

Marine fender load monitoring

Field of the invention

The present invention relates to methods and systems for monitoring the load on marine fenders.

Background of the invention

- 5 Marine fenders are commonly used to protect infrastructure and vessels during the docking of a vessel and whilst the vessel remains docked.

The infrastructure, which may (for example) be a jetty, a bulk goods terminal, a container terminal, a passenger terminal, a dolphin structure or similar, is typically provided with one or more marine fenders. When a vessel docks it will typically impact on the fender(s), with the
10 force and direction of the impact on a given fender varying depending on a number of factors such as the size and type of the vessel in question, the loading of the vessel, pilot skill, and weather or water conditions. Whilst docked a vessel will generally move about and continue to impact the fenders and/or maintain contact with the fenders and continue to bear against them. This movement may be due, for example, to tides, currents, winds, and/or the loading or
15 unloading of cargo.

Marine fenders commonly have a facing assembly including a face element against which a vessel impacts or bears during docking and whilst docked, and one or more fender elements positioned between the face element and the infrastructure. When a vessel impacts/bears upon the face element the fender element absorbs forces generated (typically by compressing and/or
20 deflecting). This serves to protect both the infrastructure and the vessel itself.

It would be advantageous to be able to monitor forces borne by marine fenders during the docking of a vessel and/or whilst the vessel remains docked.

Reference to any prior art in the specification is not, and should not be taken as, an acknowledgment or any form of suggestion that this prior art forms part of the common general
25 knowledge in Australia or any other jurisdiction or that this prior art could reasonably be expected to be ascertained, understood and regarded as relevant by a person skilled in the art.

Summary of the invention

In one aspect the present invention provides a marine fender for mounting to a structure, the marine fender including: a facing assembly for bearing against a vessel; a resilient fender element for absorbing forces on the facing assembly, the fender element being mounted between
5 the facing assembly and the structure; and one or more load sensing elements being positioned to measure forces applied to the facing assembly and outputting force data relating to the measured forces.

The one or more load sensing elements may be load bearing.

10 The marine fender may further include a first mounting assembly for mounting the facing assembly to the fender element and a second mounting assembly for mounting the fender element to the structure, and the one or more load sensing elements may form part of the first or second mounting assembly.

The one or more load sensing elements may provide a coupling arrangement for coupling together the first or second mounting assemblies.

15 The first mounting assembly may include a first mounting bracket carried by the facing assembly and a second mounting bracket carried by the fender element, and the first and second brackets may be coupled together by the one or more load sensing elements.

20 The second mounting assembly may include a first mounting bracket connected to the fender element and a second mounting bracket connected to the structure, and the first and second brackets may be coupled together by the one or more load sensing elements.

The first and second mounting brackets may be complementarily shaped.

The first second mounting brackets may be coupled together by load sensors passing through apertures carried by the first and second mounting brackets.

25 The first mounting bracket may include a first annular flange for mounting the first mounting bracket and a first set of radially extending apertured lugs spaced around the circumference of the first annular flange, the second mounting bracket may include a second annular flange for

mounting the second mounting bracket and a second set of radially extending apertured lugs spaced around the circumference of the second annular flange, and lugs of the first set of radially extending apertured lugs may inter-engage with corresponding lugs of the second set of radially extending apertured lugs, apertures of the first set of radially extending apertured lugs may align with corresponding apertures of the second set of radially extending apertured lugs, and load sensors may extend through correspondingly aligned apertures, thereby coupling the first and second mounting brackets together.

The first and second sets of radially extending apertured lugs may be equiangularly positioned around the circumferences of the first and second annular flanges respectively.

- 10 Each apertured lug in the first set of apertured lugs may inter-engage with a pair of corresponding apertured lugs in the second set of apertured lugs.

The number of load sensing elements may be selected from a group including 3 load sensing elements, 4 load sensing elements, 5 load sensing elements, and more than 5 load sensing elements.

