(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 997 972 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
03.12.2008 Bulletin 2008/49

(51) Int Cl.:
E04B 1/19 *(2006.01)*

(21) Application number: **08386009.8**

(22) Date of filing: **27.05.2008**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

(30) Priority: **29.05.2007 GR 20070100661**

(71) Applicant: **Gamanis, George A.**
552 36 Panorama, Thessaloniki (GR)

(72) Inventor: **Gamanis, George A.**
552 36 Panorama, Thessaloniki (GR)

(54) **An improved mechanism for the connection of a pipe to a node of a three-dimensional structure**

(57) An improved mechanism (12) for the connection of a pipe (9) to a node connector (1) of a three-dimensional structure includes: a bolt (8) with a pin (4); a sleeve (3) with a radial threaded hole (20) and two longitudinal grooves (14); a socket set screw (2) screwed through the radial threaded hole (20); a conical end (7) fixed to the pipe (9). The bolt (8) has a radial groove (18) between the pin (4) and the bolt head (19). The radial groove (18) and the radial threaded hole (20) have the same circumferential position; and the same longitudinal position exactly when the sleeve (3) and the bolt head (19) are in contact with the corresponding bearing surfaces (28,29) of the conical end (7). The problem of the confirmation, that the bolt (8) is completely screwed into the node connector (1), is solved; and the probability of encountering environmentally induced cracking in the bolt (8) is eliminated.

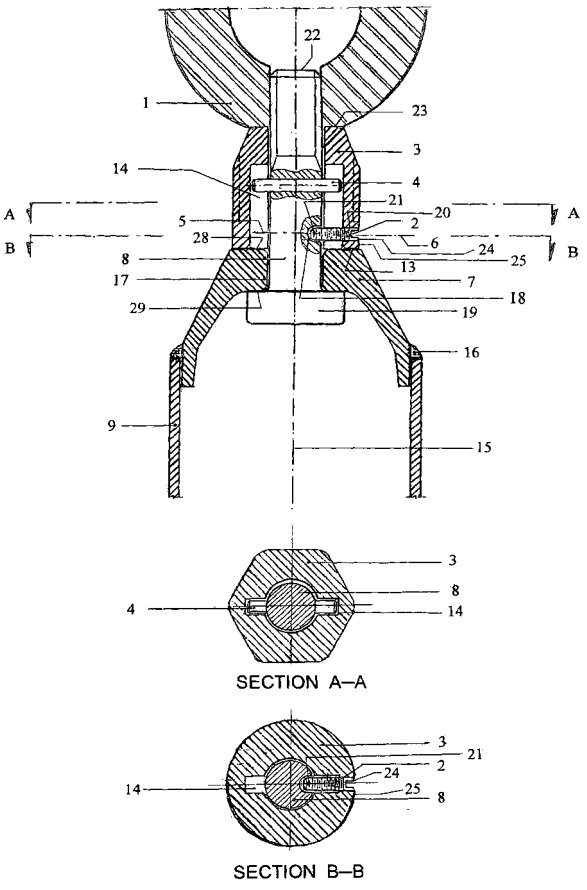


FIGURE 3

EP 1 997 972 A2

Description

Field of the Invention

[0001] The present disclosure relates to an improved mechanism having the features of the preamble of claim 1.

Background of the Invention

[0002] Mechanisms of this type are well known. They are useful for the construction of space frames of any structural form, e.g. for buildings.

[0003] The main advantage of mechanisms of this type is that there are no openings through the walls of the structural components of the tubular framework members, e.g. relatively large openings through the walls of the conical end, for the insertion of the bolts, and longitudinal slotted holes through the walls of the sleeve, for the passing through of the pin and for the longitudinal movement of the bolt with the pin with respect to the sleeve, as is shown in Figures 1, 2, 3 and 5 of document DE 901955.

[0004] In addition to the aesthetic problems, the above mentioned openings through the walls of the structural components of the tubular framework members create structural safety problems, as will be illustrated hereinafter.

[0005] In practice, a relatively large opening is made on the pipe portion of the tubular framework member for the insertion of the bolts, which reduces both the ultimate tension and the ultimate compression resistance of the pipe. In the case of compression, it is possible to have failure of the pipe due to asymmetrical local elastic-plastic buckling of the walls of the pipe ("asymmetrical" because of the fact that only one opening is provided, although claim 2 of document DE 901955 recommends symmetrical - with respect to the longitudinal axis of the tubular framework member - openings).

[0006] Furthermore, the longitudinal slotted holes through the walls of the sleeve, as in Figures 1 and 2 of document DE 901955, reduce the ultimate compression resistance of the sleeve. In this case, it is possible to have premature failure of the sleeve due to plastic buckling.

