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- (56) Fremdragne publikationer:
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DESCRIPTION

[0001] Tool assemblies and methods are disclosed herein for lifting heavy parts of a wind turbine.

BACKGROUND

[0002] Wind turbines include large and heavy parts such as a nacelle, a generator, a rotor, a gearbox, tower sections and the like. Such large and heavy parts should be handled, e.g. lifted, etc., usually in manufacturing, installation, transport, repair and replacement operations, through the use of lifting equipment such as lifting cranes or the like. The weight and the size of said large and heavy parts to be handled result in that said manufacturing, installation, transport, repair and replacement operations are difficult to be carried out. In addition, cranes used for lifting such parts are bulky and expensive, especially in offshore environment.

[0003] A number of solutions for lifting wind turbine parts have been proposed in the art. Lifting tools, such as lugs, hooks or the like are attached to the wind turbine part to be lifted which may be, for example, a structural component, by means of bolted connections.

[0004] WO2005071261 discloses the use of a tool for handling a wind turbine blade. The tool comprises two bracket-like components between which the blade is attached. Tool attachment is carried out by bolts extending through blade mounting holes. Each bracket-like component comprises a plate having the same profile as the blade and provided with flanges having a fastening hole.

[0005] US8562302 discloses a wind turbine blade having a structure for handling the blade. Such handling structure comprises attachment bores having threaded female channels for receiving a handling mechanism. Said attachment bores are formed in structural members engaged with internal spar caps extending within the blade.

[0006] Although current solutions are technically efficient, they use bolted, i.e. threaded, connections to attach the handling components to the wind turbine part to be lifted. This results in that disassembling operations take a long time and involve undesirable additional costs together with unsafe conditions for workers who have to perform operations in risky sites of the wind turbine under unsafe conditions at large heights, such as outside the nacelle, while the lifting equipment might be still in operation. In addition, removal of bolts must be carried out through the use of hydraulic tools which are heavy and require electric and/or hydraulic power to be operated and which also have to be transported up to such critical positions.

SUMMARY

[0007] A tool assembly is provided herein with which the above prior art disadvantages can be at least reduced when lifting wind turbine parts such as the nacelle, the rotor, the generator, the gearbox, tower sections and parts thereof.

[0008] The present assembly comprises a tool that may comprise, for example, an elongated body defining a stem with a first end and a second end. The assembly further comprises a stem receiving portion that is part of, is formed in, or is associated with a wind turbine part to be lifted. In one example, the stem receiving portion may be an opening formed in the part of the wind turbine to be lifted, such as, for example, the hub.

[0009] The stem of the tool is adapted to be freely passed through the stem receiving portion. Therefore, no threaded portions are provided inside the stem receiving portion. The fact that the stem can be freely passed through the stem receiving portion does not necessarily involve a direct contact between the outer surface of the stem and the inner surface of the stem receiving portion. However, in many cases, there would be contact between the stem and the stem receiving portion as the stem is passed sliding through the stem receiving portion. In any case, the stem of the tool can be freely passed through the stem receiving portion until the first end of the stem is locked such that it can not come off the stem receiving portion when the lifting equipment pulls the tool outwards for lifting the wind turbine part.

[0010] The second end of the stem may be adapted to be engaged by the lifting equipment. A quick release engagement is preferably used.

[0011] It is also preferred that the stem receiving portion is defined by at least substantially vertical walls so that the stem of the tool is vertical when it is inserted therein. A vertical position of the tool allows the lifting equipment to efficiently handle the wind turbine part.

[0012] The first end of the stem may be adapted to be releasably locked to the stem receiving portion. The tool can be thus removed from the wind turbine part once it has been lifted as compared with prior solutions where the lifting tool is permanent so it remains attached to the wind turbine part after its handling has been completed. The present lifting tool assembly can be thus reused in other lifting operations so no unnecessary weight is added to the wind turbine.