- 15 The marine fender may further include a memory for storing the data output from the one or more load sensors.

The marine fender may further include a communications interface for sending the data output from the one or more load sensors to a networked location.

- 20 In a second aspect the present invention provides a mounting assembly for mounting a marine fender facing assembly to a fender element, the mounting assembly including: a first mounting bracket adapted to be secured to the facing assembly; and a second mounting bracket adapted to be secured to the fender element; and one or more load sensing elements for, in use, coupling together the first and second mounting brackets, measuring forces applied to the facing assembly, and outputting force data relating to the measured forces.

- 25 In a third aspect the present invention provides a mounting assembly for mounting a marine fender element to a structure, the mounting assembly including: a first mounting bracket adapted to be secured to the fender element; and a second mounting bracket adapted to be secured to the

structure; and one or more load sensing elements for, in use, coupling together the first and second mounting brackets, measuring forces applied to the facing assembly, and outputting force data relating to the measured forces.

In use the one or more load sensing elements may be load bearing.

- 5 The first and second mounting brackets may be complementarily shaped.

In use the load sensors may couple the first second mounting brackets together by passing through apertures carried by the first and second mounting brackets.

- The first mounting bracket may include a first annular flange for mounting the first mounting bracket and a first set of radially extending apertured lugs spaced around the circumference of
- 10 the first annular flange, the second mounting bracket may include a second annular flange for mounting the second mounting bracket and a second set of radially extending apertured lugs spaced around the circumference of the second annular flange, and in use lugs of the first set of radially extending apertured lugs may inter-engage with corresponding lugs of the second set of radially extending apertured lugs, apertures of the first set of radially extending apertured lugs
- 15 may align with corresponding apertures of the second set of radially extending apertured lugs, and load sensors may extend through correspondingly aligned apertures, thereby coupling the first and second mounting brackets together.

The first and second sets of radially extending apertured lugs may be equiangularly positioned around the circumferences of the first and second annular flanges respectively.

- 20 Each apertured lug in the first set of apertured lugs may inter-engage with a pair of corresponding apertured lugs in the second set of apertured lugs.

The number of load sensing elements may be selected from a group including 3 load sensing elements, 4 load sensing elements, 5 load sensing elements, and more than 5 load sensing elements.

Brief description of the drawings / figures

Preferred embodiments of the invention will now be described with reference to the accompanying Figures in which:

Figure 1A shows a side view of a marine fender in accordance with an embodiment of the present invention;

Figure 1B shows a partial perspective view of the marine fender of Figure 1A;

Figure 1C shows a cut away side view of the fender element of the marine fender of figure 1A;

Figure 2A shows a perspective view of a mounting assembly in accordance with an embodiment of the invention;

Figure 2B shows a perspective view of one of the mounting brackets used in the mounting assembly depicted in figure 2A;

Figure 2C shows a perspective view of the other mounting bracket used in the mounting assembly depicted in figure 2A;

Figure 2D is a cross sectional view of the mounting assembly of figure 2A taken through line 2D—2D of figure 1A;

Figure 3A depicts a load pin suitable for use in the fender of figure 1 and mounting assembly of figure 2;

Figure 3B shows the load pin of figure 3A under load;

Figure 4 is a graph showing results of a test of a mounting arrangement similar to that of figure 2 and fender element;

Figure 5 shows a high level depiction of an installation including a plurality of marine fenders as shown in figure 1; and

Figure 6 is a graph depicting load measurements over time on four fenders.

Detailed description of the embodiments

Figure 1A shows a side view of a fender 100 in accordance with an embodiment of the present invention affixed to a structure 108. Fender 100 includes a facing assembly 102 mounted to a fender element 104 via a facing assembly mounting arrangement 106. The fender element 104 is, in turn, mounted to a structure 108 via a fender mounting arrangement 110. The structure may be any relevant infrastructure including, for example, a dock, a jetty, a goods terminal, a passenger terminal, a dolphin structure or the like.

