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A connecting rod for an engine of a vehicle**TECHNICAL FIELD**

The invention relates to a connecting rod for an internal combustion engine, in particular, a split-type connecting rod for an internal combustion engine of a vehicle. The invention

5 also relates to an internal combustion engine comprising a split-type connecting rod.

Moreover, the invention relates to a vehicle comprising a split-type connecting rod. Finally, the invention also relates to an additive manufacturing method to manufacture a connecting rod.

10 Although the invention will be described in relation to a truck, the invention is not restricted to this particular vehicle, but may also be used in other type of vehicles such as buses, construction equipment, cars, industrial construction machines, working machines, wheel loaders, etc. Furthermore, the invention may not be restricted to vehicles, but may also be used in other type of mechanical devices which utilize connecting rods.

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BACKGROUND

In the field of internal combustion engine systems for vehicles, there is an increasing demand on providing high-functional and robust engine system components. One component of the engine is the connecting rod, which is typically used in conventional

20 piston engines to connect the piston to the crankshaft. The piston is furthermore connected to the connecting rod by means of a bearing for allowing a rotational movement there between. The connecting rod reciprocates at high RPMs and carries the power of the engine to the crankshaft.

25 The further development of more compact engines delivering higher horsepower at increasingly higher RPMs has placed increased stress on the connecting rod and its bearings. Because of these demanding environments, the design and manufacturing process of the connecting rod is typically central for the reliability of the connecting rod, and thus also for the reliability of the complete engine system. To meet this challenge, the
30 manufacture of connecting rods has undergone some changes. For instance, various materials besides steel have been tested as materials used for forming connecting rods, e.g. steel alloys, titanium alloys etc. Further, method of manufacturing rods in recent years typically involves casting or forging the entire rod assembly as one piece.

Generally, connecting rods have one end that forms part of an annular bearing assembly requiring separable cap and body portions to permit insertion of the crankshaft from a direction not along the axis of the bearing. Thus, on some types of connecting rods, the big end of the connecting rod is a two-part component to allow for assembling of the
5 connecting rod with the crankshaft. In order to increase the precision of the assembly between the connecting rod and the cap portion of the connecting rod, it is typically necessary to split the big end after machining. Accordingly, a split-type connecting rod is formed such that the big end portion is fractured and divided into a rod portion and a cap portion along a splitting plane including the shaft center of a crank-pin hole. The splitting
10 surfaces of the rod portion and of the cap portion are preferably realized with irregular surfaces or with at least a sufficient roughness surfaces to allow both parts to match perfectly when reassembled. The rod portion and the cap portion are then reassembled connected to each other by one or several bolts. In this manner, the big end can be separated into two parts when it should be connected to the crankshaft.

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Currently, the split-type connecting rod may include a slot in the throughhole of the big end in order to provide a weakened region for fracture splitting. The slot is typically realized in a dedicated step of the manufacturing process, more precisely in a machining step following the manufacturing phases to realize the blank of the connecting rod. By
20 way of example, the big end can be provided with opposed notches at the sides of the throughhole which concentrate the stress so that the cap portion of the big end can be separated by fracture splitting from the rod portion of the big end. In this manner, an interface is created between the cap portion and the remainder of the connecting rod that enable refitting of the cap portion to the rod portion of the big end.

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In this type of split-type connecting rod, it is necessary to apply a big pressure on the connecting rod in order to separate the big end into the cap portion and the rod portion. By way of example, the connecting rod is arranged in a machine that thwacks the connecting rod in order to snap the center of the big end in half. The mating surfaces of
30 the cap portion and the rod portion may be jagged and sharp. When these portions are connected to each other again, these jagged edges interlock. Typically, the cap portion and the rod portion are connected to each other by one or more bolts. Another drawback is that the conventional process typically requests an additional and dedicated step corresponding to the realization of the slot in the through hole of the big end.
35 Consequently the complete process is quite complex.

Despite the activity in the field of connecting rods, in particular split-type connecting rods, it would be desire to minimize the number of manufacturing steps to realize the connecting rods.

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SUMMARY

An object of the invention is to provide an improved split-type connecting rod for an internal combustion engine that allows for a more controlled split-fracture design of the big end of the connecting rod. The object is at least partly achieved by a split-type connecting
10 rod according to claim 1. According to a first aspect of the present invention, there is provided a split-type connecting rod for an internal combustion engine. The split-type connecting rod comprises a small end, a big end having a throughhole, and a rod main body extending therebetween. The big end has a fracture-split region adapted to permit separation of the split-type connecting rod big end into a rod portion and a cap portion.
15 Moreover, the fracture-split region is directly obtained from the manufacturing step to realized connecting rod blank with a tensile strength lower than adjacent regions of the big end.

By the provision of having a fracture-split region being directly obtained from the
20 manufacturing step to realized connecting rod blank with a tensile strength lower than adjacent regions of the big end, it becomes possible to provide a more controlled fracture-split when breaking the big end of the connection rod during mounting of the connecting rod to the crank shaft. In this manner, the example embodiments provides for an increased precision in the propagation of the fracture, while decreasing the stress needed
25 to break the big end compared to a big end using a slot to define the split fracture region.

By the provision of having a fracture-split region directly obtained from the manufacturing step to realized connecting rod blank with a tensile strength lower than adjacent regions of the big end, the control of the fracture-split of the big end is improved when breaking the big end of the connection rod during mounting of the connecting rod to the crank shaft.
30 Further, the provision of having a fracture-split region directly obtained from the manufacturing step to realized connecting rod blank contributes to simplify the whole manufacturing process of a connecting rod of a split-type connecting rod. Indeed, in the process to obtain the fracture-split region according to the example embodiments, there is generally no need of having a dedicated machining step to realize the fracture-split region,

e.g. comparing to the process of obtaining a fracture-split region defined by a conventional slot.

According to one example embodiment, the step corresponding to the realization of the fracture-split region is directly integrated in the manufacturing phases to realize the blank
5 of the connecting rod.

Typically, the connecting rod is obtained by an additive manufacturing. By way of example, the connecting rod is obtained by an additive manufacturing of a metallic powder material. Moreover, by having a fracture-split region made of a metallic powder material, it is believed that the propagation of the fracture is improved as the structure of
10 the fracture-split region allows for a propagation of the fracture in all directions within the fracture-split region.

In other words, it should be readily noted that the term “metallic powder material”, as used herein, typically refers to powder material or powder metal used in an additive manufacturing process. This type of powder allows for increasing locally the porosity or
15 adjusting the macrostructure cohesion of the material. In this manner, it becomes possible to locally adjust structure and/or material properties by adjusting locally sizes and /or composition of the powder, by adjusting speed of the laser beam used in the additive manufacturing process, adjusting power intensity of the laser beam. In addition, or alternatively, it allows for adjusting density of the structure in the fracture split region or
20 creating some holes in the structure in the fracture split region.

In other words, a fracture-split region made of a metallic powder material and with a tensile strength lower than adjacent regions of the big end provides for a modification of the structure of the fracture-split region so as to create a weakness area where it is most desirable to form the split of the of the rod portion and the cap portion of the big end.

25 According to one example embodiment, the fracture-split region is obtained by additive manufacturing. A fracture-split region obtained by additive manufacturing defines a porosity area, also denoted as a hollow structure, that contributes to a more defined fracture-split region, thus a more controlled fracture split of the big end. In addition, a connecting rod having a big end in which the fracture-split region is obtained by additive
30 manufacturing provides for an improved balance between strength and weight of the big end of the connecting rod without compromising on machinability of the connecting rod as well as the function of the connecting rod.

