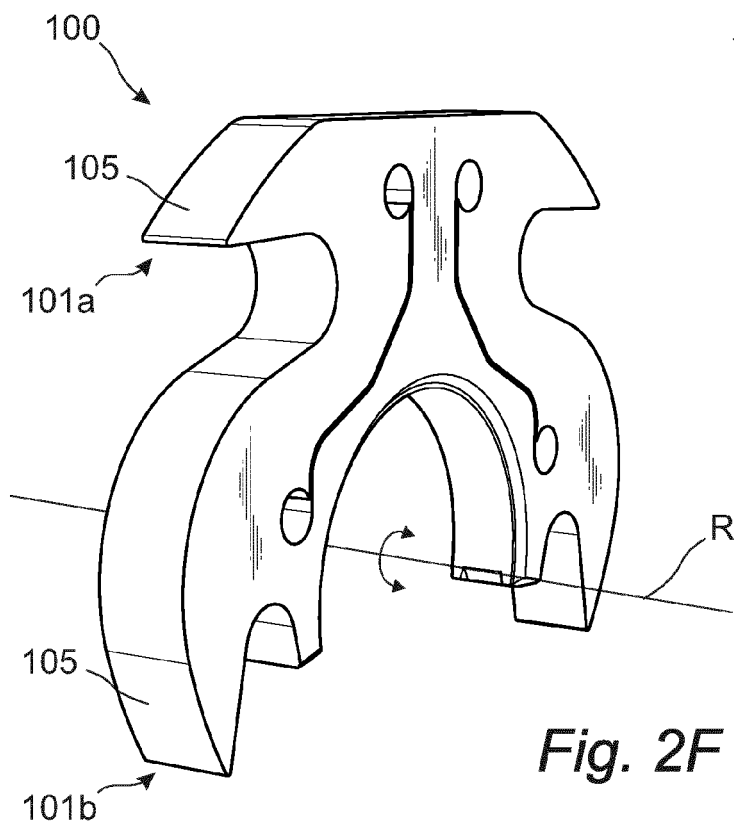


Fig. 2F

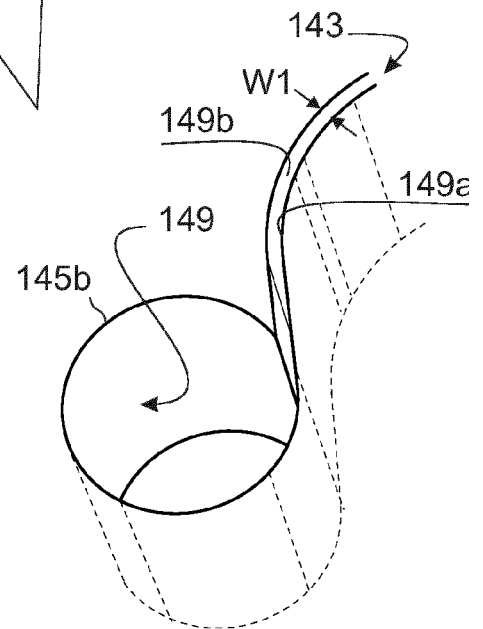


Fig. 2G

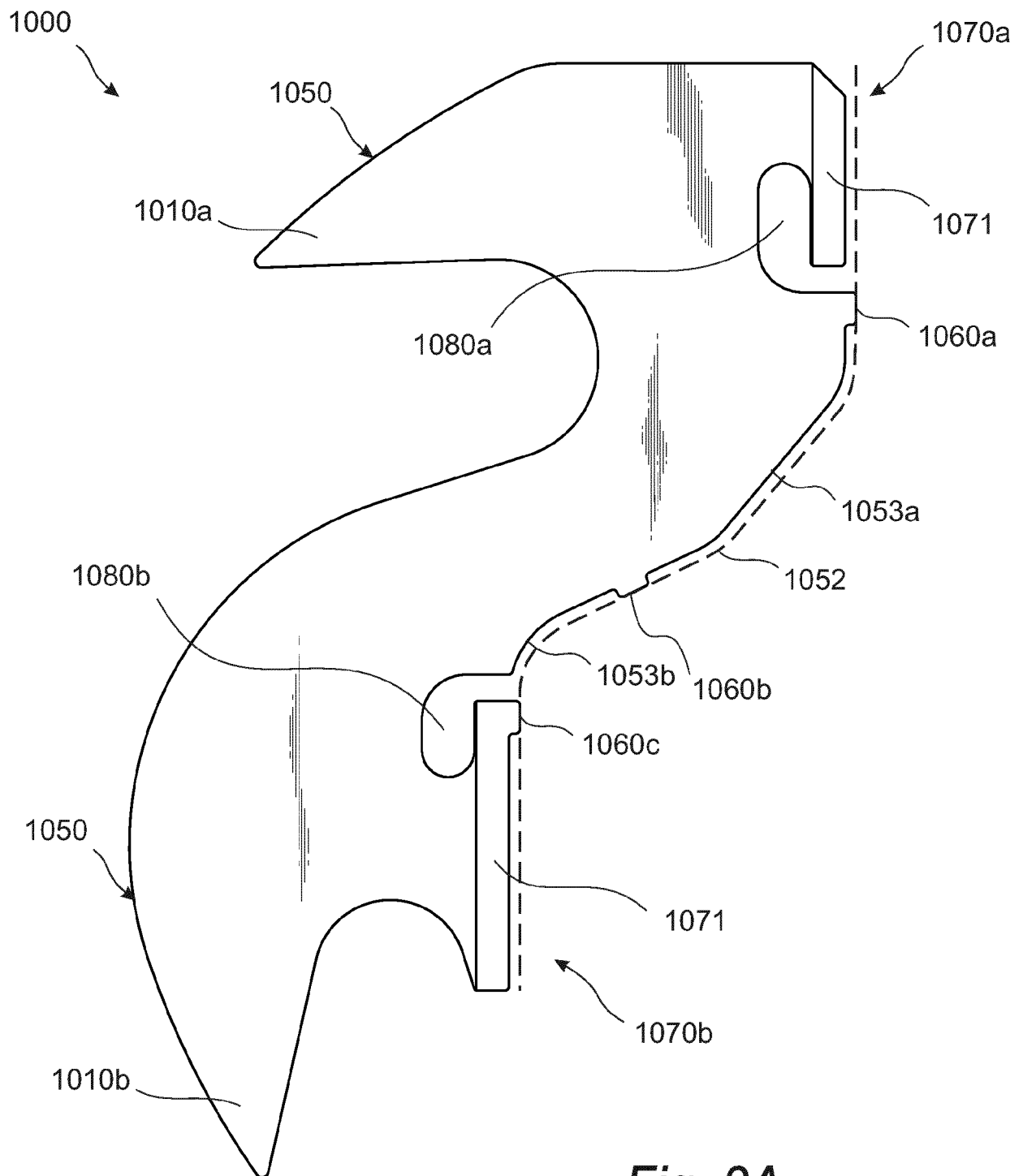