[0007] In addition to the above mentioned strength problem of the sleeve, the longitudinal slotted holes through the walls of the sleeve expose the most highly stressed portion of the bolt to the environment; thus it is possible for dust and water to collect between the bolt and the walls of the sleeve. In this case, the presence of specific chemical compounds in the environment, e.g. aqueous electrolytes, particularly when containing H_2S, may induce cracking of the bolt. This cracking (stress-corrosion cracking) may take the form of a relatively slow, stable crack extension or, as is often the case, an unpredictable catastrophic fracture. It is thus necessary to effectively protect the bolt with the pin against corrosion.

[0008] For many years, it has been the usual practice to protect the bolt with the pin against corrosion with electroplated coatings. Since, however, bolts are now made of high-strength steels, e.g. of property class 10.9, electroplating - including pickling for scale and rust removal - increases the probability for a hydrogen-induced fracture of the bolt (hydrogen embrittlement). Hydrogen embrittlement can cause dangerous and sometimes catastrophic failures, if it occurs in critical tubular framework members, particularly in wide-span roof structures. The probability of encountering hydrogen embrittlement can be reduced by using lower-strength steels, by limiting immersion times in acid or plating baths, and by in-process (intermediate) baking. According to International Standard ISO 4042:1999(E) "Fasteners - Electroplated coatings", page 3: "In cases of parts with high tensile strength or hardness or which have been surface hardened, which have absorbed hydrogen and are under tensile stress there is the risk of failure due to hydrogen embrittlement"; and, page 4: "Complete elimination of hydrogen embrittlement cannot be assured. If a reduced probability of encountering hydrogen embrittlement is desired, alternative procedures should be evaluated".

[0009] Document GR 1004166 discloses a mechanism which comprises the features of the preamble of claim 1; and document EP 0557235 B1 discloses a mechanism comprising features contained in the preamble of claim 1.

[0010] Notwithstanding the many advantages of mechanisms of this type, the problem of the confirmation - that the bolt is completely screwed into the threaded hole of the node connector - still needs to be solved.

[0011] Incomplete (i.e. less than the required) length of engagement in the threaded assembly is likely to happen under the following possible conditions: when the length of the internal thread of the node connector has been manufactured to a length shorter than the required length of engagement, when there is a manufacturing error, or damage, in the internal thread of the node connector or in the external thread of the bolt, or when the erection worker has not fully screwed the bolt into the threaded hole of the node connector. If this occurs in the assembled space frame, the corresponding mechanism cannot carry tension; and, when the space frame is loaded, the redistribution of internal forces may overload neighboring tubular framework members.

[0012] If failure of the threaded assembly should occur, it is preferable for the bolt with the pin to break rather than to have either the external or internal thread stripped; and the length of engagement of mating threads should be sufficient to carry the full load necessary to break the bolt without the threads stripping. This length determines the required length of engagement to prevent stripping of either the external or internal thread in mechanisms of this type.

Brief Description of the Invention

[0013] It is an object of the present invention to provide a solution to the problem of the confirmation that the bolt with the pin is completely screwed into the threaded hole of the node connector; and, as a consequence, that the corresponding mechanism in the assembled space frame can carry tension as well as compression.

[0014] Another object is to provide an improved mechanism which solves the connection problem of the pipe in a simple, economical and aesthetic manner; and this with a minimum number of different components.

[0015] Still another object is to provide an improved mechanism with increased structural reliability.

[0016] These objects are achieved by an improved mechanism having the features of the characterizing part of claim 1.

[0017] By rotating the sleeve, a torque is transmitted to the bolt through the pin, thus screwing the bolt into the node connector. When the bolt is fully screwed, the sleeve is in contact with both the node connector and the conical end. By applying an appropriate torque to the sleeve, the bolt with the pin tightens the node connector and the conical end on the sleeve, the bolt head being in contact with the rear bearing surface of the conical end. Next, the socket set screw is fully screwed. If the rear end of the socket set screw is at least flush with the outermost peripheral surface of the sleeve, this confirms that the bolt with the pin is completely screwed into the threaded hole of the node connector. In the assembled three-dimensional structure, tension from the pipe to the node connector, and conversely, is transmitted through the bolt; compression is transmitted through the sleeve.