[0013] In order to lock the tool to the wind turbine part to be lifted, the first end of the stem may be provided, for example, with a portion projecting, e.g. radially, from the stem such that the stem can not be passed through the stem receiving portion when the stem is pulled out by the crane for lifting the wind turbine part.

[0014] Different embodiments are possible for the stem projecting portion to lock the tool to the stem receiving portion.

[0015] In one example, the stem projecting portion comprises a ring. The ring may be formed of at least two pieces. Said pieces may be the same in size or they may be different from each

other. The pieces of the ring can be coupled to each other such that the thus formed ring surrounds the first end of the stem of the tool. The pieces of the ring can decoupled from each other as required. In general, the stem projecting portion may be removable from the first end of the stem.

[0016] The use of ring shaped projecting portion has the advantage that the parts to be handled are light in weight, specifically they weight less than the maximum permissible load that can be handled by an operator. Therefore, no external aid is required, such as by a crane or hoisting device, to handle the inner parts.

[0017] The stem receiving portion may be provided with an enlarged portion formed therein. Thus, the projecting portion may be adapted to be at least partially fitted into said enlarged portion of the stem receiving portion. Such enlarged portion may comprise a flat area which may, for example, be machined inside the stem receiving portion. The purpose of the enlarged portion is to provide good contact between the stem and the stem receiving portion. The flat area can be preferably inclined in order to provide an increased contact surface and better pressure distribution therebetween. Said arrangement of the stem receiving portion and the stem projecting portion allows the different parts to withstand mainly compressive forces during lifting.

[0018] In a further example of the stem projecting portion, at least one wedge part is provided. The wedge part is adapted to cooperate with the stem such that the relative displacement of the wedge part and the stem causes the diameter of the first end of the stem to increase preventing the stem from being passed through the stem receiving portion when the stem of the tool is pulled out for lifting the wind turbine part.

[0019] In any case, a stop plate may be also provided for distributing loads in use. The stop plate is mounted at the first end of the stem, between the stem projecting portion and the wind turbine part. The stop plate may be formed as a separate part from the stem projecting portion of forming part of the stem. The stop plate may surround completely or partially the stem.

[0020] The stem of the tool may further comprise holding means adapted to temporary hold the stem to the stem receiving portion until the stem is pulled by the lifting equipment. Specifically, such holding means may be adapted to keep the stem projecting portion fitted into the enlarged portion of the stem receiving portion. The holding means may comprise a protrusion projecting from the stem. Such protrusion may be formed in a portion opposite the stem projecting portion in a way that the stem of the tool is arranged at a predetermined relative position with respect to the stem receiving portion.

[0021] Finally, in some cases it may be preferred that the stem of the tool is suitably sealed to the stem receiving portion when it is inserted therein. Sealing may be carried out at least in the contact surface between the stem of the tool and the stem receiving portion in the exterior of the wind turbine part. Alternatively, sealing may be carried out in the contact surface between the stem of the tool and the stem receiving portion in the interior of the wind turbine part.

However, sealing may be carried out in the contact surface between the stem of the tool and the stem receiving portion both in the exterior and in the interior of the wind turbine part if required.

[0022] A method for lifting a wind turbine part is also provided herein. The lifting method comprises the steps of providing a lifting tool such as the one described above and passing said tool through a stem receiving portion formed in a wind turbine part.

[0023] Passing the tool through the stem receiving portion may be carried out from the outside of the wind turbine part through the use of a lifting crane. Then, a stem projecting portion is formed projecting outwards after which the stem of the tool is pulled outwards (upwards in the drawing) such that the stem is locked in the inner surface of the stem receiving portion in a way that the stem can not come off the stem receiving portion and therefore the wind turbine part can be lifted. Locking of the stem of the tool to the wind turbine part allows the wind turbine part to be lifted by the lifting crane.

[0024] Once the wind turbine part has been lifted, the method may include a step of disengaging the lifting equipment, e.g. the crane, from the stem of the tool and removing the tool from the wind turbine part.