Fig. 3A

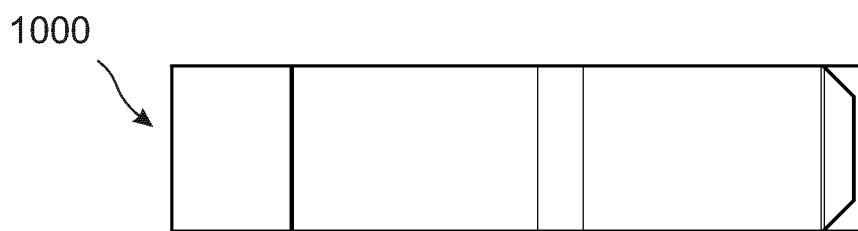


Fig. 3B

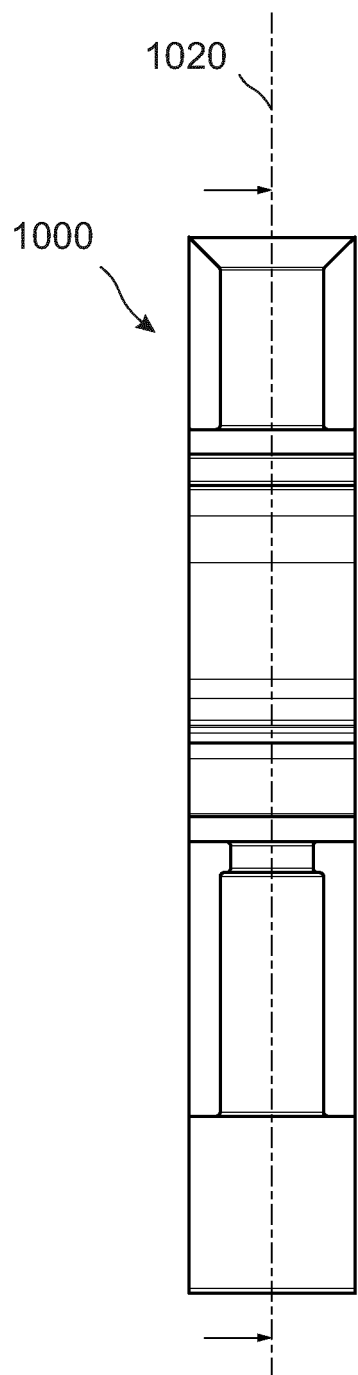


Fig. 3C