As mentioned above, the fracture-split region is made of a metallic powder material. In addition, the entire connecting rod is preferably obtained by additive manufacturing process. If the entire connecting rod is obtained by additive manufacturing process, the tensile strength of the fracture-split region is lower than the tensile strength of the adjacent regions of the big end and the remaining portions of the connecting rod. In addition, or alternatively, the rod main body is made of one or more metallic powder materials. In other words, the split-type connecting rod may be made of a metallic powder material, wherein the tensile strength of the fracture-split region is lower than the tensile strength of the adjacent regions of the big end and the remaining portions of the connecting rod.

- 10 By way of example, the lower tensile strength of the fracture-split region can be obtained by use of a metallic powder with larger particle sizes in forming the fracture-split region compared to the metallic powder used in forming the adjacent region(s) of the connecting rod.

In the context of the example embodiments, the fracture-split region is a rift propagation area. The fracture-split region typically contains a different structure than the other (adjacent) region(s) of the big end.

According to one example embodiment, the fracture-split region is designed with a density that is lower than the density of the adjacent regions. Hereby, the controlled split-fracture design of the big end of the connecting rod is even further improved.

- 20 It may be readily appreciated that “density” typically encompasses “material density”. Further, a difference of “density” may be obtained by creation locally of holes, as mentioned above, or by creation of porosities that are visible in the macrostructure fracture split-region, or by modifying the material density. Material density typically refers to the material itself, i.e. its nature, thus its microstructure.

- 25 By way of example, the fracture-split region is designed with a material density that is lower than the density of the material of the adjacent regions.

According to one example embodiment, the material density is modified by adjusting locally during the properties and / or characteristics of the metallic powder material provided in the additive manufacturing process to realize the fracture-split region. In this context, the properties and / or characteristics of the metallic powder material may refer to any one of the composition, dimensions and geometry of the powder particles.

According to one example embodiment, the material density is modified by adjusting locally during the properties and / or characteristics of the metallic powder material provided in the additive manufacturing process to realize the fracture-split region by adjusting locally a combination of the composition, dimensions and geometry of the powder particles of the metallic powder material.

According to one example embodiment, the lower material density of the fracture-split region is obtained by increasing locally the porosity of the material with respect to the porosity or absence of porosity of at least the adjacent regions. Preferably, the lower material density of the fracture-split region is obtained by increasing locally the micro-porosity of the material with respect to the porosity or absence of porosity of at least the adjacent regions.

According to one example embodiment, the increase of the porosity in the material is obtained by adjusting intensity of the laser beam and/or speed of the motion of the laser beam. Preferably, the increase of the micro-porosity in the material is obtained by adjusting intensity of the laser beam and/or speed of the motion of the laser beam.

According to one example embodiment, the fracture-split region is obtained by decreasing locally the material cohesion in at least the macro-structure.

In the context of the example embodiments, the term "micro-porosity" typically refers to a porosity within a range of mean pore size lower than one 100 μm , and preferably lower than 20 μm . According to one example embodiment, micro-porosity may refer to a material porosity of about between 1 μm and 100 μm . While micro-porosity typically refers to material porosity not visible to the eyes of a human being, macro-porosity may refer to a material porosity that is visible to the eyes of a human being. According to one example embodiment, the term "macro-porosity" may refer to a material porosity having a mean size porosity above 100 μm .

It should be noted that micro-porosity and variation of the micro-porosity in the material is typically obtained by adjusting intensity of the laser beam and speed of the motion of the laser beam.

Typically, the fracture-split region comprises a number of non-melted regions of metallic powder material. In other words, the fracture-split region may comprise a number of melted regions of metallic powder material and the number of non-melted regions.

The number of melted regions of metallic powder material and the number of non-melted regions may be obtained by modifying a laser beam trajectory during the manufacturing step for the fracture-split region. In this manner, a ratio of the melted surface region with respect to a total surface of the fracture split region is decreased.

- 5 In the non-melted regions, the metallic powder is not melted by the laser beam, thus creating a weakness or weaknesses in the fracture splint region.

Thus, according to one example embodiments, the fracture-split region is obtained by modifying the laser beam trajectory during the manufacturing step for the fracture-split region in order to decrease the ratio of the melted surface region with respect to a total
10 surface of the fracture split region.

By way of example, the laser beam trajectory covers a surface of the fracture split region less than the total surface of the fracture split region.

Typically, a ratio of the non-melted surface region with respect to a total surface of the fracture split region is at least 20% non-melted surface region. Preferably, the ratio of the
15 non-melted surface region with respect to a total surface of the fracture split region is between about 20% to 80% non-melted surface region. More preferably, the ratio of the non-melted surface region with respect to a total surface of the fracture split region is between about 40% to 80% non-melted surface region. Even more preferably, the ratio of the non-melted surface region with respect to a total surface of the fracture split region is
20 between about 60% to 80% non-melted surface region.

It should, however, be noted that the fracture split region may comprise an even higher ratio of non-melted surface region, i.e. above 80% non-melted surface region. By having a high ratio of non-melted surface region, i.e. above 80%, it becomes possible to generate a undulating (wavy) surface of non-melted material. By means of an undulating surface of
25 non-melted material, it becomes possible to provide a smooth fracture split region surface with an undulating surface topography of non-melted material. This may also be denoted as a 3D split surface. A fracture split region with opposite arranged matching undulating mating surfaces provides for an improved matching when re-assembled. That is, the opposite arranged matching undulating mating surfaces match together when re-
30 assembled.

Accordingly, the ratio of the non-melted surface region with respect to a total surface of the fracture split region may be between about 20% to 100% non-melted surface region.

More preferably, the ratio of the non-melted surface region with respect to a total surface of the fracture split region is between about 40% to 100% non-melted surface region.

Even more preferably, the ratio of the non-melted surface region with respect to a total surface of the fracture split region is between about 60% to 100% non-melted surface
5 region. According to one example, the surface of the fracture split region is a fully non-melted surface region. That is, the total surface of the fracture split region comprises 100% non-melted surface regions. Hereby, it is believed that no additional operation for fracturing the connecting rod may be required, which generally has a positive impact on factors such as required energy and cost for producing the connecting rod.

10 According to one example embodiment, the method comprising obtaining a fracture split region having opposite arranged matching undulating mating surfaces. By way of example, the fracture split region having opposite arranged matching undulating mating surfaces is obtained by modifying the laser beam trajectory during the manufacturing step for the fracture-split region in order to decrease the ratio of the melted surface region with
15 respect to the total surface of the fracture split region.

According to one example embodiment, the fracture-split region comprises a slot. The slot may be realized during the additive manufacturing process to realize the connecting rod blank or eventually during the implementation powder metallurgy process. Hence, according to one example embodiment, the method may include the provision to realize a
20 slot in the fracture split region during the additive manufacturing process. This type of slot generally has the shape of a conventional one (e.g. a V-sectional shape or half-circular sectional shape), but thanks to the additive manufacturing process it can be realized during the same step as the step to realize the connecting rod blank.

When the big end is in a fracture-split state, the big end is fracture-split into the rod portion
25 which continues from the end of the rod main body and the cap portion which is coupled to the rod portion.

Further, when the big end is fracture-split, the rod portion and the cap portion each have a fractured surface on which rugged features are present. The fracture surfaces are thus mating surfaces. In other words, the big end includes a rod portion and a cap portion
30 separable from the rod part, the rod and cap portions having mating faces.