Figure 1B provides a perspective view of the fender element 104, facing assembly mounting arrangement 106 and fender mounting arrangement 110.

As will be appreciated, the precise construction of the facing assembly 102 will depend on the intended use of the marine fender 100. By way of non-limiting example, however, the facing assembly 102 of the present embodiment includes a frame 112 carrying a plurality of face pads 114. In this instance the frame 112 is a steel closed box frame and the face pads 114 are made from a low friction material such as Ultra-high-molecular-weight polyethylene (UHMW-PE). A typical square facing assembly may have dimensions from 1x1 meters up to 4x4 meters, and a typical rectangular facing assembly may have dimensions of from 1x2 meters up to and above 4x8 meters – though, again, the actual size can be custom made as desired.

Turning to Figure 1C, the fender element 104 will be described in further detail. Figure 1C provides a side view of a fender element 104 (with a cut-away portion) suitable for use with the present invention. Fender element 104 is a hollow truncated rubber cone with height ranging from 0.3 meters up to and above a height of about 2 meters. The rubber compound of the fender may, for example, be a compound based on Natural Rubber, Styrene Butadiene Rubber, Neoprene, Butyl Rubber, EPDM, and/or Polyurethane. The specific rubber compound for a particular fender element 104 will be selected according to the performance requirements (e.g. as set out by PIANC and/or EAU).

The end of the fender element 104 proximate the facing assembly 102 is a closed face 118. Behind the closed face (i.e. inside the fender element 104) is a mounting ring or plate 120 which,

in one embodiment, is bonded into the rubber of the fender element 104 during manufacture. At the opposite end of the fender element 104 (proximate the structure 108) is a flange 122. Flange 122 also includes a mounting ring/plate 124 via which the fender element 104 is mounted to the structure 108 (described below). In one embodiment the flange 122 and ring plate 124 (along with the requisite bolts/pins) allow the fender element 104 to be mounted directly to a bracket or similar secured on the structure 108. In this instance the fender mounting arrangement 110 (including the flange 122 and ring plate 124) is formed as part of the fender element 104.

While in the present embodiment a cone fender element is described and illustrated (e.g. an element such as those manufactured by Trelleborg and used in their line of "super cone" fenders) it will, of course, be appreciated that alternative fender elements could be used. As is known in the art, however, different fender elements can be provided to deliver specific fender characteristics (e.g. deflection, reaction force, and energy absorption) for a desired use. By way of non-limiting example, the present invention could be used with alternative fender styles such as element, arch, cylindrical, or cell fenders. Further, while a fender 100 with a single fender element 104 has been depicted, there are instances where more than one fender element 104 is appropriate. The present invention can, of course, be applied to such arrangements.

The facing assembly 102 is mounted to the fender element 104 by a facing mounting arrangement 106 which, in this instance, is a load sensing mounting assembly. As can be seen, the facing assembly 102 is mounted such that the facing assembly 102 is held generally vertical/parallel to the structure 108.

Figures 2A to 2D provide various views of a load sensing mounting assembly 200 in accordance with an embodiment of the invention. The mounting assembly 200 is, in this instance, the mounting assembly used for the facing assembly mounting arrangement 106 in figure 1. It will be appreciated that the mounting assembly 200 could be adapted to mount alternative components of the fender 100 (e.g. the fender element to the structure) and/or for use with alternative fender arrangements.

The mounting assembly 200 of the present embodiment includes a first mounting bracket 202 (shown in Figure 2B) and a second mounting bracket 204 (shown in figure 2C). In the fender

100 of Figure 1, the first mounting bracket 202 mounts to the fender element 104 and the second mounting bracket 204 mounts to the facing assembly 102.