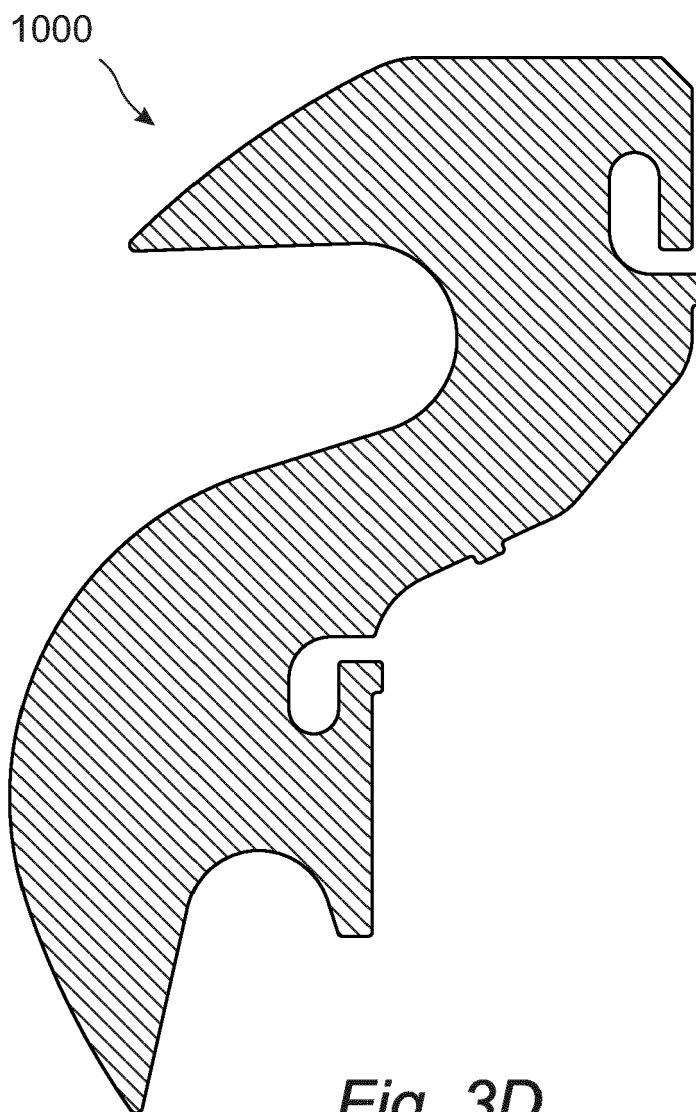


Fig. 3D

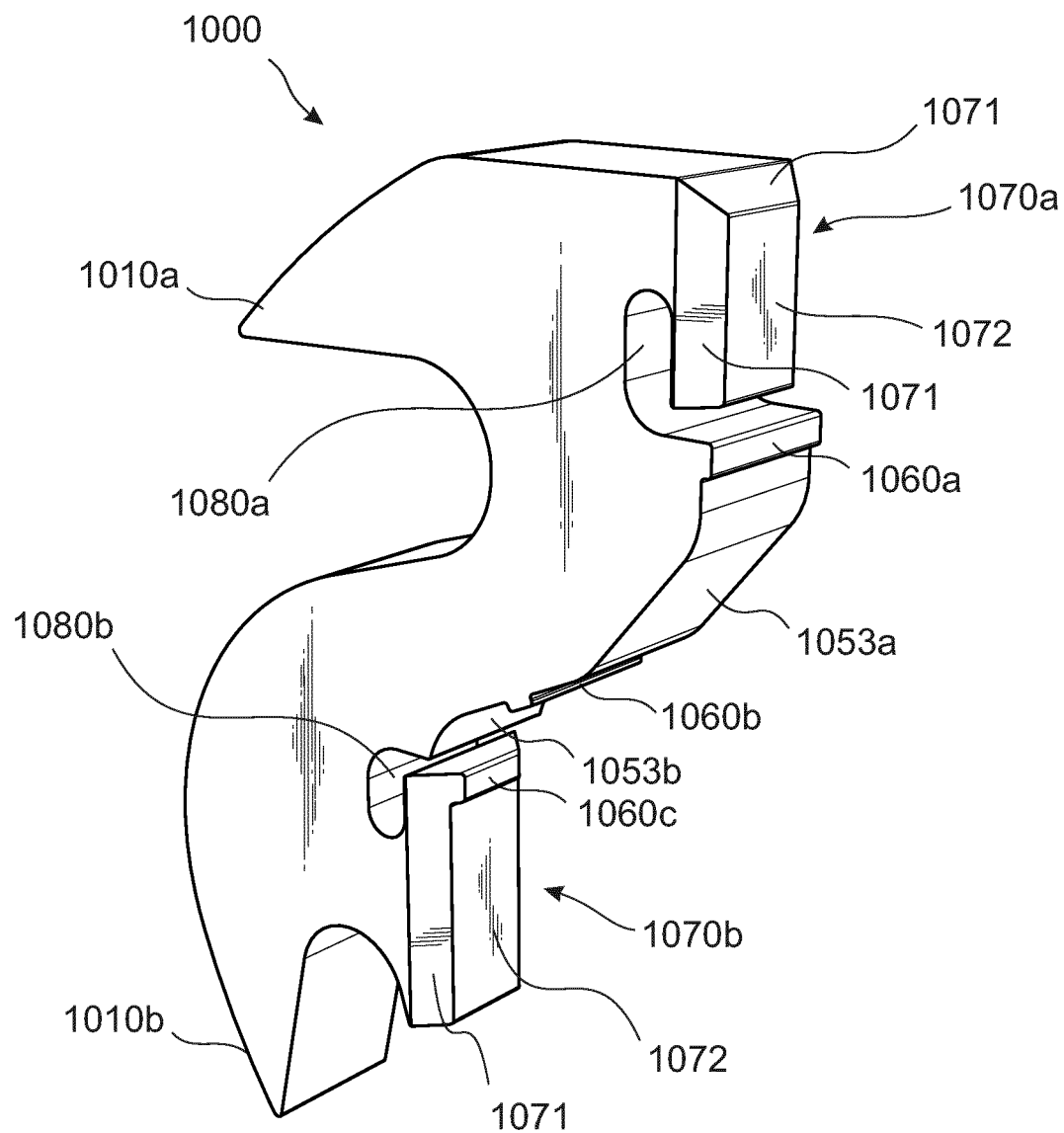


Fig. 3E

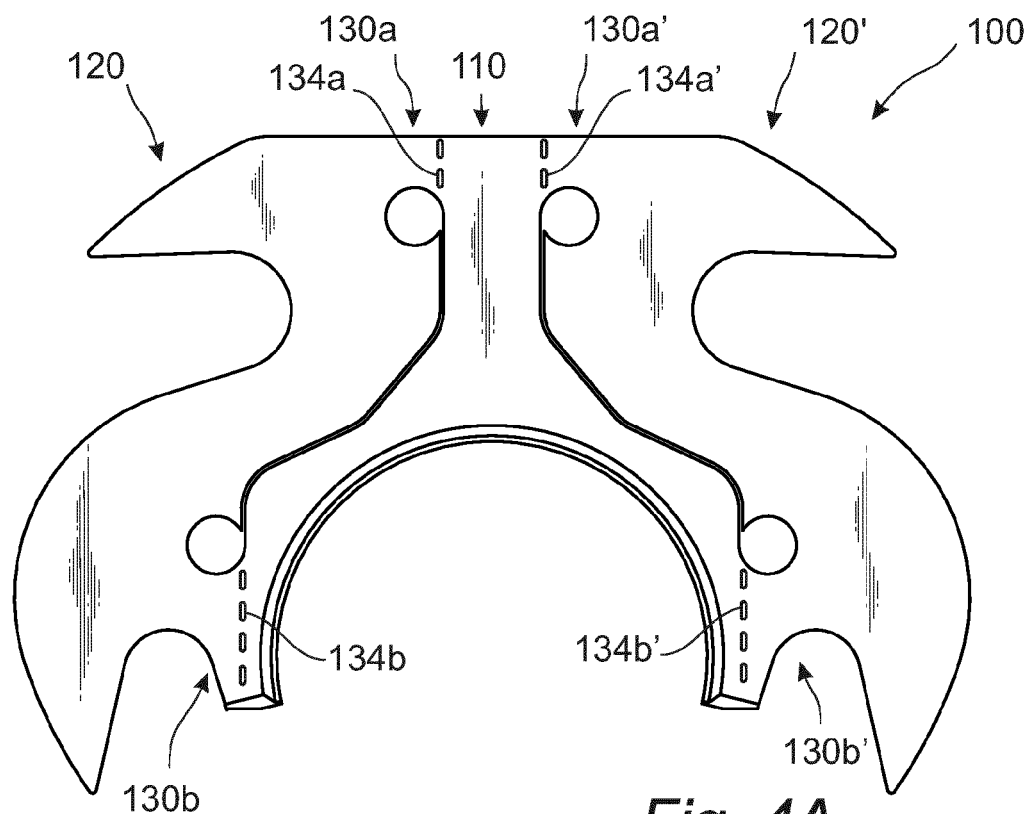