[0025] The most important advantage of the present tool assembly relates to safety. Typical bolted solutions may require workers to be outside a nacelle to remove a great number of bolts with heavy tools. By contrast, with the present tool assembly the operator works safely from the inside of the wind turbine part, for example, the hub.

[0026] A very safe, fast, simple and easy lifting of wind turbine parts is obtained while costs are reduced. In addition, as compared with current bolted solutions, the present tool assembly and the method for lifting wind turbine parts using said tool are very simple and cost effective as a reduced number of parts and steps are involved. This differs from current bolted solutions requiring a large amount of bolts, such as twenty or more bolts, for attaching structures such as shaped plates, flanges, lugs or the like to the wind turbine part to be lifted. Instead, the present tool assembly only requires a receiving portion and a lifting tool to be received therein whose stem is adapted to be freely passed therethrough and locked therein when the wind turbine is part lifted.

[0027] The present tool assembly is very easy to apply to the wind turbine part to be lifted and therefore is less time consuming. In addition, the present tool assembly is also easy to disassemble also with resulting time savings. Finally, it is to be noted that no additional tools are required to lift the wind turbine part using the present tool assembly.

[0028] Additional objects, advantages and features of embodiments of the tool assembly and method for lifting wind turbine parts will become apparent to those skilled in the art upon examination of the description, or may be learned by practice thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Particular embodiments of the present tool for lifting wind turbine parts will be described in the following by way of non-limiting examples, with reference to the appended drawings, in which:

Figures 1-6 are diagrammatic views showing one embodiment of the present tool assembly where the main steps of a method for lifting a wind turbine part using the tool are illustrated; and

Figures 7 and 8 are respectively a diagrammatic elevational and perspective view showing a particular example of the holding means to temporary hold the tool stem to the stem receiving portion.

DETAILED DESCRIPTION OF EMBODIMENTS

[0030] One of the many possible examples of the present tool assembly for lifting a wind turbine part is shown in the figures. Examples of a wind turbine part to be lifted through the present tool assembly are the wind turbine rotor, the nacelle, the generator, the gearbox, tower sections, and parts thereof. In the specific example shown in the figures, the wind turbine part to be lifted corresponds to a wind turbine hub 500.

[0031] In the specific example shown in the figures, the assembly 100 comprises a tool 110 in the form of a cylindrical body defining a stem 120 having a first end 130 and a second end 140.

[0032] The first end 130 of the stem 120 (lower end in the figures) has a radial recess 131. The radial recess 131 is adapted for receiving a portion 135 projecting radially from the stem 120. In the specific example shown, the stem projecting portion 135 comprises a ring 160 that is formed of two pieces. The two pieces of the ring 160 can be coupled with each other so that, in an assembled condition, the two pieces of the ring 160 are arranged surrounding the recess 131 of the stem 120, as shown in figures 3 and 6. The two pieces of the ring 160 can be decoupled from each other when the stem projecting portion 135 is required to be removed from the first end 130 of the stem 120.

[0033] Provision of ring 160 results in that parts to be handled are light in weight, specifically they weight less than the maximum permissible load that can be handled by an operator. Therefore, handling inner parts does not require external aid such as the crane.

[0034] The second end 140 of the stem 120 has a through bore 145 adapted to be engaged

by lifting equipment such as a crane (not shown).

[0035] A stem receiving portion 150 is formed in the hub 500 of the wind turbine. The stem receiving portion 150 in the example shown consists of a smooth-walled cylindrical opening 155 formed in the hub 500. Said cylindrical opening 155 is conveniently sized for receiving the stem 120 of the tool 110 such that the stem 120 can be freely passed therethrough.

[0036] For lifting the hub 500, the above tool assembly 100 is provided. The tool 110 is installed by passing its stem 120 freely through the stem receiving portion 150 from the outside of the hub 500 by means of a crane (not shown) that holds the tool 110 by the through bore 145 of the second end 140 of the stem 120. The operator, who is inside the hub 500, places the two pieces of the ring 160 around the recess 131 in the first end 130 of the stem 120.