The first mounting bracket 202 includes an annular flange 206 around which a plurality of apertures 208 are located. Apertures 208 allow the first mounting bracket to be mounted to the relevant fender component. In fender 100 of figure 1 the first bracket mounting 202 is bolted to the fender element 104 by bolts passing through the apertures 208, the closed face 118 of the fender element 104, and into the mounting plate/ring 120. The first mounting bracket 202 also includes a locating ring 210 extending from the inner circumference of the annular flange 206, and a plurality of radially extending lugs 212 positioned equiangularly around the annular flange 206, each lug 212 having an aperture 214 formed therein.

As can be seen, the second mounting bracket 204 is shaped complementarily to the first mounting bracket 202 to allow the two brackets 202 and 204 to be coupled together. The second mounting bracket 204 also includes an annular flange 216 with a plurality of apertures 218 by which the second mounting bracket 204 is bolted to the relevant fender component (e.g. the facing assembly 102 for the fender 100 of figure 1). The second mounting bracket 204 also includes a locating ring 220 extending from the inner circumference of the annular flange 216. To accommodate coupling with the first mounting bracket 202, the locating ring 220 of the second mounting bracket 204 is discontinuous and of a slightly larger diameter than the locating ring 210 of the first mounting bracket 202. This allows locating ring 210 to seat inside locating ring 220. The second mounting bracket 204 includes a plurality of pairs of radially extending lugs 222a and 222b, each lug 222a and 222b having an aperture 224a and 224b formed therein. As noted above, the locating ring 220 is discontinuous, being divided into five equal arcs by gaps 226 provided between each of the pairs of lugs 222a and 222b. Each gap 226 is sized to receive a corresponding lug 212 from the first mounting bracket 202.

Figure 2D shows a view of the first and second mounting brackets 202 and 204 coupled together, taken through section 2D – 2D of Figure 1A. As can be seen, when coupled together the locating ring 210 of the first mounting bracket 202 sits inside the locating ring 220 of the second mounting bracket 204. In this position each radially extending lug 212 in the first mounting bracket 202 extends into a gap 226 between a corresponding pair of radially extending lugs 222 of the second mounting bracket 204, the lugs of the first mounting bracket 202 thereby

interengaging with the lugs of the second mounting bracket 204. The aperture 214 in each lug 212 of the first mounting bracket 202 aligns with the apertures 224a and 224b in the corresponding pair of lugs 222a and 222b from the second mounting bracket 204.

To securely couple the first and second mounting brackets 202 and 204 together (thereby also
5 coupling the fender components mounted to those mounting brackets together, such as the fender element 104 and facing assembly 102), load sensors 228 (described further below) are passed through each set of aligned apertures (a set of aligned apertures being a single apertured lug 212 from the first mounting bracket 202 and the corresponding pair of apertured lugs 222a and 222b from the second mounting bracket 204). When a vessel bears against the facing assembly 102,
10 the force is transmitted to the fender element 104 via the load sensors 228 which, in addition to coupling the facing assembly 102 to the fender element 104, measure the force or load of the facing assembly on the fender element and structure 108. To allow the load sensors 228 to measure the force the radial lugs 212 and 222 and/or the apertures 214 and 224 therein are sized/positioned such that (at least at a rest position) the edges of the lugs 212/222 do not bear
15 against the annular flange 206/216 of the opposite bracket.

While in the illustrated embodiment five sets of aligned lugs/apertures 230 are shown equiangularly positioned around the annular flanges/locating rings, more or fewer sets may of course be provided. For example, in larger fenders a greater number than five may be appropriate, while in smaller fenders fewer than five sets may be appropriate.