Fig. 4A

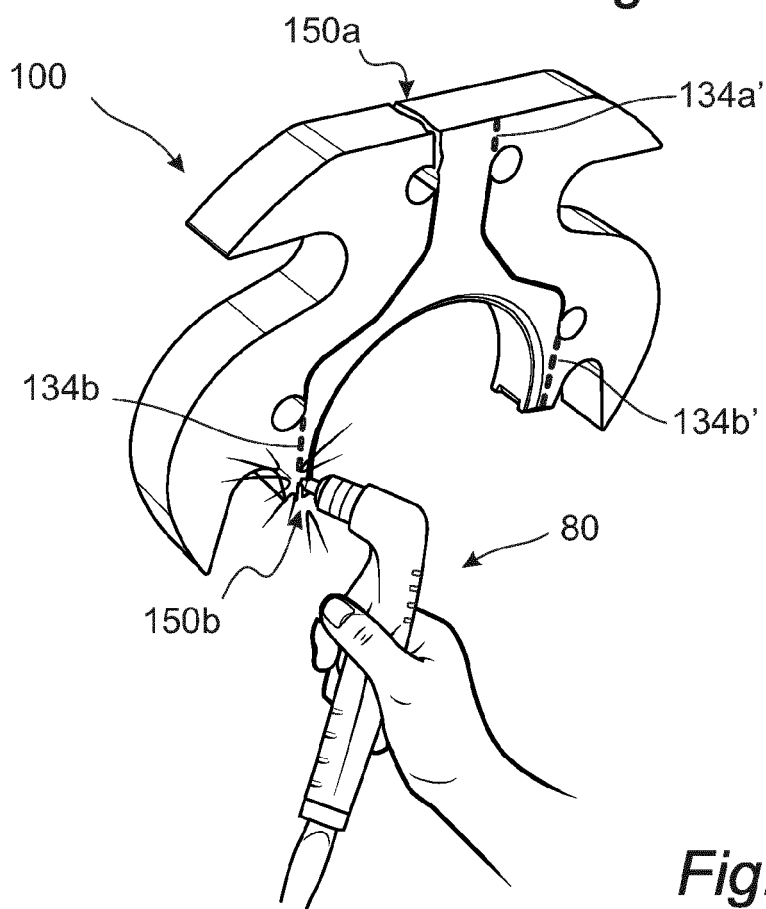
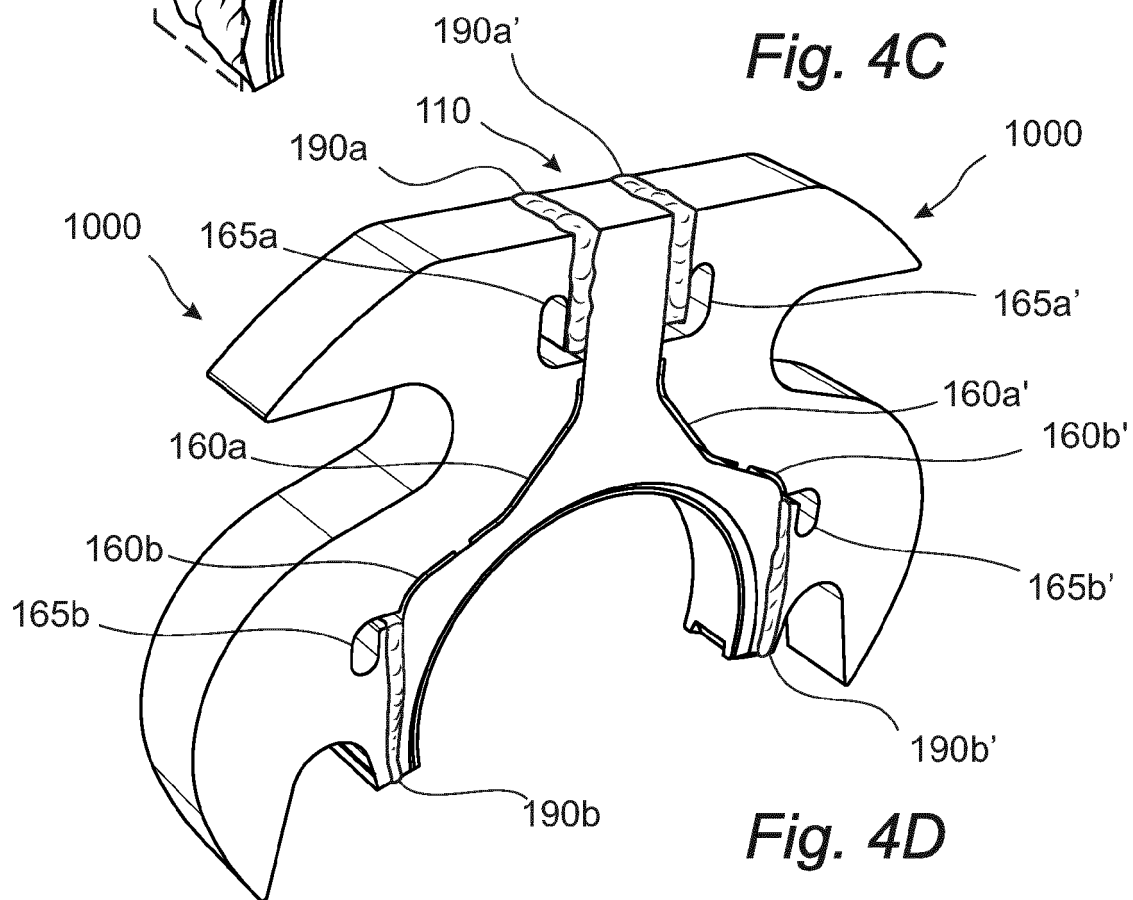
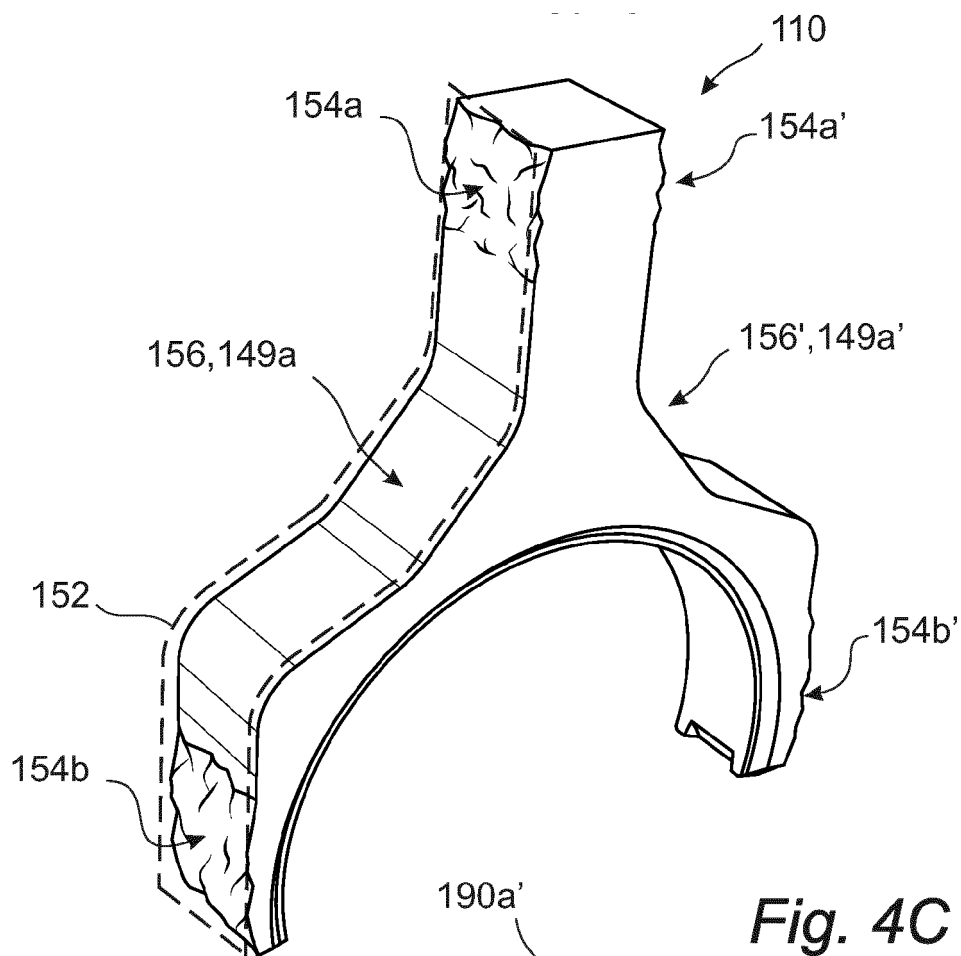


