Title: Pinion unit holding system, pinion system, rack-and-pinion type jacking system, jack-up vessel, and use

FIELD

The invention relates to a pinion unit holding system for holding a pinion unit of a rack-and-pinion type jacking system of a jack-up vessel with respect to a hull of the jack-up vessel. The invention further relates to: a pinion system comprising the pinion unit holding system; a rack-and-pinion type jacking system comprising the pinion system; a jack-up vessel provided with the jacking system; and a use of any of the systems.

BACKGROUND

Rack-and-pinion type jacking systems for jack-up vessels are known as such. Typically, racks are fixed to legs of the vessel, while pinion units are held on the vessel's hull with pinions thereof engaged with the racks, so that the legs can be raised or lowered with respect to the hull by driving the pinions. Each pinion unit typically comprises a single pinion, an associated driving motor and a transmission between motor and pinion, held together in a housing that can be stably arranged with respect to the hull.

When the motor drives rotation of the pinion, torque has to be transmitted from the motor to the pinion, while the pinion's engagement with the rack creates resistance to pinion rotation. This requires a stable holding of the pinion unit with respect to the hull, in particular in terms of transmission of a reaction torque between the pinion unit and the hull.

To provide replaceability in case of an unexpected serious failure, it may be needed or desired to be able to release the pinion unit from the hull. Therefore, permanent connections between pinion unit and hull tend to be undesired.

Meanwhile, it is desired to limit or reduce sizes and weights of parts of rack-and-pinion type jacking systems, in particular to facilitate production, installation and maintenance and to reduce material use.

In the design of known rack-and-pinion type jacking systems, the need for effective torque transmission between pinion unit and hull, the need for releasability of the pinion unit, and the need for size and weight reduction tend to compete with each other. There is a desire for improvements in this respect.

SUMMARY

An object of the invention is to provide a rack-and-pinion type jacking system for a jack-up vessel in which pinion units can be releasably held with respect to the hull with a relatively effective torque transmission therebetween in a relatively compact and light-weight manner. An object is to at least partly alleviate at least one of the above described challenges with respect to rack-and-pinion type jacking systems. An object is to at least provide an alternative rack-and-pinion type jacking system.

An aspect of the invention provides a pinion unit holding system for holding a pinion unit of a rack-and-pinion type jacking system of a jack-up vessel with respect to a hull of the jack-up vessel. The pinion unit holding system comprises a pinion unit support element configured to be fixedly arranged with respect to the hull, the pinion unit support element having a pinion unit receiving opening therein. The pinion unit holding system comprises a housing part configured to be releasably received in the pinion unit receiving opening and to form part of a housing for the pinion unit, such that a pinion rotation axis of the pinion unit extends through the pinion unit receiving opening, in particular centrally therethrough. The housing part, in particular a section thereof configured to extend in the pinion unit receiving opening, and the pinion unit receiving opening, in particular a perimeter edge or circumferential edge thereof, are both formed with a respective at least one engagement surface having a radial component with respect to the pinion rotation axis for torque transmission between the housing part and the pinion unit support element via mutual

engagement between the respective engagement surfaces, in particular as part of a holding of the pinion unit with respect to the hull by the pinion unit holding system.

Advantageously, since the engagement surfaces allow torque transmission between the housing part and the pinion unit support element via the pinion unit receiving opening, the path along which the torque transmission between the pinion unit and the pinion unit support element occurs can be relatively short and direct, which in turn allows a relatively compact and light-weight system. By contrast, in known rack-and-pinion type jacking systems, the path along which the torque transmission occurs remains at a distance from the pinion unit receiving opening, thus requiring one or more axial path sections to allow the torque to be transmitted to the support element. Typically, in known systems, the housing part comprises one or more arms that pass along one axial side of the pinion unit support element in a radially outward direction to engage with the pinion unit support element at a radially outward position from the pinion unit receiving opening. It has been found that such a relatively long and indirect path tends to result in undesired moments which then require additional material to enable sufficient strength and stiffness. The present invention is at least partly based on the insight that such moments can be avoided so as to allow a more compact and light-weight system. The engagement surfaces at the pinion unit receiving opening can be realized in various ways, as explained further elsewhere herein.