20 In the embodiment of Figure 1, the load sensing mounting assembly 200 is arranged to mount the facing assembly 102 to the fender element 104 (i.e. the load sensing mounting assembly 200 is the facing mounting arrangement 106). By way of alternative (or addition), it would be possible to provide the fender mounting arrangement 110 as a similar load sensing assembly. For example, the fender mounting arrangement 110 could include a fender (or first) mounting
25 bracket for mounting to the fender element 104 and a complementarily shaped structure (or second) mounting bracket for mounting to the structure 108 (or to a frame or similar mounted to the structure 108). As with the mounting arrangement 106 described above, the mounting brackets could have inter-engaging lugs with aligned apertures through which one or more load sensors 228 could be placed in order to both couple the brackets (and hence the structure 108 and
30 fender element 104) together and measure the load on the fender 100.

It will also be appreciated that the relative positions of the first and second mounting brackets 202 and 204 could be switched. For example, in the embodiment of figure 1 the first mounting bracket is shown as mounting to the fender element 104 and the second to the facing assembly 102. It would be equally possible to mount the first mounting bracket 102 to the facing assembly
5 102 and the second mounting bracket 204 to the fender element 104.

It is also envisaged that the mounting assembly 200 could be retrofitted to existing fenders.

As shown in Figure 3A, the load sensing device 228 is a load pin 300 and is used to convert force into an electrical signal. The load pin 300 includes a stainless steel cylindrical body 302 which is machined with a pair of grooves 304 and 306. Grooves 304 and 306 define an inner
10 shear section 308 bounded by outer shear sections 310. The body 302 also includes an axial bore 312 through which strain gauges (not shown) run. The load pin 300 of the present embodiment includes four strain gauges in a Wheatstone bridge configuration. Load cells of one strain gauge (quarter bridge) or two strain gauges (half bridge) may also be suitable. The body 302 is sealed
15 300. The body 302 also includes a signal cable 318 which transmits the load signal generated by the strain gauges from the load pin 300 to, for example, a local data logger and/or networked location as discussed below.

In use, and as discussed above, the load pin is positioned such that lug 212 of the first mounting bracket 202 bears against the inner shear section 308, and the lugs 222a and 222b of the second
20 mounting bracket 204 bear on the outer shear sections 310. When the mounting assembly 200 is subjected to an uneven force (for example, by a vessel bearing or impacting on the facing assembly 102, as depicted by arrow 320) the load pin 300 will deform, causing the strain gauges running through the bore 312 in the load pin 300 to also deform. This is illustrated in Figure 3B (the magnitude of the deformation of the load pin 300 being highly exaggerated for clarity). The
25 strain gauge converts the deformation (strain) to electrical signals which are typically in the order of a few millivolts. The signals are then amplified by an instrumentation amplifier (not shown) and processed according to known algorithms to calculate the applied force.

A test was conducted of a mounting assembly and sample SCN800 cone fender element (manufactured by Trelleborg). The mounting assembly was substantially as described above however included four calibrated load cells only. A hydraulic ram press was used to subject the cone fender element and mounting assembly to know forces of up to around 80 tonne. The results of this test are shown in graph 400 of figure 4 which shows load (in tonnes) against the deflection (compression) of the fender element (in mm). As can be seen, the test shows that the data derived from the load cell measurements (graph line 402) substantially match the data derived from the actual ram pressure (graph line 404).

Various manufacturers of load cells exist, including LCM Systems of Unit 15, Newport Business Park, Barry Way, Newport Isle of White UK. As will be appreciated, a variety of alternate load sensing devices could be used, for example strain gauge load cells, mechanical (hydraulic or hydrostatic) load cells, and/or piezo-electric load cells (useful for dynamic measurements of force). The load cell capacity will be dependant on the forces applied through the fender system, and may range from 5 tonne to above 200 tonne capacity per load cell.

As will be appreciated, a variety of arrangements and/or systems for capturing, storing, communicating, processing, and outputting data from the load sensors 228 are possible.

In one embodiment, the fender 100 may be provided with a data collection, processing, and/or communication device 126 to which sensed data from each of the load sensing elements 228 is transmitted. This transmission may be by wired (e.g. copper wire, optical fibre etc) or wireless means (e.g. by electromagnetic signal such as radio or infrared) and using appropriate data communication protocols. The data collection/processing device 126 itself may be physically located with/on the fender 100, on the structure 108 to which the fender 100 is mounted, or at a remote location.