The rod main body connects the rod portion of the big end to the small end.

Moreover, a big end fractured into the cap portion and the rod portion forms two fractional parts along a fracture line. The fractional parts can be pieced together as described below. In other words, the fracture-split region is arranged in the big end on both sides of the fracture line. When the big end is split into the rod portion and the cap portion, the fracture-split region is arranged on the rod portion and the cap portion, respectively. That is, the rod portion comprises a fracture-split rod portion region and the cap portion comprises a fracture-split cap portion region.

According to one example embodiment the entire connecting rod is obtained by additive manufacturing.

- 10 The process “additive manufacturing”, sometimes also called free-form fabrication, is a method for forming three- dimensional articles through successive fusion of chosen parts of powder layers applied to a worktable. There are several different types of additive manufacturing apparatus. One type of additive manufacturing technology is Powder Bed Fusion (PBF), which produces a solid part using a thermal source that induces fusion
- 15 (sintering or melting) between the particles of a metal powder one layer at a time. One example of a PDF technology is Electron Beam Melting (EBM), which is an additive manufacturing where an electron emitting cathode in an electron acceleration column is the source for electron beam generation, which in turn is acting as an energy beam for melting the power material.
- 20 According to one example embodiment, the fracture-split region of the big end is located at opposite transverse sides of the throughhole.

By way of example, the split-type connecting rod is configured to connect a reciprocating piston to a crank shaft of the internal combustion engine arrangement. The rod main body is typically a shaft extending between the small end and the big end. As mentioned above,

25 the split-type connecting rod comprises the big end, i.e. a large diameter end part. The big end is provided with the through hole, which is a crank receiving opening receiving a crankpin. Typically, the big end also has a crank bearing eye for connecting the connecting rod with the crank shaft of the internal combustion engine.

The split-type connecting rod also comprises the small end, i.e. a small diameter end part,

30 which is positioned at the piston side at the opposite side from the large diameter end part (big end). The small end has a piston pin opening for receiving a piston pin. The small end is thus the piston pin end. The small end may have a connecting rod bearing eye

configured to connect the connecting rod with the cylinder piston of the internal combustion engine.

After the big end is split by fracture splitting, bearing elements and a shaft element may be inserted therein and the split-type connecting rod is then pieced together again. The fracture split big end can be pieced together in several different manners. By way of example, the cap portion can be connected to the rod portion of the big end by one or more fasteners. Thus, the big end typically comprises a fastener for connecting the fracture-split cap portion to the rod portion.

According to one example embodiment, the fastener is configured to connect the cap portion to the rod portion at a predetermined load.

According to one example embodiment, the fastener is a bolt and the big end further comprises a bolt hole in which the bolt is insertable for coupling together the rod portion and the cap portion. By way of example, the bolt hole is a bottomed hole which extends from the cap portion toward the rod portion and has a bottom surface within the rod portion.

According to one example embodiment, the big end is located at an end of the rod main body.

According to one example embodiment, the split-type connecting rod is formed as a unit. That is, the big end, the small end and the rod main body are integrally connected.

The example embodiments of the connecting rod are particularly useful for internal combustion engine arrangements of vehicles, such as trucks, buses, construction equipment, cars, industrial construction machines, wheel loaders, etc. However, the example embodiments may also be used in other types of mechanical devices which utilize connecting rods.

According to one example embodiment, there is provided a split-type connecting rod for an internal combustion engine. The connecting rod comprises a small end, a big end having a throughhole, and a rod main body extending therebetween. Moreover, the big end has a fracture-split region adapted to permit separation of the rod big end into a rod portion and a cap portion. Further, the fracture-split region is obtained by additive manufacturing.

In particular, by the provision of having a fracture-split region obtained by additive manufacturing, it becomes possible to provide a fracture-split-region having a tensile strength lower than an adjacent region of the big end, thus enabling a more controlled fracture-split when breaking the big end of the connection rod during mounting of the
5 connecting rod to the crank shaft.

According to one example embodiment the entire big end is obtained by additive manufacturing such that the tensile strength of the fracture-split region is lower than the tensile strength of remaining portions of the big end.

The splitting surface of the rod portion and of the cap portion are preferably realized with
10 irregular surfaces or with at least a sufficient roughness surfaces to allow both parts to match when reassembled. The rod portion and the cap portion are then reassembled connected to each other by one or several bolts. In this manner, the big end can be separated into two parts when it should be connected to the crankshaft.

According to a second aspect of the present invention, there is provided an internal
15 combustion engine arrangement comprising:

- a combustion cylinder housing a reciprocating piston movable between a bottom dead center and a top dead center within the combustion cylinder;
- a split-type connecting rod according to any one of the example embodiments as described above in relation to the first aspect of the present invention, the split-type
20 connecting rod connecting the reciprocating piston to a crank shaft of the internal combustion engine.

Effects and features of the second aspect are largely analogous to those described above in relation to any one of the first aspect of the present invention.

Besides the combustion cylinder, the piston and the split-type connecting rod, such
25 internal combustion engine arrangement may comprise a connecting rod bearing arranged between the connecting rod and the reciprocating piston for allowing a mutual rotational movement between the connecting rod and the reciprocating piston when the reciprocating piston moves between the bottom dead center and the top dead center.

According to a third aspect of the present invention, there is provided a vehicle comprising
30 an internal combustion engine arrangement according to the second aspect of the present invention. Effects and features of the third aspect are largely analogous to those

described above in relation to any one of the first aspect and second aspect of the present invention.

According to a fourth aspect of the invention, there is provided an additive manufacturing method for manufacturing a split-type connecting rod according to any one of the example
5 embodiments as described in relation to the first aspect of the invention. Effects and features of the fourth aspect are largely analogous to those described above in relation to any one of the first aspect, second aspect and third second aspect of the present invention.

Typically, the method further comprises the step of adjusting locally a material density
10 during the properties and / or characteristics of the metallic powder material provided in the additive manufacturing process to realize the fracture-split region.

According to one example embodiment, the method comprises the step of lowering material density of the fracture-split region by increasing locally the micro-porosity of the metallic powder material with respect to the porosity of at least the adjacent regions.

15 According to one example embodiment, the method comprises the step of increasing the micro-porosity in the metallic powder material by adjusting intensity of a laser beam. In addition, or alternatively, the method comprises the step of increasing the micro-porosity in the metallic powder material by adjusting speed of the motion of the laser beam.

According to one example embodiment, the method comprises the step of obtaining the
20 fracture-split region by decreasing locally the material cohesion in at least the macro-structure.

According to one example embodiment, the method comprises the step of obtaining the fracture-split region by modifying a laser beam trajectory during the manufacturing step for the fracture-split region in order to decrease the ratio of the melted surface region with
25 respect to the total surface of the fracture split region.

According to one example embodiment, the method comprises the step of, during the additive manufacturing process, realizing a slot in the fracture split region.

It should be noted that the connecting rod manufacturing process generally comprises several different steps. One of the first steps includes manufacturing the blank of the
30 connecting rod. The manufacturing of the blank is typically followed by machining steps to

realize functional surfaces, machining step to realize conventional slot to make easier connecting rod separation and surface treatment steps.

Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. The skilled person
5 realize that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

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The various example embodiments of the invention, including its particular features and example advantages, will be readily understood from the following illustrative and non-limiting detailed description and the accompanying drawings, in which:

15 Fig. 1a is a lateral side view illustrating an example embodiment of a vehicle in the form of a truck;

Fig. 1b is a cross-section of a split-type connecting rod according to an example embodiment which is connected to an engine piston in a cylinder and to a crank shaft;

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Figs. 2a to 2b schematically illustrate an example embodiment of a split-type connecting rod according to the present invention;

Figs. 2c to 2d schematically illustrate some further details of the example embodiment of
25 the split-type connecting rod in Figs. 2a to 2b.