Optionally, the housing part, at least an axial section thereof, is configured to circumferentially mate with the pinion unit receiving opening, in particular such that respective engagement surfaces circumferentially face each other. Optionally, a circumferentially variable outer radius of the housing part substantially matches a circumferentially variable radius of the pinion unit receiving opening, wherein the circumferential variation of the radii can provide respective engagement surfaces. Optionally, a

transverse outer shape of a section of the housing part that during use extends within the pinion unit receiving opening substantially matches a transverse shape of the pinion unit receiving opening, wherein sections of the transverse shapes that have a radial component can provide respective engagement surfaces.

In this way, advantageously, torque and/or other loads may be transmitted between the housing part and the pinion unit receiving element at many circumferential positions, thereby enabling a relatively well distributed transmission.

Optionally, the at least one respective engagement surface comprises a series of engagement surfaces that are distributed along one or more circumferential ranges with respect to the pinion rotation axis. Such a circumferential range may correspond to an angular range of 10 to 360 degrees, for example.

In this way, the torque transmission can benefit from the circumferential extent of the pinion unit receiving opening to facilitate relatively effective torque transmission in a relatively compact and light-weight manner.

Optionally, the engagement surfaces are uniformly distributed along the circumferential range.

In this way, the torque transmission can be relatively homogeneous and benefit particularly well from the circumferential extent of the pinion unit receiving opening.

Optionally, the engagement surfaces are arranged to limit rotational play between the housing part and the pinion unit support element to correspond to a circumferential distance of at most 5 mm, preferably at most 3 mm, more preferably at most 2 mm, for example about 1 mm.

In this way, the pinion unit can be held relatively stably, in particular in terms of bidirectional rotational stability. Meanwhile, a small

amount of rotational play may facilitate releasability of the housing part from the pinion unit receiving opening, e.g. for maintenance purposes. Therefore, optionally, the engagement surfaces are arranged to allow the limited rotational play between the housing part and the pinion unit support element.

Optionally, the engagement surfaces within the series mutually overlap, in particular are mutually aligned, along the pinion rotation axis.

In this way, torque can be transmitted particularly effectively and efficiently.

Optionally, at least one of the housing part and the pinion unit receiving opening is formed with at least one respective radially extending cam on which at least one of the respective at least one engagement surface is formed.

Advantageously, such cams allow engagement surfaces to have a relatively large radial component, in particular without a correspondingly large tangential component or large interspacing between adjacent engagement surfaces. The torque transmission can thus be particularly effective in relation to size and weight of associated parts of the system.

Optionally, at least some of the engagement surfaces extend substantially radially with respect to the pinion rotation axis.

Such engagement surfaces are especially effective for torque transmission, in particular in relation to their size. Nevertheless, alternatively or additionally, some engagement surfaces may have a non-radial component in addition to their radial component. For example, optionally, at least some of the engagement surfaces extend substantially tangentially with respect to the pinion rotation axis.

Optionally, the at least one engagement surface of the pinion unit receiving opening is arranged centrally with respect to the pinion unit receiving opening along the pinion rotation axis.

In this way, the torque transmission to the pinion unit support element can be relatively direct and well balanced, thereby reducing undesired moments that would then require additional material.

Optionally, an axial thickness of the pinion unit support element is locally enlarged at the pinion unit receiving opening, wherein preferably an axial size of the at least one engagement surface of the pinion unit receiving opening corresponds to the locally enlarged thickness.

In this way, the pinion unit support element can be relatively strong and stiff at the pinion unit receiving opening, i.e. where the engagement surfaces are arranged and where the torque transmission is most concentrated, whereas the pinion unit support element can otherwise be relatively compact, e.g. thin, and light-weight.

Optionally, the pinion unit receiving opening is formed in a ring part of the pinion unit support element that in turn is arranged or arrangeable in an opening in a plate part of the pinion unit support element, the ring part being fixed or fixable to the plate part, in particular by welding, and the plate part preferably being arranged centrally with respect to a plane in which the plate part extends.

In this way, the engagement surfaces of the pinion unit receiving opening can be produced relatively economically. Meanwhile, the ring part can advantageously provide the preferred locally increased thickness. As a less preferred yet possible alternative to the locally increased thickness, an overall thickness of the pinion unit support element, e.g. in the form of a plate part, could be made relatively large, e.g. to provide a relatively simple construction of the pinion unit support element.