[0037] With the stem 120 already provided with the ring 160 mounted in the first end 130 of the stem 120 defining a stem projecting portion 135, the stem 120 of the tool 110 is passed through the stem receiving portion 150 upwards in the drawings as the stem 120 is lifted by the crane.

[0038] Lifting of the tool 110 causes it to be passed through the stem receiving portion 150 upwards until the ring 160 in the first end 130 of the stem 120 abuts an enlarged portion 170 formed in a lower end 180 inside the stem receiving portion 150 in the form of an inclined flat area.

[0039] In this position where the stem 120 is locked to the stem receiving portion 150, the stem 120 is positioned vertical when it has been inserted into the stem receiving portion 150 and it is prevented from passing through the stem receiving portion 150 completely as the hub 500 is being lifted by the crane.

[0040] Temporary holding means, not shown, may be used to hold the stem 120 of the tool 110 to the stem receiving portion 150 until the stem 120 of the tool 110 is pulled by the crane. In the particular example shown in figures 7 and 8, the holding means comprise a radial protrusion 190 projecting from the stem 120. The tool 110 is thus inserted downwards into the stem receiving portion 150 until the radial protrusion 190 abuts the outer surface of the hub 500. This results in that the stem 120 is arranged at a predetermined relative position with respect to the stem receiving portion 150 suitable for being pulled by the crane.

[0041] Again referring to figures 7 and 8, a stop plate 200 is provided in this example. The purpose of the stop plate 200 is distributing loads when the tool 110 is in use, with its stem 120 fitted into the stem receiving portion 150. As shown in figure 7, the stop plate 200 is mounted at the first end 120 of the stem 120, between the ring 160 and the hub 500, against a lower portion of the stem receiving portion 150. Compressive loads in the ring 160 are thus evenly distributed on said lower portion of the stem receiving portion 150, inside the hub 500.

[0042] A step of providing a seal between the stem 120 of the tool 110 and the stem receiving

portion 150 may be carried out before lifting the hub 500 of the wind turbine.

[0043] When the hub 500 of the wind turbine has been lifted, the crane is disengaged from the through bore 145 of the second end 140 of the stem 120 and the tool 110 is removed by the operator from the hub 500. Once the tool 110 has been removed, the stem receiving portion 150 may be properly sealed or covered preventing water, dirt, objects, etc. from entering the stem receiving portion 150.

[0044] Although only a number of particular embodiments and examples of the tool assembly and method for lifting wind turbine parts have been disclosed herein, it will be understood by those skilled in the art that other alternative embodiments and/or uses and obvious modifications and equivalents thereof are possible. Furthermore, the present disclosure covers all possible combinations of the particular embodiments described. Thus, the scope of the present disclosure should not be limited by particular embodiments, but should be determined only by a fair reading of the claims that follow.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- [WO2005071261A \[0004\]](#)
- [US8562302B \[0005\]](#)

Patentkrav

1. Værktøjsanordning (100) til at løfte en vindmøllenacelle og/eller -nav (500), hvilken anordning (100) omfatter et værktøj (110) med et skaft (120), som har
5 en første ende (130) anbragt inden i nacellen og/eller navet (500), og en anden ende (140), hvor anordningen (100) yderligere omfatter en skaftmodtagelsesdel (150), der er en del af, eller den er associeret med, vindmøllenacellen og/eller -navet (500), som skal løftes, hvor værktøjets (110) skaft (120) er indrettet til at blive frit passeret igennem skaftmodtagelsesdelen (150), indtil den første ende
10 (130) af skaftet (120) er låst til skaftmodtagelsesdelen (150) fra det indre af vindmøllenacellen og/eller -navet (500), hvilket forhindrer skaftet (120) i at slippe ud af skaftmodtagelsesdelen (150) under løftning af vindmøllenacellen og/eller -navet (500).
- 15 2. Anordningen (100) ifølge krav 1, hvor den anden ende (140) af skaftet (120) er indrettet til at indgribes af et løfteudstyr.
3. Anordningen (100) ifølge krav 1, hvor skaftmodtagelsesdelen (150) er defineret af mindst i alt væsentligt vertikale vægge, således at værktøjets (110)
20 skaft (120) er vertikalt, når indsat deri.
4. Anordningen (100) ifølge et hvilket som helst af de foregående krav, hvor den første ende (130) af skaftet (120) er indrettet til at løsbart låses til skaftmodtagelsesdelen (150).
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5. Anordningen (100) ifølge et hvilket som helst af de foregående krav, hvor den første ende (130) af værktøjets (120) skaft (120) har en del (135) udstikkende fra skaftet (120), således at skaftet (120) ikke kan passeres igennem skaftmodtagelsesdelen (150), når skaftet (120) trækkes ud til løftning af
30 vindmøllenacellen og/eller -navet (500).