[0018] Some advantages of the present invention are:

- it provides a simple, economical and aesthetic solution to the connection problem of the pipe, and this with a minimum number of different components;
- the resulting connection assembly is "closed", i.e. there are no openings through the walls of the tubular framework members, according to the valid corrosion protection standards, e.g. DIN 55928;
- the required engagement of the bolt thread into the node connector can be confirmed by visual inspection and/or by touch;
- it can be used in the realization of three-dimensional structures of any structural form, e.g. flat, cylindrical, spherical or free-form;
- the length of engagement of mating threads can be long, which assists in the realization of connections of pipes to nodes made of lower-strength material, e.g. aluminum or engineering plastic;
- due to the increased structural reliability of the connection, it is possible to realize wide span three-dimensional structures having spans wider than the spans which can be realized with the mechanisms according to the prior art.

Brief Description of the Drawings

[0019] The invention will be further described, by way of example only, with reference to the accompanying drawings wherein like elements are numbered alike in the several Figures:

Figure 1 shows part of a three-dimensional structure with node connectors and pipes, wherein the improved mechanism according to the present invention is used.

Figure 2 shows one longitudinal section and two cross-sections of the improved mechanism according to the present invention just before the start of the bolt screwing.

Figure 3 shows one longitudinal section and two cross-sections of the improved mechanism according to the present invention after the bolt and the socket set screw have been screwed.

Figure 4 shows one longitudinal section and two cross-sections of the improved mechanism according to the present invention, where the bolt is at the rearmost position with respect to the conical end of the pipe.

Detailed Description of the Invention

[0020] Hereinafter, the best mode for carrying out the present invention is described in detail.

[0021] The structure according to Figure 1 is called a three-dimensional structure or space frame and comprises the node connectors 1 and the tubular framework members 30.

[0022] The three-dimensional structure according to Figure 1 is useful for the construction of wide span roofs in buildings, such as exhibition pavilions, airport halls, covered sports facilities, shopping centers, training centers, museums, etc.

[0023] The node connectors 1 are spherical, with partial flat bearing surfaces 11, distributed on their outer surface, having radial threaded holes 10.

[0024] Each tubular framework member 30 comprises one metal pipe 9 and two improved mechanisms 12, fixed to the ends of the metal pipe 9, which connect the ends of the metal pipe 9 to the node connectors 1.

[0025] Each improved mechanism 12 comprises a bolt 8, a pin 4, a sleeve 3, a socket set screw 2 and a conical end 7.

[0026] The bolt 8 has a hole for the passing through of the pin 4 and a radial groove 18, preferably cylindrical with a bottom which has the form of a spherical cap. The axis 5 of the radial groove 18 is perpendicular to the longitudinal axis 15 of the bolt 8; and is in the same plane with the longitudinal axis 15 of the bolt 8.

[0027] The sleeve 3 has a front bearing surface 23, a

rear bearing surface 13, a longitudinal hole for the passing through of the bolt 8, two opposite longitudinal grooves 14, on the walls of the longitudinal hole, where the ends of the pin 4 move, and a radial threaded hole 20 of small diameter, which has the same circumferential position with either one of the two opposite longitudinal grooves 14, the axis 6 of which is approximately perpendicular to the longitudinal axis 15 of the bolt 8 and is in the same plane with the longitudinal axis 15 of the bolt 8. The small diameter radial threaded hole 20 is very close to the rear bearing surface 13 of the sleeve 3.

[0028] The socket set screw 2 is screwed through the radial threaded hole 20.

[0029] The conical end 7 has a longitudinal hole 17 for the passing through of the bolt 8 and is welded to the pipe 9 with a circumferential weld 16 which has preferably been ground.

[0030] The bolt 8, the sleeve 3, the conical end 7 and the pipe 9 have a common longitudinal axis 15. This common longitudinal axis 15 is the longitudinal axis of the tubular framework member 30.

[0031] The axis 5 of the radial groove 18 and the axis 6 of the radial threaded hole 20 are configured to have the same circumferential position, and the same longitudinal position exactly when the bolt 8 is fully screwed and the bolt head 19 is in contact with the rear bearing surface 29 of the conical end 7, as is shown in Figure 3.

[0032] When the bolt 8 is at the rearmost position, as shown in Figure 2, the pin 4 is in contact with the socket set screw 2, part of which is in the longitudinal groove 14 of the sleeve 3. At the moment the pin comes in contact with the socket set screw, the end of the bolt 22 of the improved mechanism 12 projects several millimeters off the front bearing surface 23 of the sleeve 3. By pushing the bolt 8 on the threaded hole 10 of the node connector 1 of the three dimensional structure and by rotating the sleeve 3, the bolt 8 is screwed and at the same time the ends of the pin 4 move in the two opposite longitudinal grooves 14 of the sleeve 3.