Optionally, the housing part extends between a first axial end and an opposite second axial end, wherein the at least one engagement surface of the housing part is arranged at the first axial end, spaced apart from the second axial end.

In this way, the housing part can form part of the housing for the pinion unit along an axial range substantially bound by the axial position of the pinion unit receiving opening.

Optionally, the housing part has a larger inner diameter at the second axial end compared to the first axial end.

In this way, the pinion unit receiving opening can be relatively moderately sized while the pinion unit can still be relatively wide.

Optionally, an axial section of the housing part has a substantially frustoconical shape.

In this way, a combination of different diameters of the housing part can be provided in a strong and stable manner with a relatively small amount of material. The axial section may axially extend along at least 30%, preferably at least 40%, for example about 50% of the axial size of the housing part.

Optionally, a pinion of the pinion unit is arranged to be coupled to a motor of the pinion unit on an axial side of the pinion unit corresponding to the second axial end of the housing part. Optionally, a pinion of the pinion unit is arranged to engage with a rack of the rack-and-pinion type jacking system on an axial side of the pinion unit corresponding to the first axial end of the housing part.

In this way, the housing part can facilitate torque transmission and other load transmission at an axial position relatively close to where the pinion engages the rack, so as to limit warping in the pinion unit.

Optionally, the housing part is configured to surround a shaft section of a pinion of the pinion unit. Optionally, a bearing for the pinion is arranged between the shaft section and the housing part. Optionally, along the pinion rotation axis, the bearing is arranged centrally with respect to the at least one engagement surface of the housing part.

In this way, load from the pinion can be transmitted to the pinion unit support element relatively effectively and directly.

Optionally, the pinion unit holding system is configured to inhibit axial movement between the pinion unit and the pinion unit support element.

In this way, axial stability of the pinion unit with respect to the hull can be provided, thereby promoting stable engagement of the pinion with the rack for jacking. The inhibition of axial movement is preferably selective in the sense that it can be released if and when needed to allow the pinion unit to be released from the pinion unit receiving opening, e.g. for maintenance purposes. For example, the inhibition of axial movement may be provided by axially extending bolts connecting the housing part to the pinion unit support element at a distance from the pinion unit receiving opening. Alternatively or additionally, a releasable axial locking may be provided, e.g. at an axial end of the pinion of the pinion unit.

Optionally, the housing part has one or more tool engagement structures for engagement by a pinion unit release tool for releasing the housing part from the pinion unit receiving opening. For example, as a tool engagement structure, a circumferential flange may be provided axially spaced apart from the engagement surfaces, in particular for engagement by a pinion unit release tool that may be arranged between the flange and the pinion unit support element to exert an axial pushing force therebetween. In this way, releasability of the pinion unit can be facilitated.

Optionally, the pinion unit support element is part of a pinion unit support structure that comprises a further pinion unit support element axially spaced apart from the pinion unit support element, in particular so that a pinion of the pinion unit is arranged to engage with a rack of the rack-and-pinion type jacking system at an axial position between the pinion unit support element and the further pinion unit support element.

Such a further pinion unit support element can advantageously enable support of the pinion unit at a further axial position, thereby

promoting pinion unit stability and reducing moments at the pinion unit support element.

A further aspect provides a pinion system for a rack-and-pinion type jacking system of a jack-up vessel, comprising: a pinion unit holding system as described herein; and the pinion unit. The pinion unit preferably comprises a pinion, a driving motor for driving the pinion and a transmission between the motor and the pinion. Advantages of such a pinion system correspond to those described above for the pinion unit holding system.

Preferably, the pinion unit comprises a single pinion for engagement with a rack of the jacking system. Thus, each pinion of the jacking system may be part of a respective pinion unit and be associated with a respective motor and transmission.

Preferably, the housing part and the pinion unit support element are configured to additionally provide radial load transmission therebetween, for example between radially inward facing ends of cams of the pinion unit support element and corresponding radially outward facing surfaces between cams of the housing part. In this way, transverse loads between pinion unit and pinion unit support element can be transmitted relatively directly, in particular without excessive use of the engagement surfaces that provide torque transmission. Transverse loads may in particular be present as so-called jacking loads, i.e. loads associated with supporting the hull on the legs and adjusting the levels of the hull and the legs with respect to each other. In known systems, the interface between the housing part and the pinion unit receiving opening allows transmission of such transverse loads without allowing any torque transmission. Advantageously, the present invention allows these types of transmissions to be provided essentially by a same circumferential interface.