6. Anordningen (100) ifølge krav 5, hvor den fra skaftet udstikkende del (135) er fjernbar fra den første ende (130) af skaftet (120).

7. Anordningen (100) ifølge krav 5 eller 6, hvor den fra skaftet udstikkende del (135) omfatter en ring (160).

8. Anordningen (100) ifølge et hvilket som helst af kravene 5-7, hvor den fra skaftet udstikkende del (135) er indrettet til mindst delvist at tilpasses i en forstørret del (170) dannet i skaftmodtagelsesdelen (150).

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9. Anordningen (100) ifølge krav 1, hvor den yderligere omfatter mindst en kiledel samvirkende med skaftet (120), således at den relative forskydning af kiledelen og værktøjets (110) skaft (120) forårsager at diameteren af den første ende (130) af skaftet (120) forøges for derved at forhindre skaftet (120) i at passere igennem skaftmodtagelsesdelen (150), når værktøjets (110) skaft (120) trækkes ud til løftning af vindmøllenacellen og/eller -navet (500).

10. Anordningen (100) ifølge et hvilket som helst af de foregående krav, hvor den yderligere omfatter holdeorgan til midlertidigt at holde værktøjsskaftet (120) til skaftmodtagelsesdelen (150), indtil værktøjsskaftet (120) trækkes af løfteudstyret.

11. Anordningen (100) ifølge krav 10, hvor holdeorganet omfatter et fremspring (190) udstikkende fra skaftet (120), således at skaftet (120) anbringes ved en forudbestemt relativ position i forhold til skaftmodtagelsesdelen (150).

12. Anordningen (100) ifølge et hvilket som helst af kravene 5-11, hvor den yderligere omfatter en anslagsplade (200) tilvejebragt ved den første ende (130) af skaftet (120), mellem den fra skaftet udstikkende del (135) og vindmøllenacellen og/eller -navet (500).

13. Fremgangsmåde til at løfte en vindmøllenacelle og/eller -nav (500), omfattende trinnene:

- at tilvejebringe en løfteværktøj (110);
- at passere værktøjet (110) igennem en skaftmodtagelsesdel (150) dannet i en vindmøllenacelle og/eller -nav (500);
- at placere en skaft-udstikkende del (135) inden i nacellen og/eller navet (500) i den første ende (130) af skaftet (120), således at den første ende (130) af værktøjets (110) skaft (120) tilstøder en indvendig flade af skaftmodtagelsesdelen (150); og
- at trække løfteværktøjet (110) ved en ende deraf til løftning af vindmøllenacellen og/eller -navet (500).

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14. Fremgangsmåden ifølge krav 13, hvor den yderligere omfatter et trin, når vindmøllenacellen og/eller -navet (500) er løftet, at afkoble løfteudstyret fra værktøjets (110) skaft (120) og at fjerne værktøjet (110) fra vindmøllenacellen og/eller -navet (500).

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15. Fremgangsmåden ifølge et hvilket som helst af kravene 13-14, hvor den yderligere omfatter et trin at dække skaftmodtagelsesdelen (150), når værktøjet (110) er fjernet derfra.