DETAILED DESCRIPTION OF SOME EXAMPLE EMBODIMENTS OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the
30 accompanying drawings, in which exemplary embodiments of the invention are shown.

The 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. Like reference characters refer to like elements throughout the description. The drawings are not necessarily to scale and

certain features may be exaggerated in order to better illustrate and explain the exemplary embodiments of the present invention.

Referring now to the figures and e.g. Fig. 1a there is depicted a vehicle 1 in the form of a truck. The vehicle 1 comprises a prime mover 12 in the form of an internal combustion engine arranged in an internal combustion engine arrangement 10. The internal combustion engine arrangement 10 may be propelled by e.g. a conventional fuel such as diesel, although other alternatives are conceivable. The internal combustion engine 12 is typically operated in a four stroke fashion, i.e. operated by an intake stroke, a compression stroke, a combustion stroke, and an exhaust stroke. However, the combustion engine may in other examples work according to the equally well-known two-stroke principle. In Fig. 1b, which is a cross-sectional view of parts of the internal combustion engine arrangement, there is depicted one cylinder 3 of the engine 12. By way of example, the internal combustion engine arrangement 10 comprises a number of cylinders. In Fig. 1b, the internal combustion engine 12 comprises the combustion cylinder 3 housing a reciprocating piston 4 movable between a bottom dead center and a top dead center within the combustion cylinder. Typically, the internal combustion engine further comprises an injector 25 for injecting fuel into the combustion cylinder. Thus, in order to inject fuel into a combustion chamber of a combustion engine cylinder of the internal combustion engine, the engine typically comprises the fuel injector. However, it should be readily appreciated that the engine may include a plurality of injectors for injecting fuel into a combustion chamber of a combustion engine cylinder.

Accordingly, although not shown in the figures, the engine may generally comprise the cylinder and the piston, which reciprocates in the cylinder and is connected to the crankshaft so that the piston is set to reverse in the cylinder at an upper and lower dead centre position. As is also common, one end of the cylinder cavity is closed by an engine cylinder head (not shown). In other words, the internal combustion engine system 10 is provided with at least one engine cylinder 3. Typically, the internal combustion engine system includes a plurality of cylinders, e.g. six to eight cylinders 3, each one having a reciprocating piston. Thus, each cylinder 3 comprises a corresponding reciprocating piston 4, which may be of any type which is suitable for compression ignition. The cylinder 3 is only described in general terms since its parts and functionality is well known in the art. The cylinder configuration may be e.g. straight, V-shaped or any other suitable kind. Each cylinder 3 of Fig. 1b comprises at its vertical top end at least one and typically a

multiple number of inlet channels 31 for inlet air, and at least one and typically a multiple number of outlet channels 32 for exhaust gases from the fuel combustion process taking place within the cylinder 3.

5 Moreover, the piston 4 is connected to a connecting rod 20 according to an example embodiment. The connecting rod connects the reciprocating piston 4 to a crank shaft 18 of the internal combustion engine 12. The connecting rod is thus configured to connect the reciprocating piston to the crank shaft of the internal combustion engine. The connecting rod is a so called split-type connecting rod according to any of the example
10 embodiments as described further in relation to Figs. 2a – 2d. As illustrated in Fig. 1b, the piston 4 of the combustion cylinder 3 is connected to the crankshaft 18 for translating the vertical movement of the piston 4 to a rotational movement of the crankshaft 18. The crankshaft 18 is located within a crankcase 26. The piston 4 is connected to the crankshaft 18 via the connecting rod 20. The connecting rod 20 is arranged between the
15 crankshaft 18 and the piston 4.

The crankshaft is then connected to the engine block by one or several main bearings (not shown). The connecting rod may typically have a connecting rod bearing arranged between the connecting rod and the reciprocating piston for allowing a mutual rotational
20 movement between the connecting rod and the reciprocating piston when the reciprocating piston moves between the bottom dead center and the top dead center. In this example, the connecting rod 20 is connected to a piston pin of the piston 4 via a connecting rod bearing. Furthermore, the connecting rod may comprise a lubricant conduit (not shown). The lubricant conduit is arranged inside the connecting rod and
25 configured to supply a lubricating medium to the connecting rod bearing.

The combustion causes the piston 4 to reciprocate between its uppermost position, the so called top dead center, TDC, and its lowermost position, the bottom dead center, BDC. In Fig. 1b the piston 4 is located close to its BDC. The volume within the cylinder 3 between
30 the BDC of the piston 4 and the cylinder top is called the combustion chamber. This is where i.a. combustion of fuel takes place.

As mentioned above, the connecting rod is a so called split-type connecting rod. The description below with reference to Figs. 2a to 2d will present various alternatives of
35 providing a split-type connecting rod according to various example embodiments. These

types of split-type connecting rods can be installed in an internal combustion engine arrangement of a vehicle as described in relation to Figs. 1a and 1b.

Turning now to the split-type connecting rod and Figs. 2a to 2d, the piston 4 is typically
5 connected to the split-type connecting rod 20 at a connecting rod small end 16 (see Fig. 2a). Furthermore, the split-type connecting rod 20 is connected via a big end 15 to the crankshaft 18. The split-type connecting rod has an extension in a longitudinal direction X, an extension in a transverse direction Y, and an extension in a thickness direction Z. in other words, the directions correspond to the three perpendicularly arranged axis of a
10 typical coordinate system.

As illustrated in Fig. 2a, the split-type connecting rod comprises the small end 16, the big end 15 having a through hole 23, and a rod main body 14 extending therebetween. The rod main body 14 is here an inter-connecting rod shaft. The rod main body connects the
15 rod portion of the big end to the small end. The small end 16 and the big end 15 are arranged on opposite sides of the inter-connecting rod shaft 14. That is, the small end 16 and the big end 15 are arranged on opposite longitudinal sides of the inter-connecting rod shaft 14, as illustrated in Fig. 2a. Accordingly, the inter-connecting rod main body 14 extends between the low end 16 and the big end 15. The big end is located at an end of
20 the rod main body. Typically, the small end 16, the big end 15 and the inter-connecting rod main body 14 are integral parts of the split-type connecting rod 20. However, the small end 16, the big end 15 and the inter-connecting rod main body 14 may likewise be separate parts connected to form the split-type connecting rod 20.

25 Moreover, as illustrated in Fig. 2a, the big end 15 comprises a rod portion 26 which continues from the end of the rod main body 14 and a cap portion 27 which is coupled to the rod portion 26. In addition, the big end has a fracture-split region 22 adapted to permit separation of the connecting rod big end 15 into the rod portion 26 and the cap portion 27.

30 That is, the cap portion of the big end can be separated by fracture splitting from the rod portion 26 of the big end, which creates an interface between the cap portion and the remainder of the connecting rod that allows refitting of the cap portion to the remainder with a sufficient positional accuracy.

In the example embodiment described in relation to Figs. 2a to 2d, the fracture-split region 22 of the big end 15 is located at opposite transverse sides of the throughhole 23.