Preferably, the mutual engagement between the respective engagement surfaces of the housing part and the pinion unit receiving

opening is a non-resilient mutual engagement. Thereto, the pinion unit holding system is preferably free from resilient material between the respective engagement surfaces. In this way, torque can be transmitted particularly effectively and robustly.

A further aspect provides a rack-and-pinion type jacking system for a jack-up vessel, comprising a pinion system as described herein; and a rack configured to be fixedly arranged with respect to a leg of the jack-up vessel to be engageable by a pinion of the pinion unit for jacking of the jack-up vessel. Advantages of such a jacking system correspond to those described above for the pinion unit holding system.

A further aspect provides a jack-up vessel provided with a rack-and-pinion type jacking system as described herein. Advantages of such a jack-up vessel correspond to those described above for the pinion unit holding system.

A further aspect provides a use of a pinion unit holding system, a pinion system, and/or a rack-and-pinion type jacking system as described herein, wherein, during the jacking, torque is transmitted between the housing part and the pinion unit support element via the mutual engagement between the respective engagement surfaces, in particular as part of a holding of the pinion unit with respect to the hull by the pinion unit holding system. Advantages of such a use correspond to those described above for the pinion unit holding system.

It shall be appreciated that the aspects and options described herein can be mutually combined.

DETAILED DESCRIPTION

In the following, the invention will be explained further using examples of embodiments and drawings. The drawings are schematic and merely show examples. In the drawings, corresponding elements are indicated with corresponding reference signs. For clarity of the drawings, where multiple elements of the same type are shown in a same figure, in some cases only one or some of such elements are indicated with a reference sign. In the drawings:

Fig. 1 shows a side view in cross section of a jack-up vessel;

Fig. 2 shows a top view in cross section of a rack-and-pinion type jacking system associated with a leg of the jack-up vessel;

Fig. 3 shows a top view in cross section of a pinion system of the rack-and-pinion type jacking system;

Fig. 4 shows a perspective view of the pinion system;

Fig. 5 shows a perspective view of a pinion unit holding system for the pinion system, wherein the housing part is received in the pinion unit receiving opening;

Fig. 6 shows a perspective view of the pinion unit holding system, wherein the housing part is released from the pinion unit receiving opening;

Fig. 7 shows a top view of the pinion unit holding system in the state of Fig. 5;

Fig. 8 shows a top view of the housing part of the pinion unit holding system;

Fig. 9 shows a cross sectional side view of the pinion unit holding system in the state of Figs. 5 and 7 along the line IX-IX in Fig 8;

Fig. 10 shows side views of possible variations of the pinion unit holding system, in particular with respect to the engagement surfaces; and

Fig. 11 shows a detail XI of Fig. 9.

The figures illustrate examples of a pinion unit holding system 1 for holding a pinion unit 2 of a rack-and-pinion type jacking system 3 of a

jack-up vessel 4 with respect to a hull 5 of the jack-up vessel 4. The pinion unit holding system 1 comprises a pinion unit support element 6 configured to be fixedly arranged with respect to the hull 5, the pinion unit support element 6 having a pinion unit receiving opening 7 therein. The pinion unit holding system 1 comprises a housing part 8 configured to be releasably received in the pinion unit receiving opening 7 and to form part of a housing for the pinion unit 2, such that a pinion rotation axis R of the pinion unit 2 extends through the pinion unit receiving opening 7, in particular centrally therethrough. The housing part 8, in particular a section thereof configured to extend in the pinion unit receiving opening 7, and the pinion unit receiving opening 7, in particular a perimeter edge or circumferential edge 9 thereof, are both formed with a respective at least one engagement surface 10 having a radial component with respect to the pinion rotation axis R for torque transmission between the housing part 8 and the pinion unit support element 6 via mutual engagement between the respective engagement surfaces 10, in particular as part of a holding of the pinion unit 2 with respect to the hull 5 by the pinion unit holding system 1.