In an alternative embodiment, load sensing data from a plurality of different fenders 100 may be transmitted either directly or indirectly (e.g. via a public or private network) to a central data collection/processing system. Once again, transmission of data from the various load sensing elements 228 of the various fenders 100 may be by wired or wireless physical transmission means and corresponding communication protocols, or even by transportation of a physical data storage device. Figure 3 provides a schematic diagram of this embodiment.

In the installation 500 of figure 5, a structure 502 is provided with a number of fenders 504, 505, 506, 507. More or fewer fenders could, of course, be provided. Each fender 504 to 507 has load sensing capabilities (e.g. as per fender 100 described above) and has one or more load sensing elements for sensing and recording/transmitting the load on that fender. The load sensing element or elements of each fender 504 to 507 are configured to transmit sensed data to a central system 508. This transmission may be via a wired or wireless network, and may be direct transmission to the system 508, or indirect via an intermediate system.

Central system 508 is a computer system and, as will be appreciated, may take any number of forms. By way of example, the central system 508 may include a processor 510, a volatile memory unit 512 (e.g. RAM), a persistent memory unit 314 (e.g. one or more hard drives), user interface equipment 516 (e.g. a monitor, keyboard, mouse, etc), and at least one communications interface 518 for wired and/or wireless data transmission/reception (e.g. a network interface card, modem, router etc).

The central system 508 runs software which receives and processes data from each of the fenders 504 to 507. The fenders 504 to 507 may be configured to automatically transmit (in real time) captured data to the central system 308. Alternatively, the fenders 504 to 507 may store sensed data on a dedicated memory and make periodic transmissions of the sensed data to the central system 508 (such periodic transmissions may, for example, be at programmed intervals, on the occurrence of a particular event, or in response to a specific request from the central system 508).

By way of a simple example, data from the each of the load sensors may be stored in a simple table such as:

Date/time stamp	Fender identifier	Load sensor identifier	Reading
[date and data recorded]	[identifier of particular fender]	[identifier of particular load sensor on fender]	[force data]

In alternative embodiments, readings from all load sensors on a given fender may be processed (either at the fender or by the central system 508) and stored as a single cumulative force reading for the fender at the given time.

With this data the central system software can generate force graphs showing the load on a particular fender over time (or, if desired, one or more particular load sensors in a particular fender). For example, Figure 6 provides a graph 600 showing the load measured over time on four fenders 602, 604, 606, and 608.

- 5 As will be appreciated, many variations to graph 600 are possible. For example, the graph could be provided with individual lines for each load sensor in a particular fender, and/or could display a single line representative of data recorded by all load sensors on a particular fender.

In addition to the load sensing information, the central system 508 may be configured to also receive additional data of relevance which can be associated with the load sensor data (e.g. by
10 matching with the date/time stamp of the sensed data). Such data may, for example, include vessel specific data – e.g. for a specific docking operation, the fenders involved, the type of vessel, the pilot of the vessel, the angle and velocity at which the vessel impacted the fender(s) involved. The additional data may also or alternatively include environmental data, such as tidal information, current information, wind speed and direction information, and/or visibility
15 information.

The additional/supplementary data may be obtained from a variety of sources, including but not limited to: the Trelleborg SmartHook® (capable of measuring tensile load on mooring lines); the Trelleborg SmartDock® Laser system (providing distance and angle information for docking vessels); the Trelleborg SmartDock® GPS system (providing positional and heading
20 information).

By way of further example, the additional data may include data pertaining to the physical deflection facing assembly. This data may, for example, be obtained from a system such as that described in PCT application AU2006/000711 (Publication number WO 2006/125277) which uses sensors to measure/track movement of the facing assembly.