[0033] Just before the bolt 8 reaches the most forward position of its relative movement with respect to the conical end 7, as is shown in Figure 3, the bolt head 19 is in contact with the internal end 29 of tubular framework member 30. At the same time, the front bearing surface 28 of the conical end 7 is in contact with the rear bearing surface 13 of the sleeve 3 and the front bearing surface 23 of the sleeve 3 is in contact with the flat bearing surface 11 of the node connector 1 of the space frame. By applying an appropriate torque to the sleeve 3, e.g. using a wrench, this torque is transmitted to the bolt 8 through the pin 4, and the conical end 7 and the node connector 1 are tightened on the sleeve 3. Next, the socket set screw 2 is fully screwed.

[0034] If the rear end 24 of the socket set screw 2, after it has been fully screwed, projects outwardly from the outermost peripheral surface 25 of the sleeve3, as is shown in the longitudinal section and in the section B-B of Figure 2, this means that the bolt 8 is not fully screwed into the node connector 1.

[0035] The maximum relative displacement of the bolt 8 of the improved mechanism 12, with respect to the conical end 7, is restrained by the contact of the pin 4 on the front bearing surface 28 of the conical end 7, when the socket set screw 2 does not project into the longitudinal groove 14 of the sleeve 3, as shown in the longitudinal section and in the section B-B of Figure 4.

[0036] Towards the opposite direction, as is shown in Figure 3, this maximum relative displacement is restrained by the bearing of the head 19 of the bolt 8 on the internal end 29 of the tubular framework member 30.

[0037] Figure 4 also shows another embodiment of the improved mechanism 12 according to the present invention, in which the sleeve 3 is configured so that, when the bolt 8 is at its rearmost position with respect to the conical end 7, and the rear bearing surface 13 of the sleeve 3 is in contact with the conical end 7, the front end 22 of the bolt 8 is flush with the front bearing surface 23 of the sleeve 3. This embodiment allows for the replacement of the tubular framework member 30, e.g. in case of damage or assembly error during erection, when the tubular framework member 30 is located between two node connectors 1 which have constant distance in space, i.e. their relative positions in space with respect to time remain constant, provided that the tubular framework member 30 has not been loaded. In order to assemble the tubular framework member 30 between two node connectors 1 of constant distance, pipe 9 has a relatively small - with respect to the diameter of the pipe 9 - opening 26 so that by using a suitable tool, e.g. a long, and of small size, Allen wrench, a gentle force can be applied to the head of the bolt 8, so that the front end 22 of the bolt 8 comes into contact with the threaded hole 10 of the node connector 1 for the start of the bolt screwing. After the assembly of the space frame, the relatively small opening 26 is sealed using a plug 27 or by any other appropriate manner.

[0038] In areas with low temperatures and when it is possible for water to collect within the tubular framework member 30 (e.g. during temporary storage before erection), repeated freezing can lead to rupture of the wall of the pipe 9 through successive expansion and contraction until the elongation limit is reached. In order to prevent this phenomenon, the small opening 26 at the end of the pipe 9 is placed at the lowest relative elevation during the assembly of the space frame and is sealed using a plug 27 after the construction of the roof cladding.

[0039] The improved mechanism of Figure 4 is useful for the construction of space frames of any structural form, e.g. cylindrical, spherical or free-form.

Claims

1. An improved mechanism (12) for the connection of a pipe (9) to a node connector (1) of a three dimensional structure comprising:

- a bolt (8) with a pin (4), said bolt (8) having a hole for the passing through of said pin (4);
- a sleeve (3) configured to rotate said pin (4), said sleeve (3) having a radial threaded hole (20) and just two opposite longitudinal grooves (14) where the ends of said pin (4) move, said radial threaded hole (20) having the same circumferential position with either one of said just two opposite longitudinal grooves (14);
- a socket set screw (2) screwed through said radial threaded hole (20);
- a conical end (7) fixed to said pipe (9), said conical end (7) having a longitudinal hole (17) for the passing through of said bolt (8);

characterized in that:

- said bolt (8) has a radial groove (18) between said hole for the passing through of said pin (4) and the bolt head (19), said radial groove (18) formed by volume subtraction of a solid from the volume of said bolt (8), said solid comprising a solid of revolution; and
- said radial groove (18) and said radial threaded hole (20) have the same circumferential position; and the same longitudinal position exactly when said sleeve (3) is in contact with the front bearing surface (28) of said conical end (7), and said bolt head (19) is in contact with the rear bearing surface (29) of said conical end (7).

2. An improved mechanism (12) according to claim 1, **characterized in that** said solid further comprises a spherical cap.

3. An improved mechanism (12) according to claim 1, **characterized in that** the rear end (24) of said socket set screw (2) is at least flush with the outermost peripheral surface (25) of said sleeve (3), when the front end (21) of said socket set screw (2) is inserted into said radial groove (18), said front end (21) of said socket set screw (2) reaching the bottom of said radial groove (18).