The figures also illustrate examples of a pinion system 11 for a rack-and-pinion type jacking system 3 of a jack-up vessel 4, comprising the pinion unit holding system 1 and the pinion unit 2.

The figures also illustrate examples of a rack-and-pinion type jacking system 3 for a jack-up vessel 4, comprising the pinion system 11 and a rack 12 configured to be fixedly arranged with respect to a leg 13 of the jack-up vessel 4 to be engageable by a pinion 14 of the pinion unit 2 for jacking of the jack-up vessel 4.

The figures also illustrate a jack-up vessel 4 provided with the rack-and-pinion type jacking system 3.

For clarity of the drawing, in Fig. 2, only pinion systems 11 and associated elements for one of the three racks 12 have been indicated with reference signs, wherein it shall be appreciated that corresponding

arrangements are shown in Fig. 2 at the other two racks 12. Further for clarity of the drawings, in Figs. 6 and 8 to 11, only some of the shown engagement surfaces 10 and cams 15 have been indicated with reference signs, wherein it shall be appreciated that similar further engagement surfaces and cams are shown in the same figures.

Although Figs. 5 to 9 relate to the same example, from the six different examples (a) to (f) shown in Fig. 10, it shall be appreciated that many different variants are possible with respect to the configuration of the engagement surfaces 10, as explained further elsewhere herein.

In the shown examples, the housing part 8, in particular an axial section thereof adjacent a first axial end 18, is configured to circumferentially mate with the pinion unit receiving opening 7, in particular such that respective engagement surfaces 10 circumferentially face each other. In other words, in the shown examples, a circumferentially variable outer radius of the housing part 8 substantially matches a circumferentially variable radius of the pinion unit receiving opening 7, wherein the circumferential variation of the radii can provide respective engagement surfaces 10. In still other words, in the shown examples, a transverse outer shape of a section of the housing part 8 that during use extends within the pinion unit receiving opening 7 substantially matches a transverse shape of the pinion unit receiving opening, wherein sections of the transverse shapes that have a radial component can provide respective engagement surfaces 10.

In the shown examples, the at least one respective engagement surface 10 comprises a series of engagement surfaces 10 that are distributed along one or more circumferential ranges with respect to the pinion rotation axis R. In the shown examples except examples (e) and (f) of Fig. 10, the engagement surfaces 10 are uniformly distributed along a full circumferential range. In example (f) of Fig. 10, the engagement surfaces

are uniformly distributed along two circumferential ranges each corresponding to an angular range of about 90 degrees.

Optionally, the engagement surfaces 10 are arranged to limit rotational play between the housing part 8 and the pinion unit support element 6 to correspond to a circumferential distance of at most 5 mm, preferably at most 3 mm, more preferably at most 2 mm, for example about 1 mm.. Such play is not shown in the figures but can be realized in a straight forward manner by appropriate dimensioning.

In the shown examples, the engagement surfaces 10 within the series mutually overlap, in particular are mutually aligned, along the pinion rotation axis R.

Preferably, as best seen in Fig. 11 as an example, the housing part 8 and the pinion unit support element 6 are configured to additionally provide radial load transmission therebetween. In some embodiments, for example as shown in Fig. 11, said radial load transmission may be between radially inward facing ends of cams 15 of the pinion unit support element 6 and corresponding radially outward facing surfaces between cams 15 of the housing part 8. Alternatively, for example, said radial load transmission may be between radially outward facing ends of cams of the housing part and corresponding radially inward facing surfaces between cams of the pinion unit support element. In this way, transverse loads such as jacking loads between pinion unit 2 and pinion unit support element 6 can be transmitted relatively directly, in particular without excessive use of the engagement surfaces 10 that provide torque transmission. Crowning and/or end relief, known as such from the field of gear teeth design, may be applied to some or all of the cams 15, in particular to those cams whose outward facing ends are involved in the radial load transmission as described.

Optionally, as illustrated in Fig. 11 as an example, oxidation resistant cladding 30, e.g. from bronze, may be provided at one or more of the engagement surfaces 10 and/or at surfaces providing radial load

transmission. In this way, attachment of the opposing surfaces by oxidation may be prevented to facilitate releasability of the housing part 8 from the pinion unit receiving opening 7. Alternatively or additionally, such releasability may be facilitated by rotational play as explained elsewhere herein. In that case, the attachment by oxidation can be released by driving the pinion unit 2 in a rotational direction that moves the relevant surfaces apart using the rotational play.