Fig. 4B



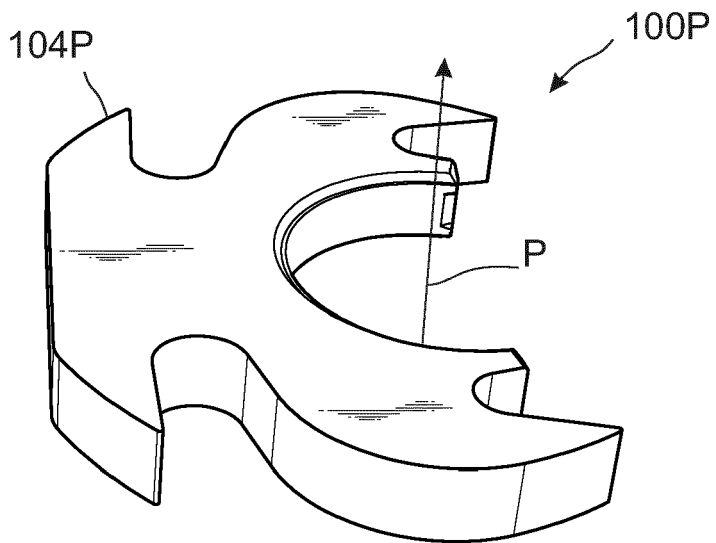


Fig. 5A

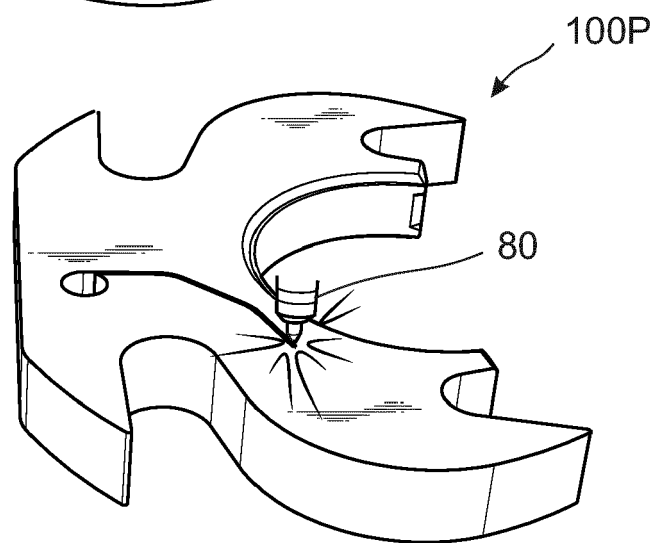


Fig. 5B

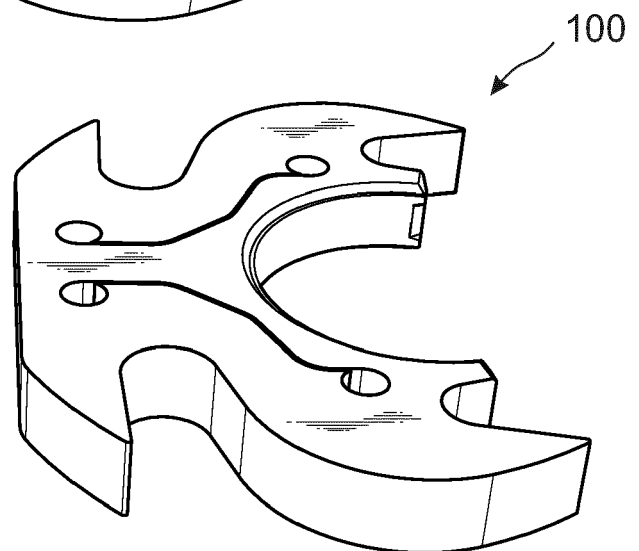
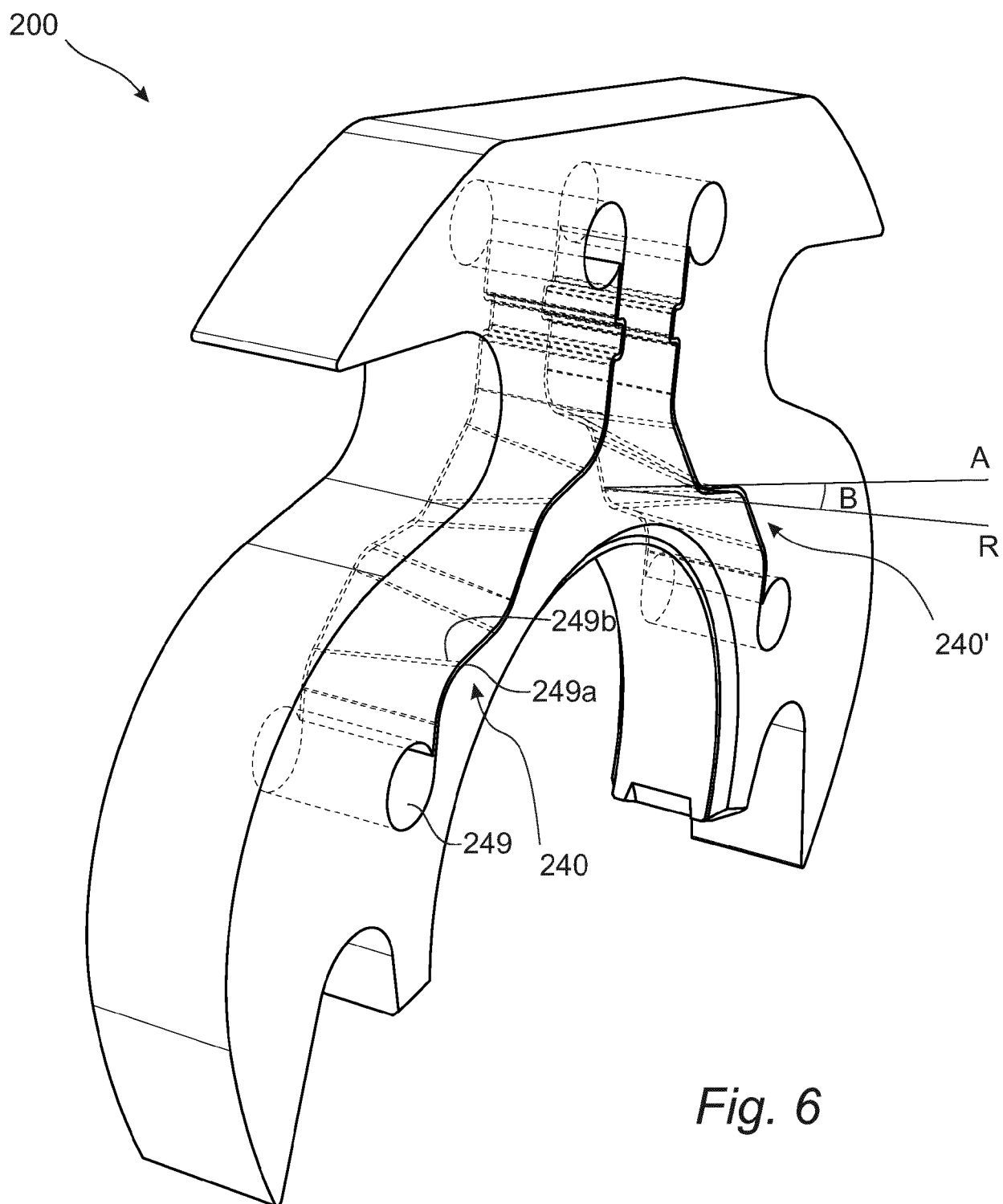