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DRAWINGS

FIG. 1

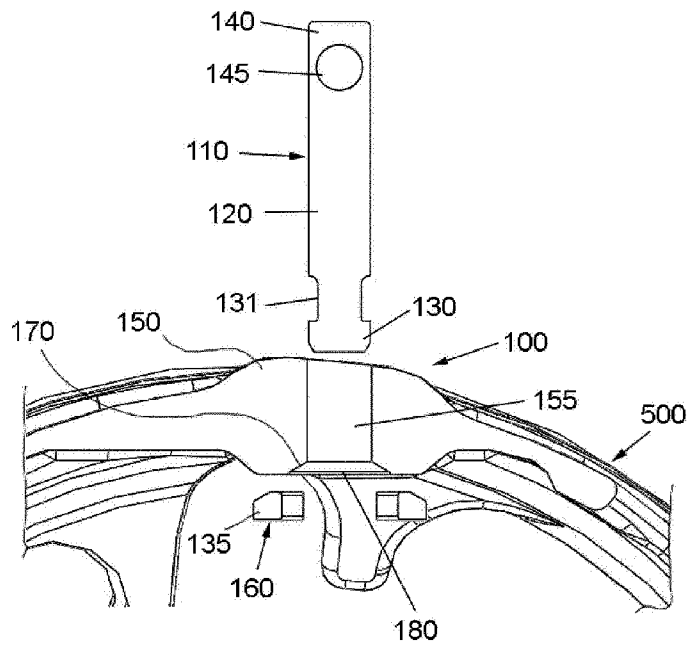


FIG. 2

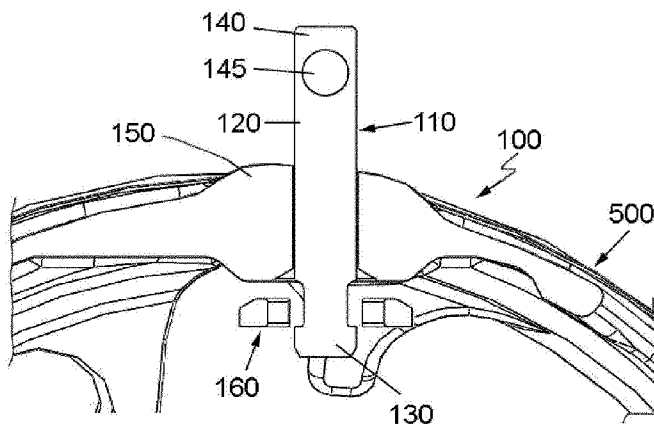


FIG. 3

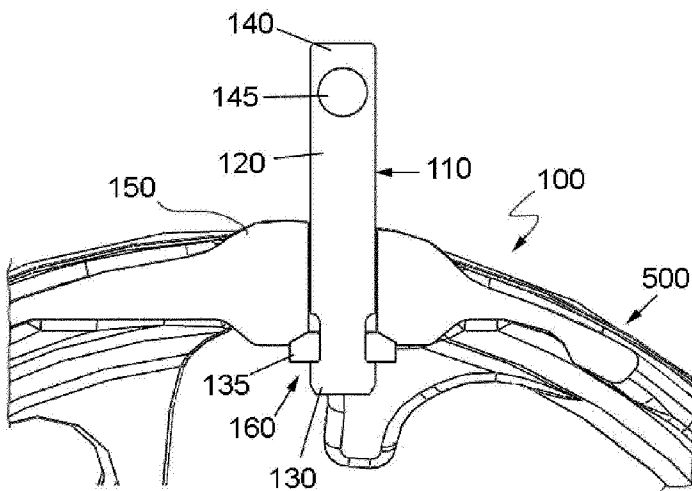