However, the fracture-split region may likewise be located at another location about the throughhole. In this example, the fracture-split region extends completely through the transverse extension of the big end. By way of example, the fracture-split region extends from an inner surface 22a to an outer surface 22b of the big end, as illustrated in Fig. 2b. That is, the fracture-split region extends along the total transverse section of the connecting rod. In other words, the fracture-split region extends from an inner surface 22a to an outer surface 22b of the big end of both opposite transverse sides of the throughhole 23.

As illustrated in e.g. Fig. 2a, the big end is fractured into the cap portion 27 and the rod portion 26 along an imaginary fracture line 31. Hence, when the big end is fractured into the cap portion 27 and the rod portion 26, two fractional parts are formed along the fracture line 31. In other words, the fracture-split region 22 is arranged in the big end on both sides of the fracture line 31. When the big end is split into the rod portion 26 and the cap portion 27, a part of the fracture-split region 22 is arranged on the rod portion and another part of the fracture-split region is arranged on the cap portion, respectively. That is, the rod portion 26 comprises a fracture-split rod portion region 62 and the cap portion comprises a fracture-split cap portion region 52, as shown in e.g. Fig. 2b.

It may also be noted that in this example of the split-type connecting rod, the cap portion is engaged to the rod portion by a fastener 17. Thus, the big end comprises a fastener 17 for connecting the fracture-split cap portion 27 to the rod portion 26. Typically, the fastener is configured to connect the cap portion to the rod portion at a predetermined load. By way of example, the fastener is a bolt (not shown) and the big end 15 further comprises a bolt hole 34 (Fig. 2b) in which the bolt is insertable for coupling together the rod portion 26 and the cap portion 27. By way of example, the bolt hole is a bottomed hole which extends from the cap portion 27 toward the rod portion 26 and has a bottom surface 35 within the rod portion. The bolt holes extend in the longitudinal direction X, and are generally parallel with the rod main body. In addition the bolt holes are bored into the cap portion and the rod portion of the big end on opposite sides of the throughhole 23 from the cap portion. The bolt holes may also be tapped so that bolts with or without nuts can be used to secure the cap portion to the rod portion after they are fracture separated.

Accordingly, when the big end is in a fracture-split state, the big end is fracture-split into the rod portion 26 which continues from the end of the rod main body 14 and the cap portion 27 which is de-coupled from the rod portion. Further, when the big end is fracture-split, the rod portion and the cap portion each have a fractured surface 29 on which
5 rugged features are present. The fractured surfaces are thus mating surfaces. In other words, the big end 15 includes the rod portion and the cap portion separable from the rod part, the rod and cap portions having mating faces. As mentioned above, the big end is fractured and split into the rod portion and the cap portion along the fracture plane (straight line 31 in the Fig. 2a). Fracturing and splitting into the rod portion and cap portion
10 can be performed by a conventional method. Then, these fractured and split rod portion and cap portion may be aligned with each other by contacting both fractured and split surfaces with each other and coupled by the bolts fitted in the respective bolt holes. Turning again to the fracture-split region 22 of the big end of the connecting rod, the fracture-split region 22 is directly obtained from the manufacturing step to realized
15 connecting rod blank with a tensile strength lower than adjacent regions 28 of the big end 15. The term "blank", as used herein, generally refers to a piece shaped as a connecting rod blank. It should be noted that the connecting rod manufacturing process generally comprises several different steps. One of the first steps includes manufacturing the blank of the connecting rod.

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Further, in this example embodiment, the fracture-split region 22, and the connecting rod, is obtained by an additive manufacturing process. By way of example, the fracture-split region 22 is made of a metallic powder material. In other words, the connecting rod 20 as illustrated in Figs. 2a to 2d is obtained by an additive manufacturing of a metallic powder
25 material.

The fracture-split region 22 and the adjacent regions 28 of the big end 15 are depicted in e.g. Fig. 2b. An adjacent region is here defined as a portion of the big end closest to the fracture-split region. The adjacent region is thus typically located on both longitudinal
30 sides of the fracture-split region 22, as shown in Fig. 2a, when the split-type connecting rod is in its non-split state. It is to be noted that the adjacent region of the big end may also refer to the remaining portions of the big end except the fracture-split region 22.

The fracture-split region is thus adapted to permit separation of the rod big end into a rod
35 portion and a cap portion upon a breaking force. In the context of the example

embodiments, the fracture-split region is a rift propagation area. By forming the fracture-split region 22 directly from the manufacturing step to realized connecting rod blank, the fracture-split region typically contains a different structure than the other (adjacent) region(s) of the big end. A fracture-split region having a lower tensile strength than the adjacent region(s) of the big end can be provided in several different manners by the manufacturing step to realized connecting rod blank. By way of example, the fracture-split region can be obtained by additive manufacturing so as to lower density by for instance creating porosities. In other words, the fracture-split region is designed with a density that is lower than the density of the adjacent regions. As an example, the fracture-split region is designed with a material density that is lower than the density of the material of the adjacent regions. The material density is here modified by adjusting locally the properties and / or characteristics of the metallic powder material provided in the additive manufacturing process to realize the fracture-split region. In this context, the properties and / or characteristics of the metallic powder material may refer to any one of the composition, dimensions and geometry of the metallic powder particles. According to one example embodiment, the material density is modified by adjusting locally the properties and / or characteristics of the metallic powder material provided in the additive manufacturing process to realize the fracture-split region by adjusting locally a combination of the composition, dimensions and geometry of the powder particles of the metallic powder material.

In addition, or alternatively, the fracture-split region can be obtained by additive manufacturing so as to create some holes in the fracture-split region. Fig. 2c illustrates one example of a fracture-split region 22 of the big end, in which the porosity is different between the fracture-split region 22 and the adjacent regions 28 of the big end of the connecting rod. By way of example, the lower material density of the fracture-split region is obtained by increasing locally the micro-porosity of the material with respect to the porosity of at least the adjacent regions. The increase of the micro-porosity in the material is typically obtained by adjusting intensity of the laser beam and/or speed of the motion of the laser beam.

In addition, or alternatively, the fracture-split region can be obtained by additive manufacturing so as to decrease a ratio of melted surface / total surface of the fracture split section. By way of example, the fracture-split region is obtained by decreasing locally the material cohesion in at least the macro-structure.

In addition, or alternatively, the fracture-split region can be obtained by additive manufacturing so as to lower a macrostructure cohesion in the fracture-split region by, for instance, increasing speed of laser beam and/or lowering laser beam intensity and/or
5 using bigger powder material particles.

Fig. 2d illustrates another example of obtaining the fracture-split region 22. Fig. 2d is a cross-sectional view of the fracture-split region of the connecting rod described in relation to Fig. 2a to 2c. In this example, the fracture-split region 22 is obtained by additive
10 manufacturing by modifying the laser beam trajectory 74 during the manufacturing step for the fracture-split region in order to decrease the ratio of the melted surface region with respect to the a total surface of the fracture split region. In this manner, a fracture-split region 22 is obtained that comprises a number of non-melted regions 70 of metallic powder material. In other words, the fracture-split region 22 comprises a number of
15 melted regions 72 of metallic powder material and the number of non-melted regions 70.

The number of melted regions 72 of metallic powder material and the number of non-melted regions 70 are thus obtained by modifying the laser beam trajectory 74 during the manufacturing step for the fracture-split region 22. In this manner, a ratio of the melted
20 surface region with respect to a total surface of the fracture split region is decreased. In the non-melted regions, the metallic powder is not melted by the laser beam, thus creating a weakness or weaknesses in the fracture splint region. As may gleaned from Fig. 2d, the laser beam trajectory covers a surface of the fracture split region less than the total surface of the fracture split region.