In the example of Figs. 5 to 9 and examples (c) to (f) of Fig. 10, at least one of the housing part 8 and the pinion unit receiving opening 7 is formed with at least one respective radially extending cam 15 on which at least one of the respective at least one engagement surface 10 is formed.

In the example of Figs. 5 to 9, at least some of the engagement surfaces 10 extend substantially radially with respect to the pinion rotation axis R. In examples (a) and (b) of Fig. 10, at least some of the engagement surfaces 10 extend substantially tangentially with respect to the pinion rotation axis R.

In the shown examples, the at least one engagement surface 10 of the pinion unit receiving opening 7 is arranged centrally with respect to the pinion unit receiving opening 7 along the pinion rotation axis R.

In the shown examples, an axial thickness of the pinion unit support element 6 is locally enlarged at the pinion unit receiving opening 7, wherein preferably an axial size of the at least one engagement surface 10 of the pinion unit receiving opening 7 corresponds to the locally enlarged thickness.

In the shown examples, the pinion unit receiving opening 7 is formed in a ring part 16 of the pinion unit support element 6 that in turn is arranged in an opening in a plate part 17 of the pinion unit support element 6, the ring part 16 being fixed or fixable to the plate part 17, in particular by welding, and the ring part 16 preferably being arranged centrally with respect to a plane P in which the plate part 17 extends.

In the shown examples, the housing part 8 extends between a first axial end 18 and an opposite second axial 19 end, wherein the at least one engagement surface 10 of the housing part 8 is arranged at the first axial end 18, spaced apart from the second axial end 19.

In the shown examples, the housing part 8 has a larger inner diameter at the second axial 19 end compared to the first axial end 18. In the shown examples, an axial section 20 of the housing part 8 has a substantially frustoconical shape. In the shown examples, a pinion 14 of the pinion unit 2 is arranged to be coupled to a motor 21 of the pinion unit 2 on an axial side of the pinion unit 2 corresponding to the second axial end 19 of the housing part 8. Such coupling may be provided by a transmission 29, e.g. as shown in Fig. 4. In the shown examples, a pinion 14 of the pinion unit 2 is arranged to engage with a rack 12 of the rack-and-pinion type jacking system 3 on an axial side of the pinion unit 2 corresponding to the first axial end 18 of the housing part 8.

In the shown examples, the housing part 8 is configured to surround a shaft section 22 of a pinion 14 of the pinion unit 2. In the example of Fig. 3, a bearing 23 for the pinion 14 is arranged between the shaft section 22 and the housing part 8. In the example of Fig. 3, along the pinion rotation axis R, the bearing 23 is arranged centrally with respect to the at least one engagement surface 10 of the housing part 8.

In the example of Fig. 4, the pinion unit holding system 1 is configured to inhibit axial movement between the pinion unit 2 and the pinion unit support element 6, in particular using axially extending bolts 28 engaged with the pinion unit support element 6 and with ears 27 of the housing part 8. Alternatively or additionally, for example, a releasable axial locking arrangement may be provided at the optional further bearing 26 arranged between the pinion 14 and a further pinion unit support element 25 as indicated in Fig. 3. As explained in the summary section above, to facilitate releasability, the housing part 8 may have one or more tool

engagement structures such as a circumferential flange, which may for example be arranged at the second axial end 19.

In the example of Figs. 3 and 4, the pinion unit support element 6 is part of a pinion unit support structure 24 that comprises a further pinion unit support element 25 axially spaced apart from the pinion unit support element 6, in particular so that a pinion 14 of the pinion unit 2 is arranged to engage with a rack 12 of the rack-and-pinion type jacking system 3 at an axial position between the pinion unit support element 6 and the further pinion unit support element 25. As may be understood from Fig. 2, also in a more general sense pinion unit support structures 24 and/or pinion unit support elements 6 thereof for adjacent pinion units 2 may be interconnected and/or integrally formed, e.g. so as to share one or more common plates and/or frame members.