- 25 Further additionally or alternatively, a fender could be fitted with one or more accelerometers for providing acceleration data. For example, the face assembly 102 of fender 100 could be provided with accelerometer 128 to measure the acceleration at a particular point on the facing assembly. In order to provide more detailed information on the movement/deflection of the facing assembly

102 multiple accelerometers could be provided, for example one on each corner of the assembly 102.

The central system software may automatically receive/obtain the additional/alternative data described above (e.g. via the Internet or other networked sources) and/or user's may enter such
5 data manually.

Data from the load sensors can be used in a variety of ways. For example, the load data on a particular fender may be used to determine when maintenance and/or replacement of a fender (or fender component) is necessary. In the event of an accident and/or fender failing, the data can potentially be used to provide information as to why the fender failed. When combined with
10 additional data (for example data as to particular vessels, shipping companies, or pilots), the load data may be mined to provide intelligence on particular vessels/companies/pilots that consistently dock dangerously or poorly.

The information obtained from the analysis of the data could, in turn, be used in a wide variety of ways, such as in analysing berthing dynamics, assisting with future fender/wharf design,
15 feeding into the revision of safe/acceptable berthing operations/procedures. As an additional or alternative use, the data may be used to assist in forensic analysis of berthing accidents – e.g. for the purposes of analysing insurance claims.

It will be understood that the invention disclosed and defined in this specification extends to all alternative combinations of two or more of the individual features mentioned or evident from the
20 text or drawings. All of these different combinations constitute various alternative aspects of the invention.

The claims defining the invention are as follows:

1. A marine fender for mounting to a structure, the marine fender including:
 - a facing assembly for bearing against a vessel;
 - a resilient fender element for absorbing forces on the facing assembly, the fender element
5 being mounted between the facing assembly and the structure; and
 - one or more load sensing elements being positioned to measure forces applied to the facing assembly and outputting force data relating to the measured forces.
2. A marine fender according to claim 1, wherein the one or more load sensing elements are load bearing.
- 10 3. A marine fender according to claim 1 or claim 2, wherein the marine fender further includes a first mounting assembly for mounting the facing assembly to the fender element and a second mounting assembly for mounting the fender element to the structure, and wherein the one or more load sensing elements form part of the first or second mounting assembly.
4. A marine fender according to claim 3, wherein the one or more load sensing elements
15 provides a coupling arrangement for coupling together the first or second mounting assemblies.
5. A marine fender according to claim 3 or claim 4, wherein the first mounting assembly includes a first mounting bracket carried by the facing assembly and a second mounting bracket carried by the fender element, and wherein the first and second brackets are coupled together by the one or more load sensing elements.
- 20 6. A marine fender according to claim 3 or claim 4, wherein the second mounting assembly includes a first mounting bracket connected to the fender element and a second mounting bracket connected to the structure, and wherein the first and second brackets are coupled together by the one or more load sensing elements.

7. A marine fender according to claims 5 or claim 6, wherein the first and second mounting brackets are complementarily shaped.

8. A marine fender according to any one of claims 5 to 7, wherein the first second mounting brackets are coupled together by load sensors passing through apertures carried by the first and
5 second mounting brackets.

9. A marine fender according to any one of claims 5 to 8, wherein

the first mounting bracket includes a first annular flange for mounting the first mounting bracket and a first set of radially extending apertured lugs spaced around the circumference of the first annular flange,

10 the second mounting bracket includes a second annular flange for mounting the second mounting bracket and a second set of radially extending apertured lugs spaced around the circumference of the second annular flange, wherein

lugs of the first set of radially extending apertured lugs inter-engage with corresponding lugs of the second set of radially extending apertured lugs,

15 apertures of the first set of radially extending apertured lugs align with corresponding apertures of the second set of radially extending apertured lugs, and

load sensors in the form of load pins extend through correspondingly aligned apertures, thereby coupling the first and second mounting brackets together.