FIG. 4

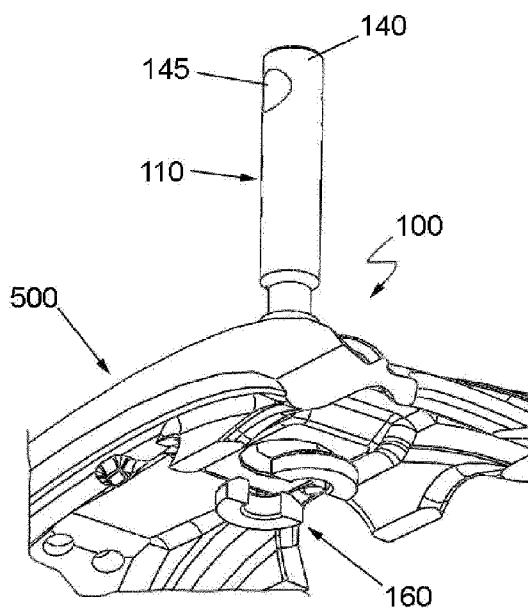


FIG. 5

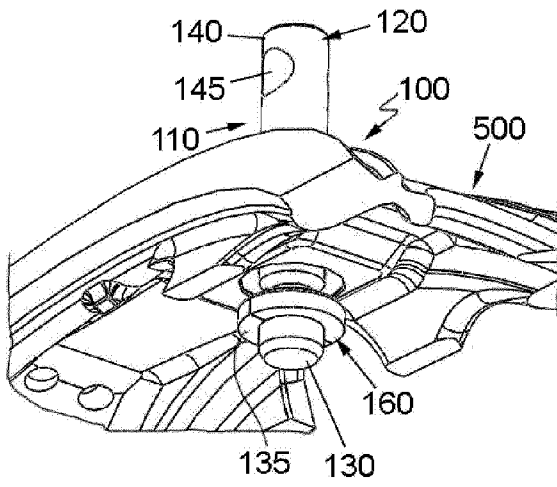


FIG. 6

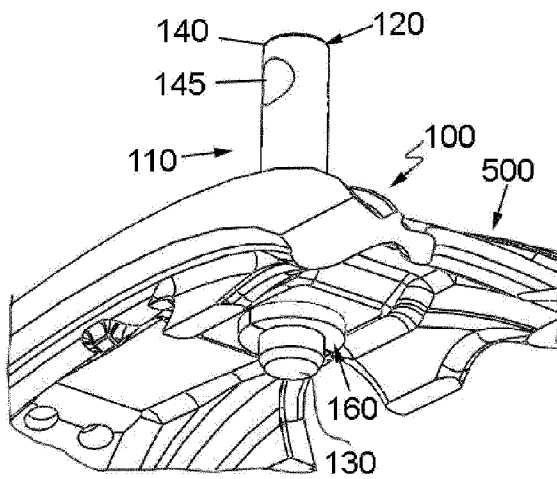


FIG. 7

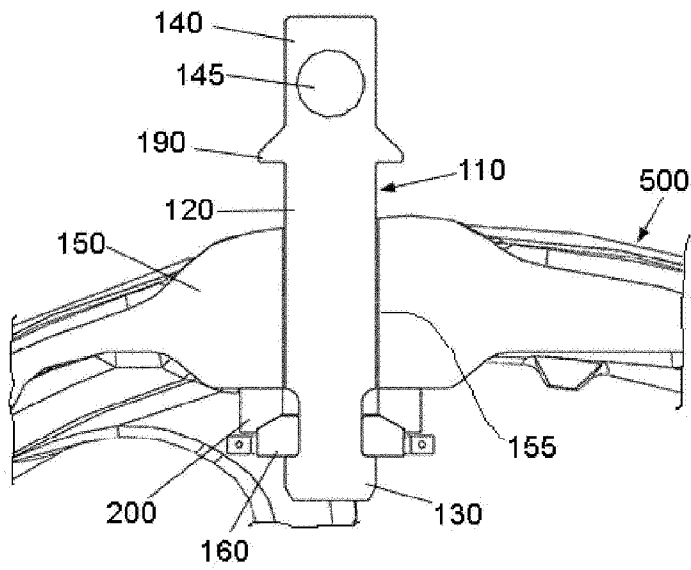


FIG. 8