In view of the present description, it shall be appreciated that the pinion unit holding system 1, the pinion system 11 and/or the rack-and-pinion type jacking system 3 may thus be used for jacking of a jack-up vessel 4, wherein, during the jacking, torque is transmitted between the housing part 8 and the pinion unit support element 6 via the mutual engagement between the respective engagement surfaces 10, in particular as part of a holding of the pinion unit 2 with respect to the hull 5 by the pinion unit holding system 1.

With reference to Fig. 3, when the pinion 14 is engaged with the rack 12 (shown in Fig. 2), the rack 12 may exert some sideways load on the pinion 14 that urges the pinion 14 to rotate about a vertical axis, illustrated in an exaggerated manner in Fig. 3 by an angle $\alpha$. Advantageously, the pinion holding system 1 can tolerate such effects relatively well without compromising strength or stability and without requiring excessive material. By contrast, in known systems with less direct torque transmission, such effects tend to result in adverse moments in the system, in particular in a transmission between a motor and associated pinion.

Although the invention has been explained herein with reference to examples of embodiments and drawings, it shall be appreciated that these do not limit the scope of the invention as determined by the claims. Within said scope, many variations, combinations and extensions are possible, as shall be understood by the skilled person having the benefit of the present disclosure. For example, one or more of the engagement surfaces may be part of a curved surface having a radial component at least at one or more positions along the curved surface. In addition to the engagement surfaces as described herein, a pinion holding system according to the invention may or may not comprise additional means for torque transmission between the housing part and the pinion unit support element. Such additional means may or may not be arranged centrally with respect to the pinion unit receiving opening along the pinion rotation axis. All such variants are included within the scope of the invention as determined by the claims.

LIST OF REFERENCE SIGNS

1. Pinion unit holding system
2. Pinion unit
3. Rack-and-pinion type jacking system
4. Jack-up vessel
5. Hull
6. Pinion unit support element
7. Pinion unit receiving opening
8. Housing part
9. Edge of pinion unit receiving opening
10. Engagement surface
11. Pinion system
12. Rack
13. Leg
14. Pinion

15. Cam
16. Ring part
17. Plate part
18. First axial end
19. Second axial end
20. Axial section
21. Motor
22. Shaft section
23. Bearing
24. Pinion unit support structure
25. Further pinion unit support element
26. Further bearing
27. Ear
28. Bolt
29. Transmission
30. Cladding

P. Plane in which plate part extends

R. Pinion rotation axis

Claims

1. Pinion unit holding system for holding a pinion unit of a rack-and-pinion type jacking system of a jack-up vessel with respect to a hull of the jack-up vessel, comprising:

- a pinion unit support element configured to be fixedly arranged with respect to the hull, the pinion unit support element having a pinion unit receiving opening therein;

- a housing part configured to be releasably received in the pinion unit receiving opening and to form part of a housing for the pinion unit, such that a pinion rotation axis of the pinion unit extends through the pinion unit receiving opening,

wherein the housing part and the pinion unit receiving opening are both formed with a respective at least one engagement surface having a radial component with respect to the pinion rotation axis for torque transmission between the housing part and the pinion unit support element via mutual engagement between the respective engagement surfaces, in particular as part of a holding of the pinion unit with respect to the hull by the pinion unit holding system.

2. Pinion unit holding system according to claim 1, wherein:

- the housing part, at least an axial section thereof, is configured to circumferentially mate with the pinion unit receiving opening, in particular such that respective engagement surfaces circumferentially face each other; and/or

- a circumferentially variable outer radius of the housing part substantially matches a circumferentially variable radius of the pinion unit receiving opening, in particular wherein the circumferential variation of the radii provides respective engagement surfaces; and/or

- a transverse outer shape of a section of the housing part that during use extends within the pinion unit receiving opening substantially matches a transverse shape of the pinion unit receiving opening, in particular wherein sections of the transverse shapes that have a radial component provide respective engagement surfaces.

3. Pinion unit holding system according to claim 1 or 2, wherein the at least one respective engagement surface comprises a series of engagement surfaces that are distributed along one or more circumferential ranges with respect to the pinion rotation axis.

4. Pinion unit holding system according to any of the preceding claims, wherein the engagement surfaces are arranged to limit rotational play between the housing part and the pinion unit support element to correspond to a circumferential distance of at most 5 mm, preferably at most 3 mm, more preferably at most 2 mm, for example about 1 mm.