4. An improved mechanism (12) according to claim 1, **characterized in that** the longitudinal displacement of said bolt (8) with respect to said conical end (7) is restrained:

- by the contact of said pin (4) on said socket set screw (2), the front end (21) of said socket set screw (2) projecting into said longitudinal groove (14), and said sleeve (3) being in contact with said front bearing surface (28) of said conical end (7); and, towards the opposite direction,
- by the bearing of said bolt head (19) on said rear bearing surface (29) of said conical end (7).

5. An improved mechanism (12) according to claim 1, **characterized in that** the maximum longitudinal displacement of said bolt (8) with respect to said conical end (7) is restrained:

- by the contact of said pin (4) on said front bearing surface (28) of said conical end (7), the front end of (21) of said socket set screw (2) not projecting into said longitudinal groove (14); and, towards the opposite direction,
- by the bearing of said bolt head (19) on said rear bearing surface (29) of said conical end (7).

6. An improved mechanism (12) according to claim 1, **characterized in that** the front end (22) of said bolt (8) is flush with the front bearing surface (23) of said sleeve (3), when said pin (4) is in contact with said front bearing surface (28) of said conical end (7), said sleeve (3) being in contact with said front bearing surface (28) of said conical end (7).

7. An improved mechanism (12) according to claim 1, **characterized in that** said pipe (9) has at least one radial hole (26).

8. An improved mechanism (12) according to claim 7, further comprising a sealing means (27) for said at least one radial hole (26).