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Typically, the powder material is a metallic powder material, . The fracture-split region is further obtained by additive manufacturing. It should be noted that the fracture-split region as well as the entire big end is obtained by additive manufacturing as long as the additive manufacturing process is carried out such that the tensile strength of the fracture-split region 22 is lower than the tensile strength of remaining portions 28 of the big end. In
30 another example, the entire split-type connecting rod is obtained by additive manufacturing, while the additive manufacturing process is carried out such that the tensile strength of the fracture-split region 22 is lower than the tensile strength of remaining portions 28 of the big end.

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It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims. Thus even though the disclosure has been described with reference to specific
5 exemplifying embodiments thereof, many different alterations, modifications and the like will become apparent for those skilled in the art. Variations to the disclosed embodiments can be understood and effected by the skilled addressee in practicing the claimed disclosure, from a study of the drawings, the disclosure, and the appended claims.

Furthermore, in the claims, the word "comprising" does not exclude other elements or
10 steps, and the indefinite article "a" or "an" does not exclude a plurality.

CLAIMS

1. A split-type connecting rod (20) for an internal combustion engine (12), the connecting rod comprising a small end (16), a big end (15) having a throughhole, and a rod main body (14) extending therebetween, the big end having a fracture-split region (22) adapted to permit separation of the rod big end into a rod portion and a cap portion, and wherein the fracture-split region is directly obtained from a manufacturing step to realized connecting rod blank with a tensile strength lower than adjacent regions of the big end.
2. Connecting rod according to claim 1, wherein the connecting rod (20) is obtained by an additive manufacturing preferably of a metallic powder material.
3. Connecting rod according to claims 1 or 2, wherein the fracture-split region is designed with a density (92) that is lower than the density (94) of the adjacent regions.
4. Connecting rod according to claim 3, wherein the fracture-split region is designed with a material density that is lower than the density of the material of the adjacent regions.
5. Connecting rod according to claim 4 when depending on claim 2, wherein the material density is modified by adjusting locally the properties and / or characteristics of the powder provided in the additive manufacturing process to realize the fracture-split region.
6. Connecting rod according to claim 4, wherein the lower material density of the fracture-split region is obtained by increasing locally the porosity (96) of the material, preferably its micro-porosity, with respect to the porosity (98) or absence of porosity of at least the adjacent regions.
7. Connecting rod according to claim 6, wherein the increase of the porosity in the material is obtained by adjusting intensity of the laser beam and/or speed of the motion of the laser beam.

8. Connecting rod according to claim 3, wherein the fracture-split region is obtained by decreasing locally the material cohesion in at least a macro-structure.
- 5 9. Connecting rod according to any one of the preceding claims, wherein the fracture-split region comprises a number of non-melted regions (70) of metallic powder material.
- 10 10. Connecting rod according to claim 9, wherein the fracture-split region is obtained by modifying a laser beam trajectory during the manufacturing step for the fracture-split region in order to decrease a ratio of the melted surface region with respect to a total surface of the fracture split region.
- 15 11. Connecting rod according to claim 10, wherein the laser beam trajectory covers a surface of the fracture split region less than the total surface of the fracture split region.
- 20 12. Connecting rod according to any one of the preceding claims, when dependent on claim 2, wherein the fracture-split region comprises a slot, said slot being realized during the additive manufacturing process to realize the connecting rod blank.
13. Connecting rod according to any one of the preceding claims, wherein the entire big end is obtained by additive manufacturing.
- 25 14. An internal combustion engine arrangement (10) comprising:
- a combustion cylinder housing a reciprocating piston movable between a bottom dead center and a top dead center within the combustion cylinder; and
 - a connecting rod according to any one of the preceding claims 1 to 13, the connecting rod connecting the reciprocating piston to a crank shaft of the internal combustion engine.
- 30 15. A vehicle (1) comprising an internal combustion engine arrangement according to claim 14.
- 35 16. An additive manufacturing method for manufacturing a split-type connecting rod (20), according to any one of the preceding claims 1 to 13.

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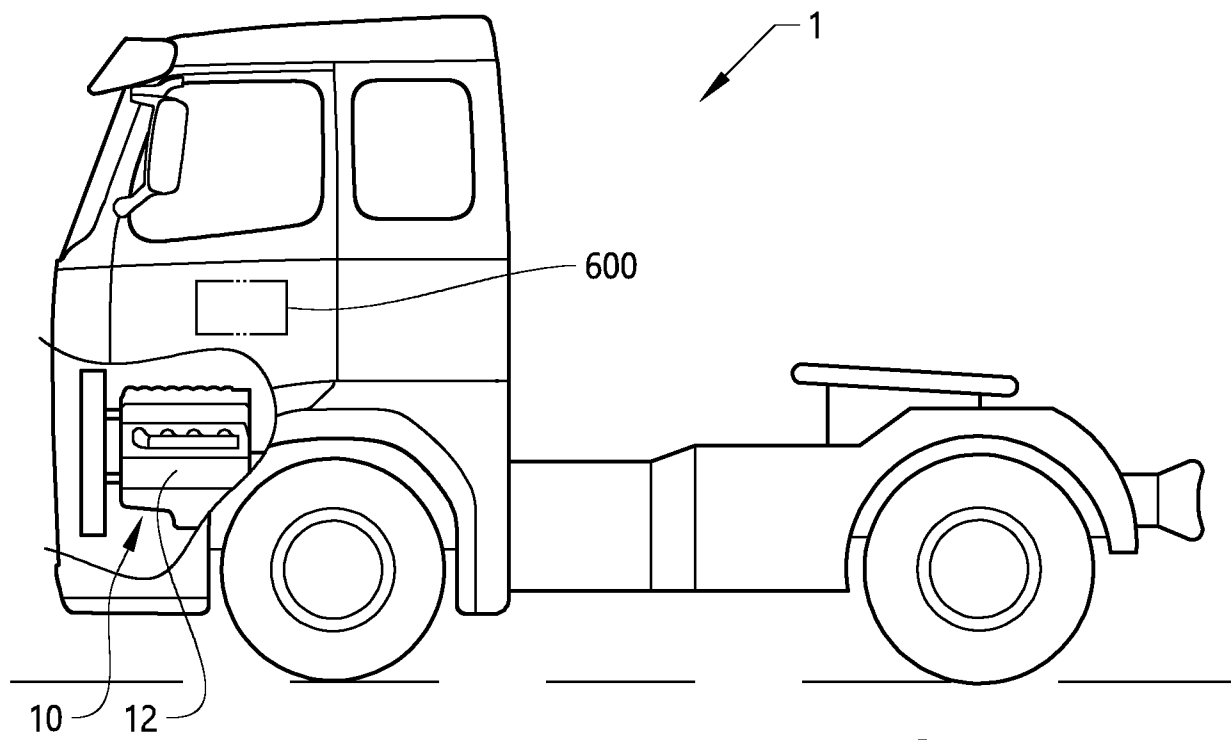