5. Pinion unit holding system according to any of the preceding claims, wherein at least one of the housing part and the pinion unit receiving opening is formed with at least one respective radially extending cam on which at least one of the respective at least one engagement surface is formed.

6. Pinion unit holding system according to any of the preceding claims, wherein at least some of the engagement surfaces extend substantially radially with respect to the pinion rotation axis.

7. Pinion unit holding system according to any of the preceding claims, wherein at least some of the engagement surfaces extend substantially tangentially with respect to the pinion rotation axis.

8. Pinion unit holding system according to any of the preceding claims, wherein the at least one engagement surface of the pinion unit receiving opening is arranged centrally with respect to the pinion unit receiving opening along the pinion rotation axis.

9. Pinion unit holding system according to any of the preceding claims, wherein an axial thickness of the pinion unit support element is locally enlarged at the pinion unit receiving opening, wherein preferably an axial size of the at least one engagement surface of the pinion unit receiving opening corresponds to the locally enlarged thickness.

10. Pinion unit holding system according to any of the preceding claims, wherein the pinion unit receiving opening is formed in a ring part of the pinion unit support element that in turn is arranged or arrangeable in an opening in a plate part of the pinion unit support element, the ring part being fixed or fixable to the plate part, in particular by welding, and the ring part preferably being arranged centrally with respect to a plane in which the plate part extends.

11. Pinion unit holding system according to any of the preceding claims, wherein the housing part extends between a first axial end and an opposite second axial end, wherein the at least one engagement surface of the housing part is arranged at the first axial end, spaced apart from the second axial end.

12. Pinion unit holding system according to claim 11, wherein the housing part has a larger inner diameter at the second axial end compared to the first axial end.

13. Pinion unit holding system according to claim 11 or 12, wherein an axial section of the housing part has a substantially frustoconical shape.

14. Pinion unit holding system according to any of claim 11 – 13, wherein a pinion of the pinion unit is arranged to be coupled to a motor of the pinion unit on an axial side of the pinion unit corresponding to the second axial end of the housing part.

15. Pinion unit holding system according to any of claims 11 – 14, wherein a pinion of the pinion unit is arranged to engage with a rack of the rack-and-pinion type jacking system on an axial side of the pinion unit corresponding to the first axial end of the housing part.

16. Pinion unit holding system according to any of the preceding claims, wherein the housing part is configured to surround a shaft section of a pinion of the pinion unit.

17. Pinion unit holding system according to claim 16, wherein a bearing for the pinion is arranged between the shaft section and the housing part.

18. Pinion unit holding system according to claim 17, wherein, along the pinion rotation axis, the bearing is arranged centrally with respect to the at least one engagement surface of the housing part.

19. Pinion unit holding system according to any of the preceding claims, configured to inhibit axial movement between the pinion unit and the pinion unit support element.

20. Pinion unit holding system according to any of the preceding claims, wherein the pinion unit support element is part of a pinion unit support structure that comprises a further pinion unit support element axially spaced apart from the pinion unit support element, in particular so that a pinion of the pinion unit is arranged to engage with a rack of the rack-and-pinion type jacking system at an axial position between the pinion unit support element and the further pinion unit support element.

21. Pinion unit holding system according to any of the preceding claims, wherein the housing part and the pinion unit support element are configured to additionally provide radial load transmission therebetween.

22. Pinion system for a rack-and-pinion type jacking system of a jack-up vessel, comprising:

- a pinion unit holding system according to any of the preceding claims; and
- the pinion unit.

23. Rack-and-pinion type jacking system for a jack-up vessel, comprising:

- a pinion system according to claim 22; and
- a rack configured to be fixedly arranged with respect to a leg of the jack-up vessel to be engageable by a pinion of the pinion unit for jacking of the jack-up vessel.

24. Jack-up vessel provided with a rack-and-pinion type jacking system according to claim 23.

25. Use of a pinion unit holding system according to any of claims 1 – 21, a pinion system according to claim 22, and/or a rack-and-pinion type

jacking system according to claim 23 for jacking of a jack-up vessel, wherein, during the jacking, torque is transmitted between the housing part and the pinion unit support element via the mutual engagement between the respective engagement surfaces, in particular as part of a holding of the pinion unit with respect to the hull by the pinion unit holding system.