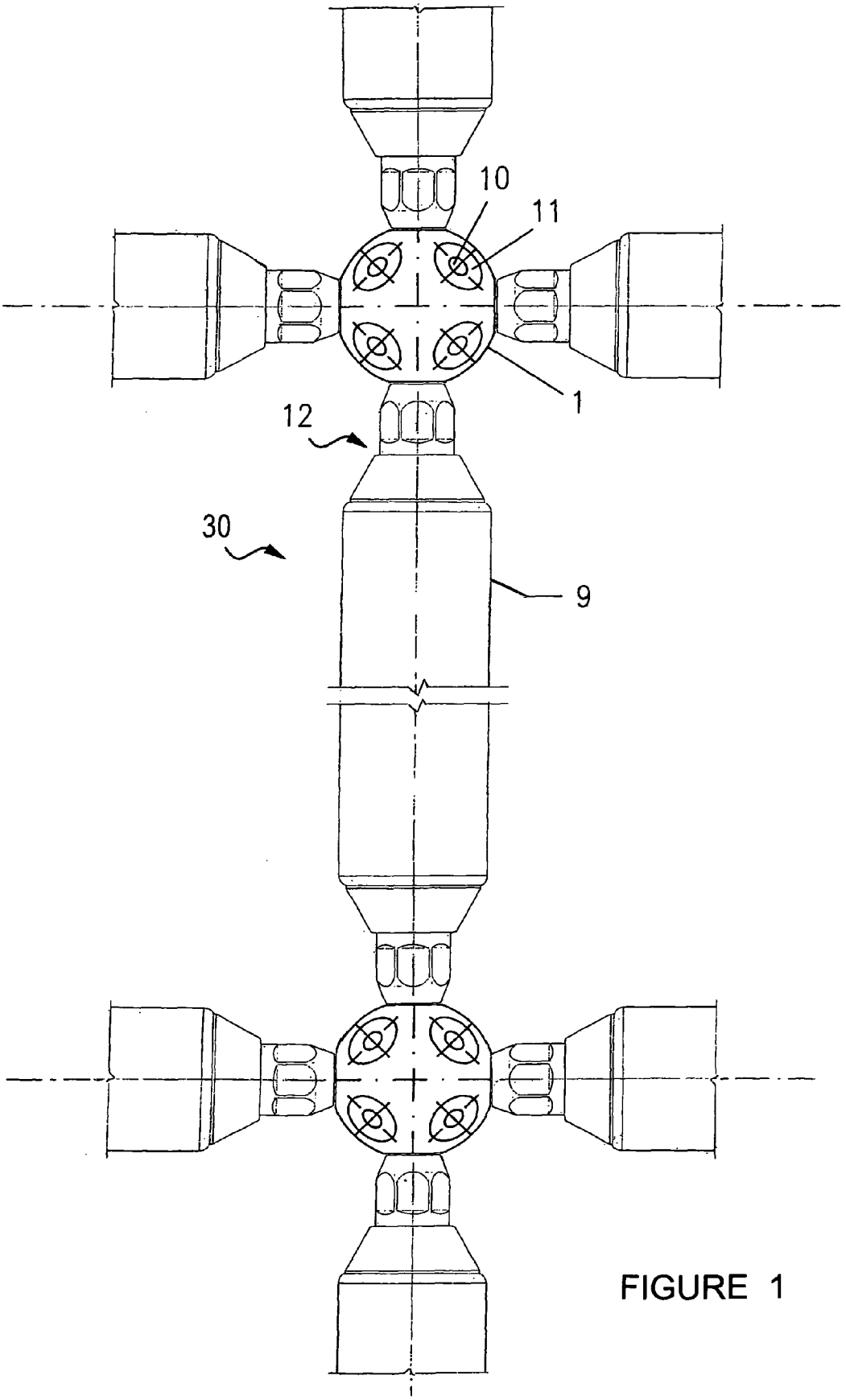
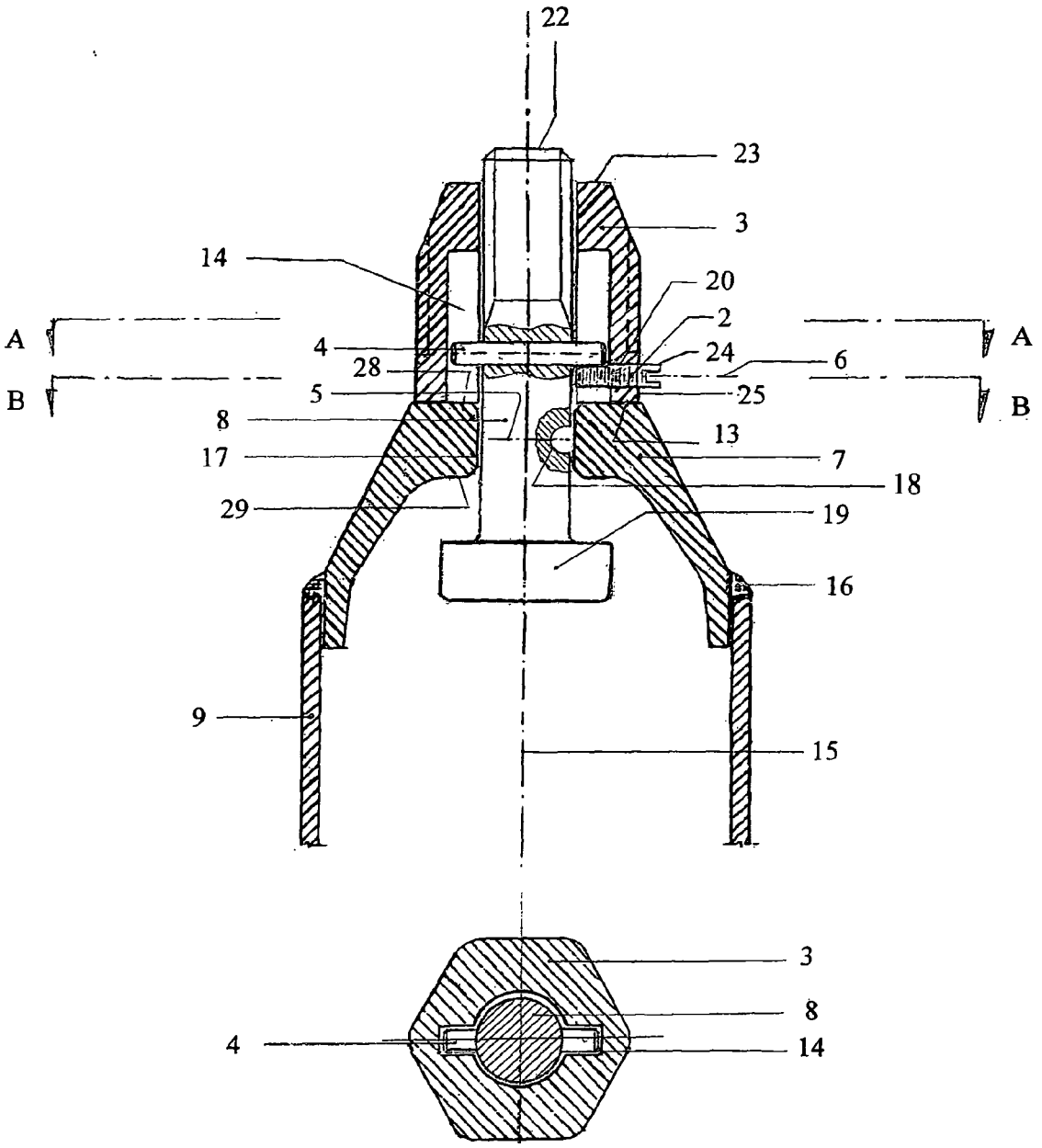
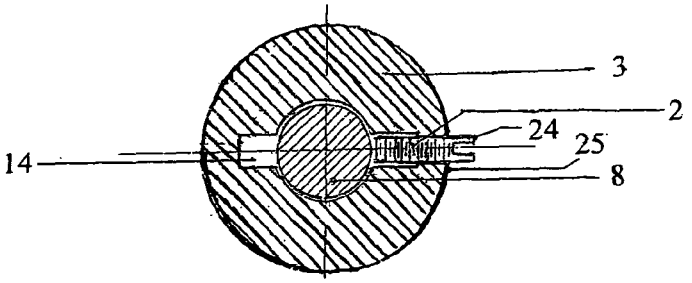