FIG. 1a

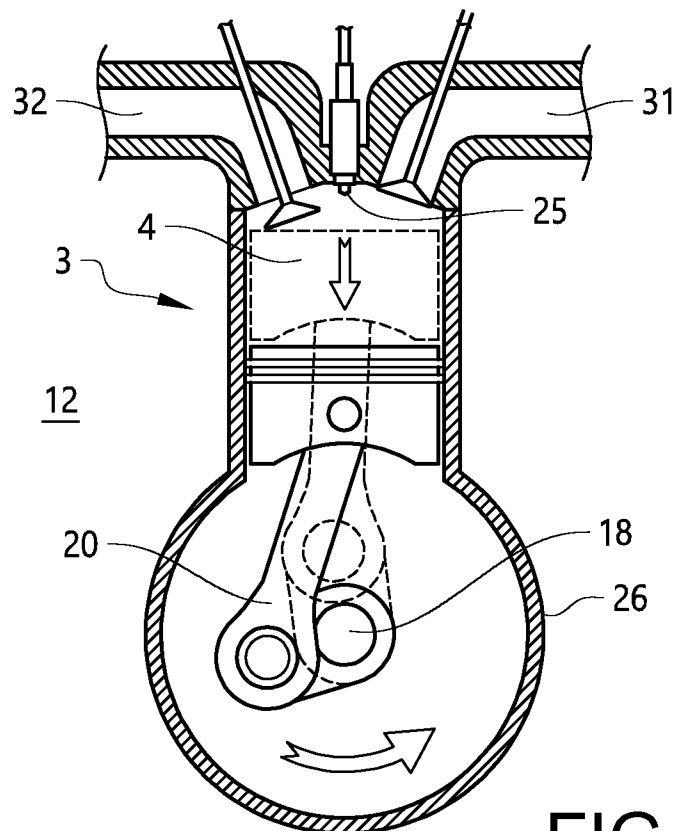
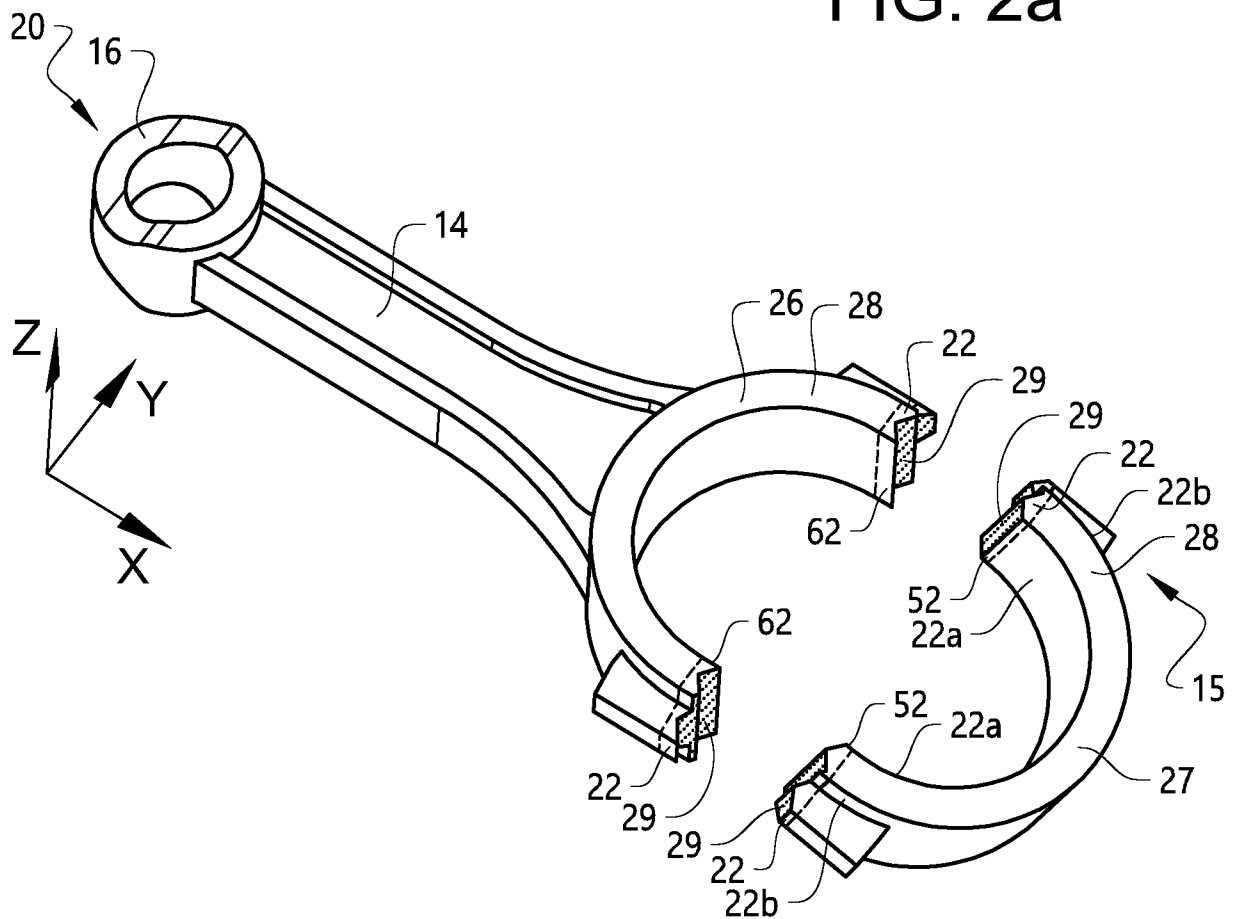
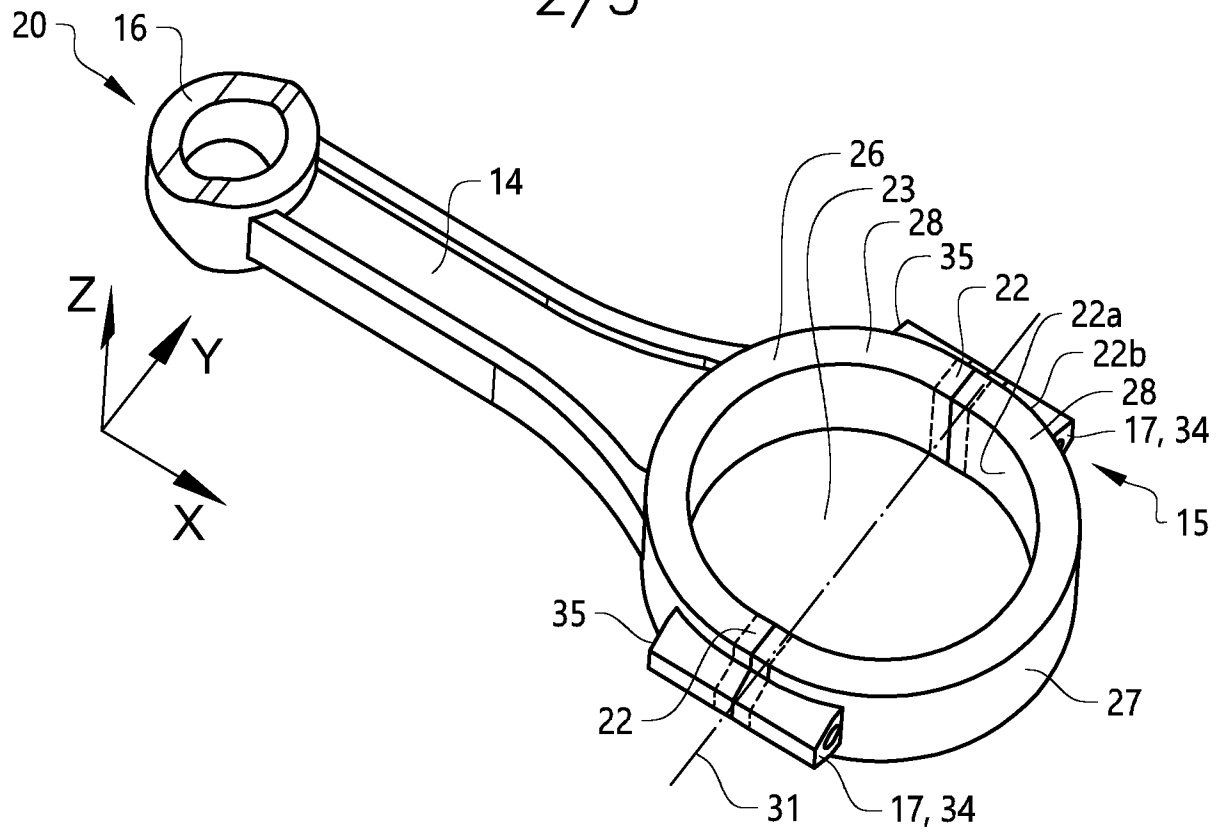