10. A marine fender according to claim 9, wherein the first and second sets of radially
20 extending apertured lugs are equiangularly positioned around the circumferences of the first and second annular flanges respectively.

11. A marine fender according to claim 9 or claim 10, wherein each apertured lug in the first set of apertured lugs inter-engages with a pair of corresponding apertured lugs in the second set of apertured lugs.

12. A marine fender according to any one of claims 1 to 11, wherein the number of load sensing elements is selected from a group including 3 load sensing elements, 4 load sensing elements, 5 load sensing elements, and more than 5 load sensing elements.

13. A marine fender according to any one of claims 1 to 12, further including a memory for
5 storing the data output from the one or more load sensors.

14. A marine fender according to any one of claims 1 to 13, further including a communications interface for sending the data output from the one or more load sensors to a networked location.

15. A mounting assembly for mounting a marine fender facing assembly to a fender element,
10 the mounting assembly including:

a first mounting bracket adapted to be secured to the facing assembly; and

a second mounting bracket adapted to be secured to the fender element; and

one or more load sensing elements for, in use, coupling together the first and second mounting brackets, measuring forces applied to the facing assembly, and outputting force data
15 relating to the measured forces.

16. A mounting assembly for mounting a marine fender element to a structure, the mounting assembly including:

a first mounting bracket adapted to be secured to the fender element; and

a second mounting bracket adapted to be secured to the structure; and

20 one or more load sensing elements for, in use, coupling together the first and second mounting brackets, measuring forces applied to the facing assembly, and outputting force data relating to the measured forces.

17. A mounting assembly according to claim 15 or claim 16, wherein in use the one or more load sensing elements are load bearing.

18. A mounting assembly according to any one of claims 15 to 17, wherein the first and second mounting brackets are complementarily shaped.

5 19. A mounting assembly according to any one of claims 15 to 18, wherein in use the load sensors couple the first second mounting brackets together by passing through apertures carried by the first and second mounting brackets.

20. A mounting assembly according to any one of claims 15 to 19, wherein

10 the first mounting bracket includes a first annular flange for mounting the first mounting bracket and a first set of radially extending apertured lugs spaced around the circumference of the first annular flange,

the second mounting bracket includes a second annular flange for mounting the second mounting bracket and a second set of radially extending apertured lugs spaced around the circumference of the second annular flange, wherein in use

15 lugs of the first set of radially extending apertured lugs inter-engage with corresponding lugs of the second set of radially extending apertured lugs,

apertures of the first set of radially extending apertured lugs align with corresponding apertures of the second set of radially extending apertured lugs, and

20 load sensors extend through correspondingly aligned apertures, thereby coupling the first and second mounting brackets together.

21. A mounting assembly according to claim 20, wherein the first and second sets of radially extending apertured lugs are equiangularly positioned around the circumferences of the first and second annular flanges respectively.

22. A mounting assembly according to claim 20 or claim 21, wherein each apertured lug in the first set of apertured lugs inter-engages with a pair of corresponding apertured lugs in the second set of apertured lugs.

23. A mounting assembly according to any one of claims 15 to 22, wherein the number of
5 load sensing elements is selected from a group including 3 load sensing elements, 4 load sensing elements, 5 load sensing elements, and more than 5 load sensing elements.

24. A load monitoring system including:

a plurality of marine fenders for mounting to a structure, each marine fender including:

a facing assembly for bearing against a vessel;

10 a resilient fender element for absorbing forces on the facing assembly, the fender element being mounted between the facing assembly and the structure;

one or more load sensing elements being positioned to measure forces applied to the facing assembly and outputting force data relating to the measured forces; and

a communications interface for transmitting the data output to a networked location,

15 the networked location including:

a receiver for receiving data output from the one or more load sensing elements of each marine fender;

a memory for storing the data output from the one or more load sensing elements of each marine fender; and

20 a processor for processing the data.