FIGURE 1



SECTION A–A



SECTION B–B

FIGURE 2

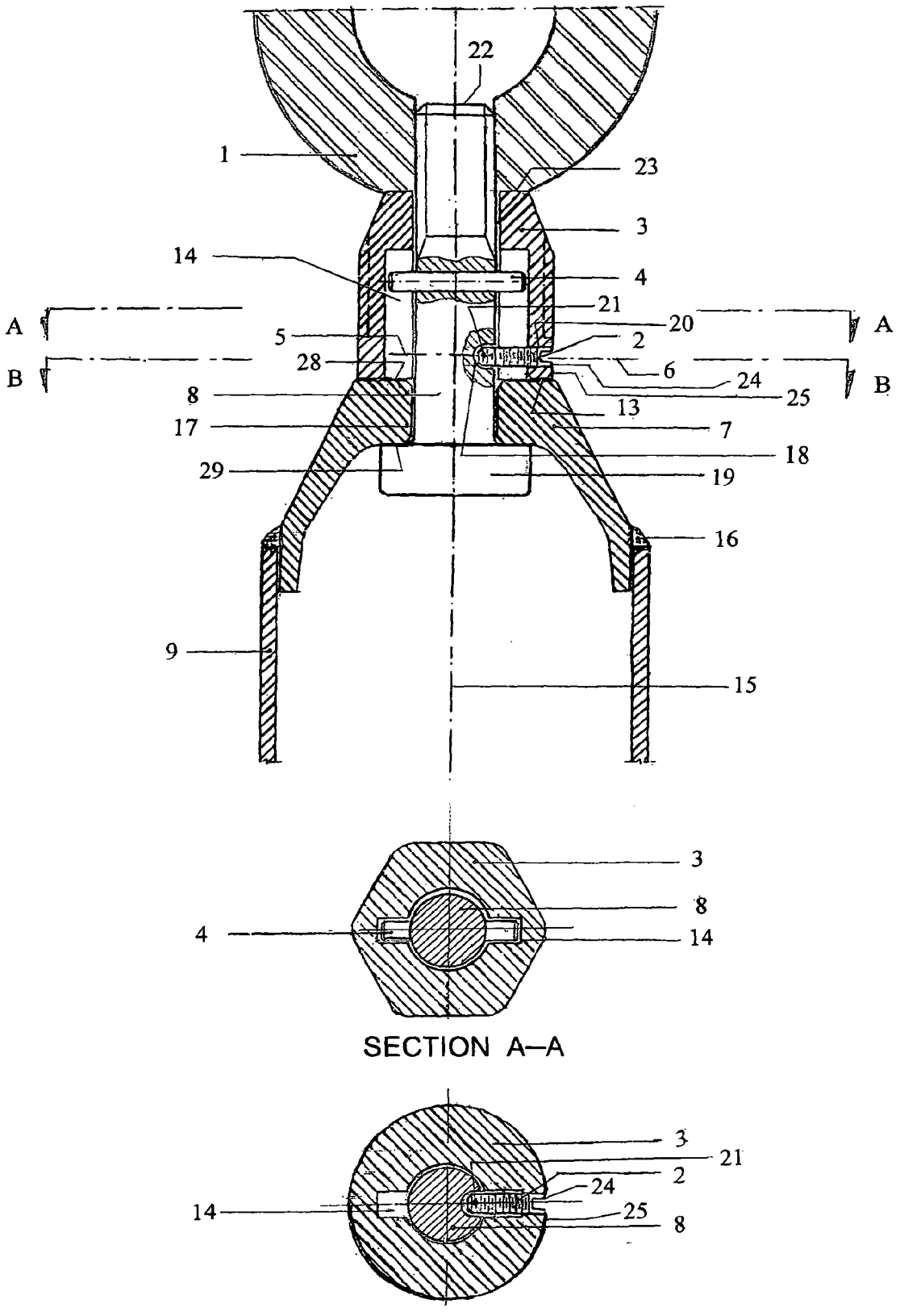

22
1
23
3
14
4
21
A
20
A
5
2
28
6
B
24
B
25
8
13
17
7
18
29
19
16
9
15
3
8
4
14
SECTION A–A
3
21
2
24
14
25
8
SECTION B–B