FIG. 1b

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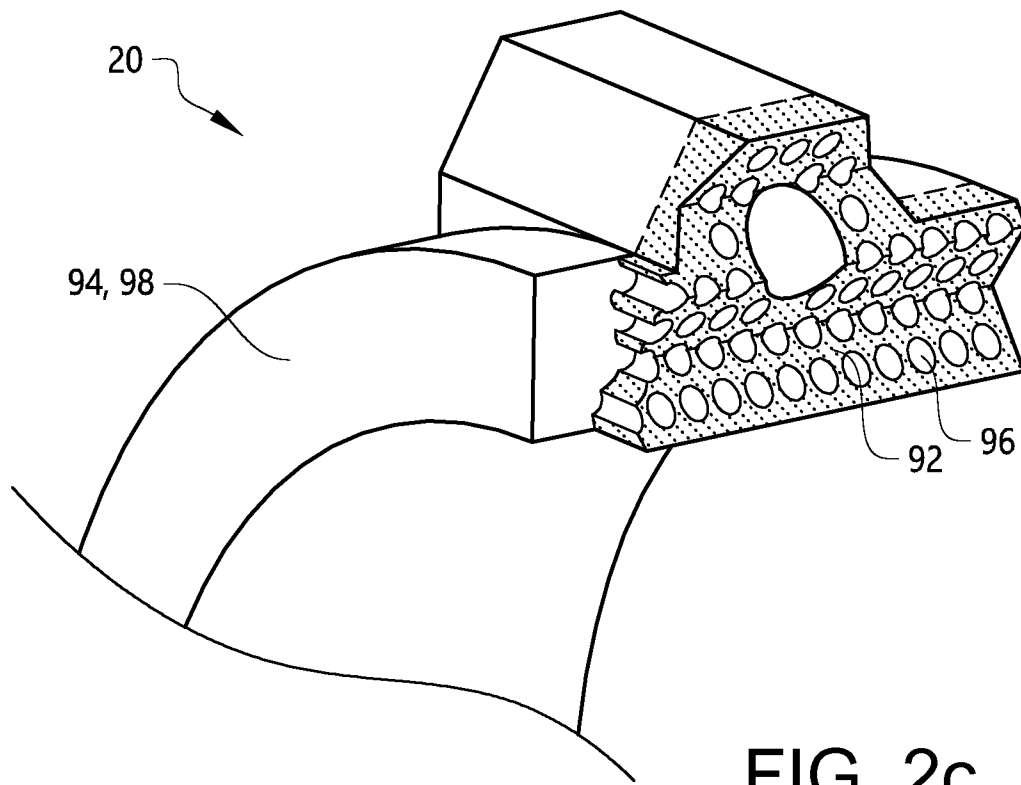


FIG. 2c

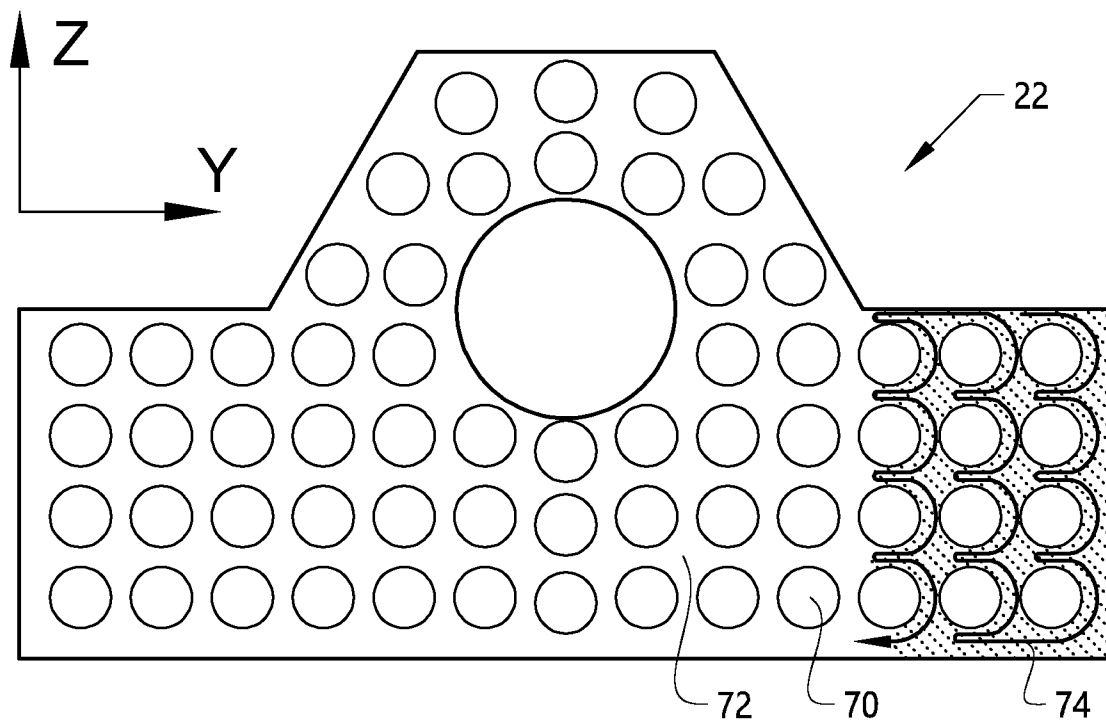


FIG. 2d

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/086304

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16C7/02 B22F3/105 B22F5/00 B23K26/342 B33Y10/00
B33Y80/00 F16C9/04 F16C33/14

ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16C C22C B23K B22F B33Y

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	JP H05 279704 A (-) 26 October 1993 (1993-10-26) paragraphs [0011], [0015]; figure 2 -----	1,3,4, 14,15
X	JP H11 80805 A (TOYOTA MOTOR CORP) 26 March 1999 (1999-03-26) paragraphs [0010], [0016]; figure 2 -----	1,3,4, 14,15
X	JP H07 127627 A (TOYOTA MOTOR CORP) 16 May 1995 (1995-05-16) paragraphs [0006], [0014]; figure 2 ----- -/--	1,3,4, 14,15

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

☒ See patent family annex.

* Special categories of cited documents :

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

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Date of the actual completion of the international search

30 August 2019

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11/09/2019

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2018/086304

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/209629 A1 (MINEMURA KAZUO [JP] ET AL) 13 September 2007 (2007-09-13) paragraphs [0004], [0027], [0030]; figures 3A-3E -----	1,3,4, 14,15
A	DE 195 11 772 A1 (EOS ELECTRO OPTICAL SYST [DE]) 2 October 1996 (1996-10-02) claims 10-21 This document is mentioned in DE 10 2011 101857 (D1) -----	16

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