Fig. 5C



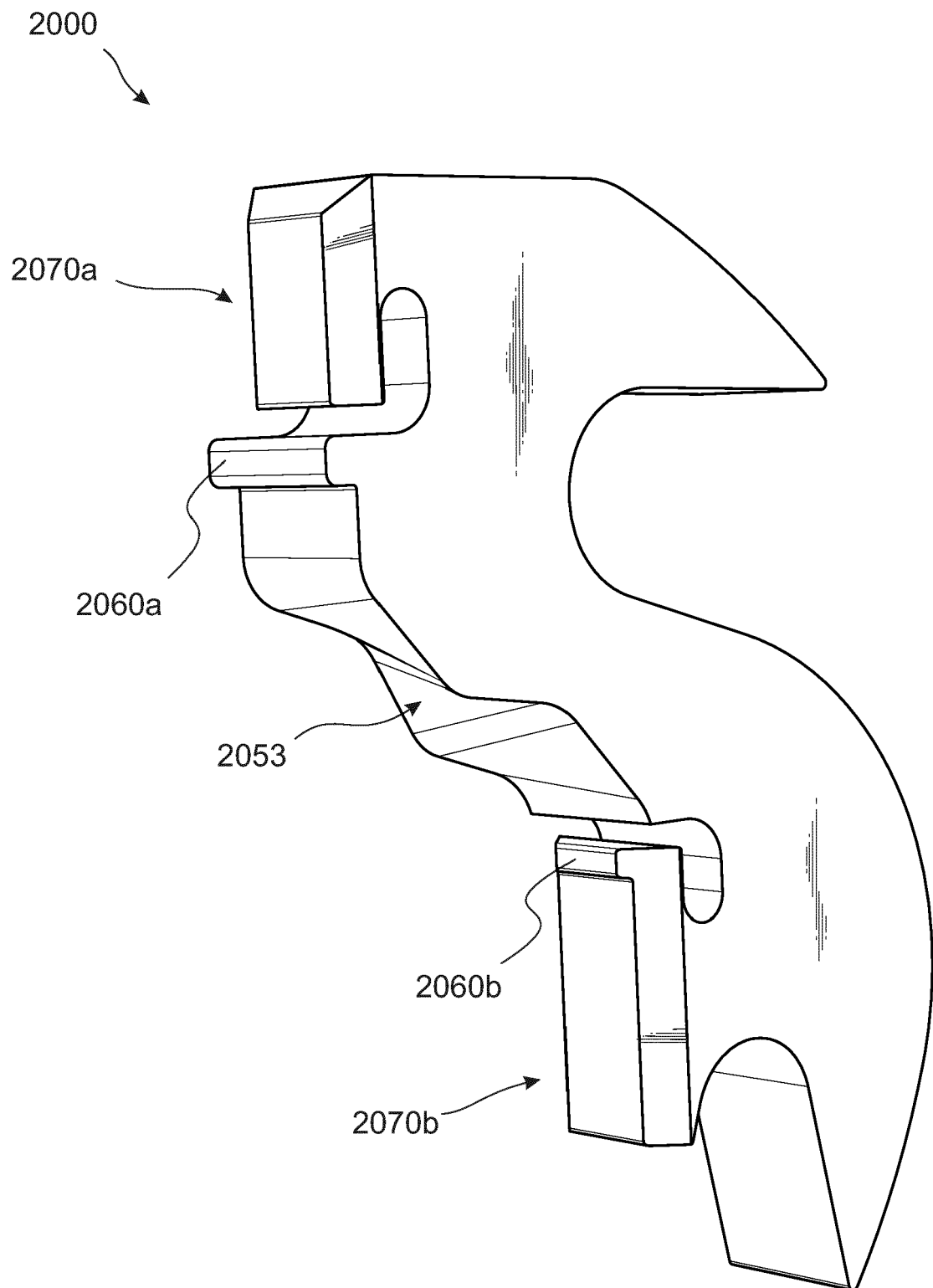


Fig. 7

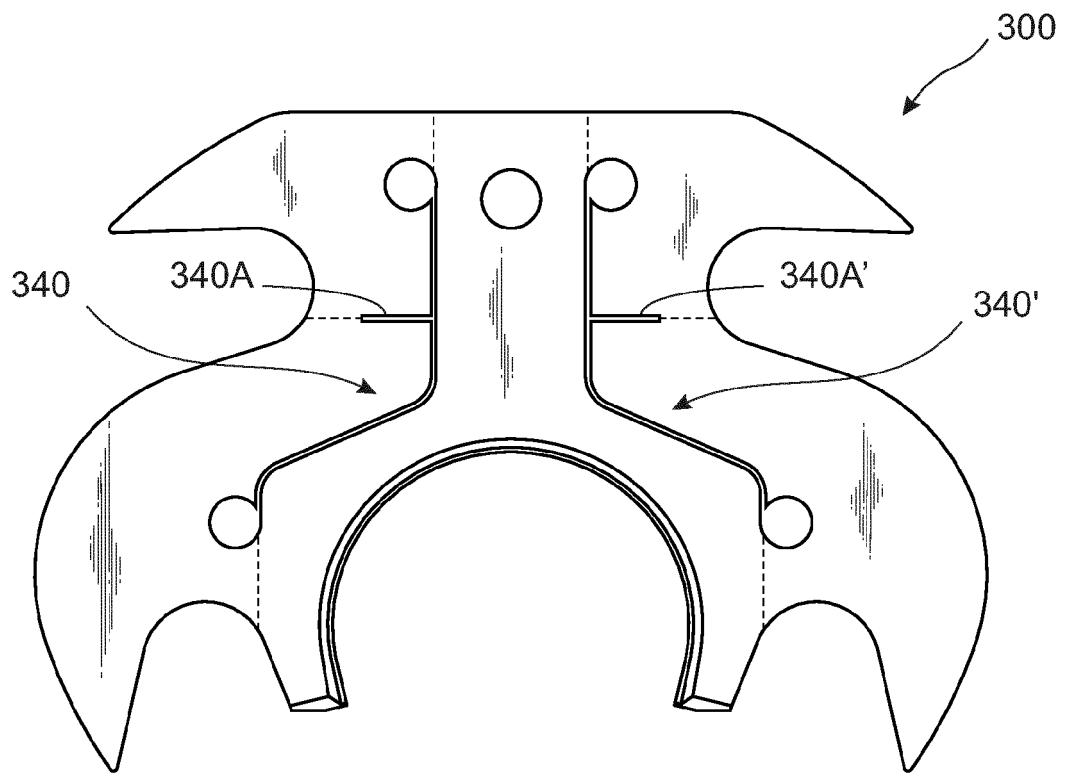


Fig. 8

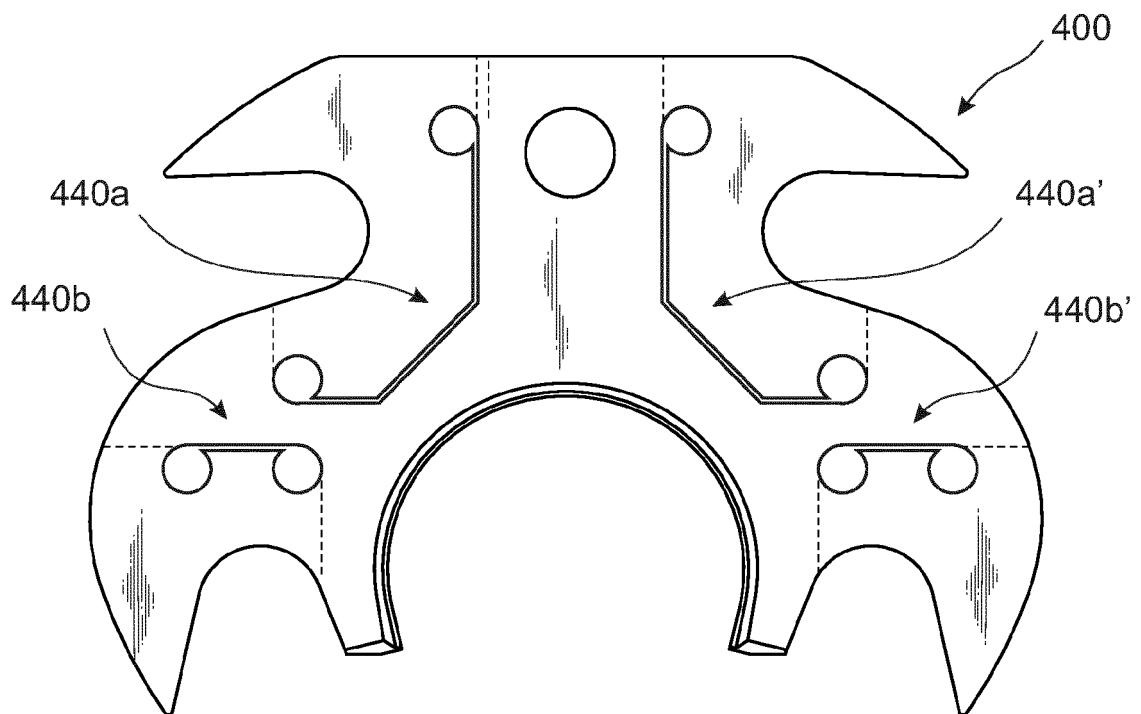


Fig. 9

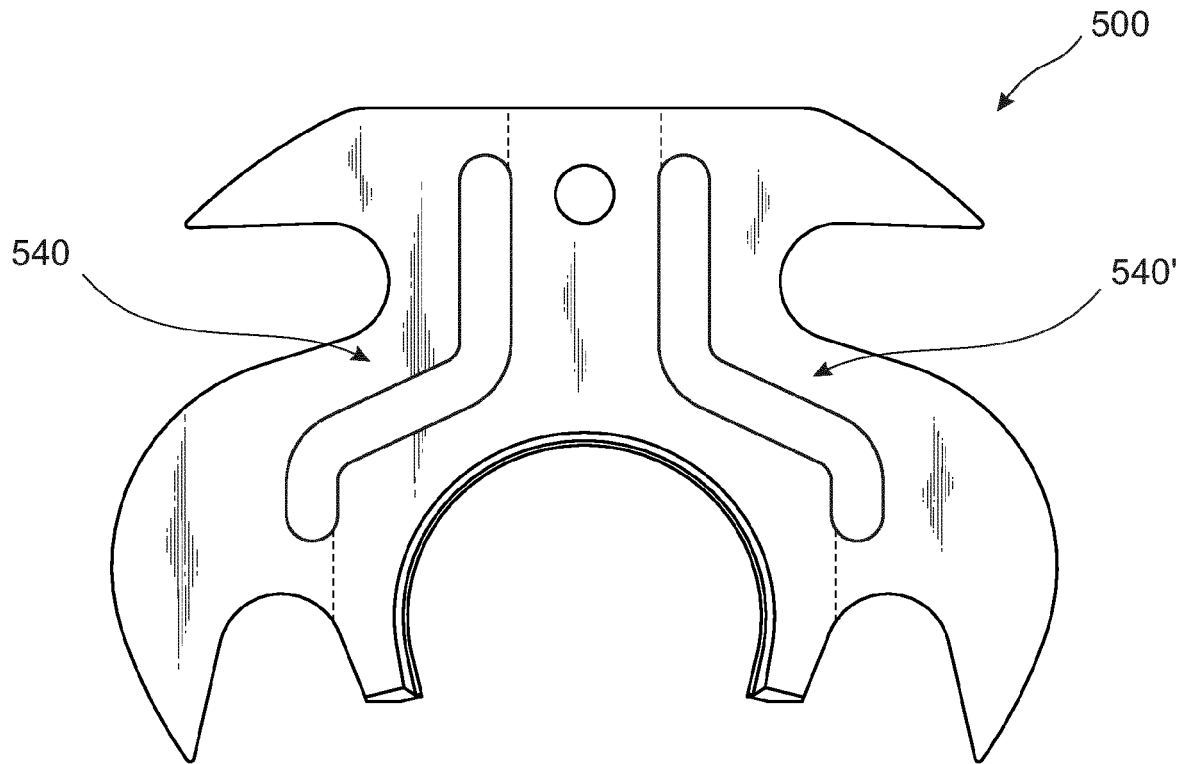


Fig. 10

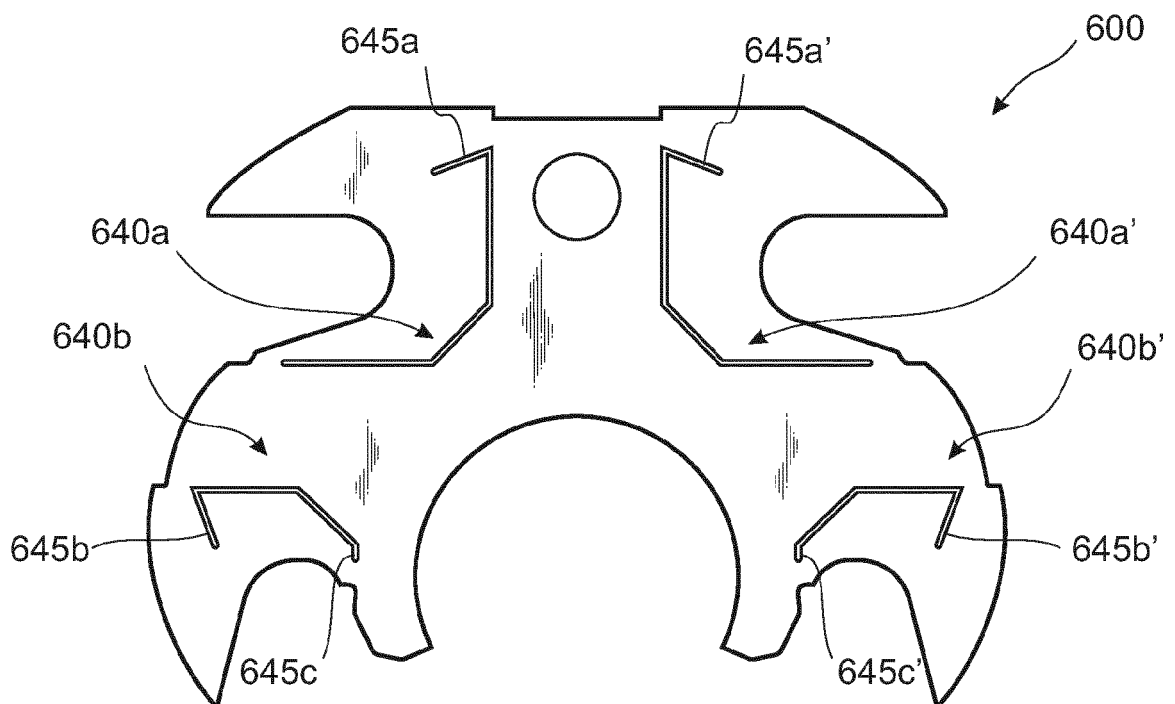


Fig. 11



EUROPEAN SEARCH REPORT

 Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2004/159729 A1 (STRONG JAMES L [US]) 19 August 2004 (2004-08-19) * figures *	1-21,25,26	INV. B02C18/18 B02C18/14 B26D7/26
A	DE 92 17 598 U1 (UNTERWURZACHER PATENTVERWERTUNGSGESELLSCHAFT MBH) 4 March 1993 (1993-03-04) * figures *	1-21,25,26	
X	DE 203 13 038 U1 (BE MASCHINENMESSER GMBH & CO K [DE]) 30 October 2003 (2003-10-30) * figures *	22	
A	DE 100 15 220 A1 (EUREC TECHNOLOGY GMBH ENTSORGU [DE]) 4 October 2001 (2001-10-04) * figures *	23,24	
A	DE 100 15 220 A1 (EUREC TECHNOLOGY GMBH ENTSORGU [DE]) 4 October 2001 (2001-10-04) * figures *	22-24	
			TECHNICAL FIELDS SEARCHED (IPC)
			B02C
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 4 February 2020	Examiner Kopacz, Ireneusz
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.02 (P04C01)



Application Number

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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 19 17 8181

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-16, 25, 26(completely); 17-21(partially)

A cutting knife, cutting shaft, a comminution apparatus and method of replacing a knife tip part.

2. claims: 22-24(completely); 17-21(partially)

A knife tip replacement part and method of replacing a knife tip part.

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 19 17 8181

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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04-02-2020

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REFERENCES CITED IN THE DESCRIPTION

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