FIGURE 3

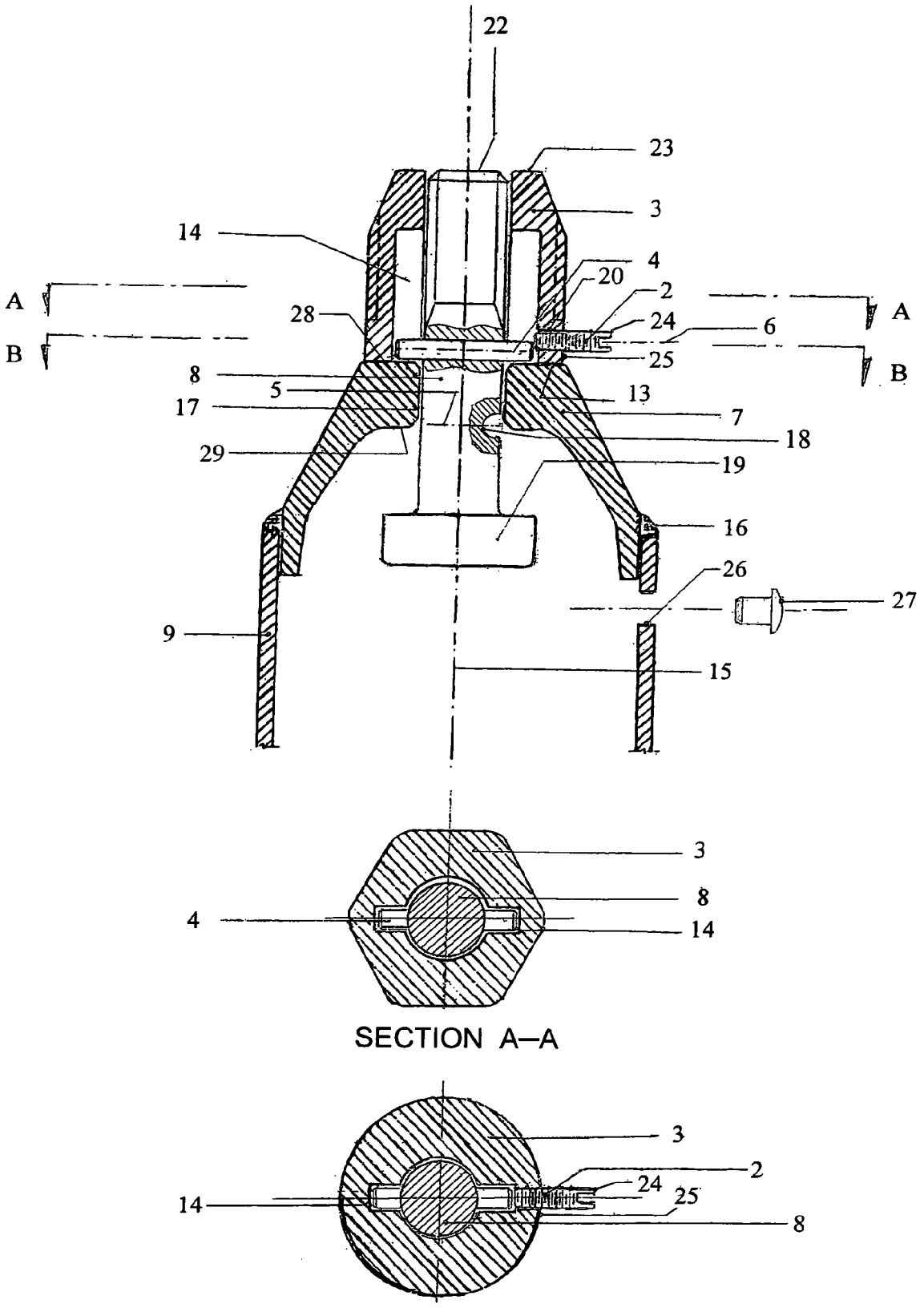

22
23
3
14
4
20
2
A
A
28
24
6
B
B
25
8
5
13
17
7
18
29
19
16
26
27
9
15
3
8
4
14
SECTION A–A
3
2
24
14
25
8
SECTION B–B

FIGURE 4

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

- DE 901955 **[0003] [0005] [0006]**
- GR 1004166 **[0009]**
- EP 0557235 B1 **[0009]**