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## MANAGEMENT SYSTEM AND METHOD OF PNEUMATIC FENDER

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### Abstract

A management system and method that can easily and more stably grasp a condition of an individual pneumatic fender and has excellent maintainability a passive IC tag, a pressure sensor, and a temperature sensor which are activated by a transmission radio wave from a communication unit outside a pneumatic fender in which the passive IC tag integrating the pressure sensor and the temperature sensor is installed. A return radio wave from the IC tag activated is transmitted in response to the transmission radio wave, wireless communication between the IC tag and the communication unit is performed, the communication unit thus acquires identification information of the IC tag and detection data of the pressure sensor and the temperature sensor when the IC tag is activated, and a calculation device specifies the pneumatic fender based on the identification information and determines a condition of the pneumatic fender based on the detection data.

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## **Background/Summary**

### **TECHNICAL FIELD**

[0001] The present invention relates to a management system and method for grasping a condition of a pneumatic fender.

### **BACKGROUND ART**

[0002] A management system for grasping a use state of a pneumatic fender installed on a quay or the like has been proposed (see Patent Document 1). The management system proposed in Patent Document 1 includes an identification tag and a sensor installed in a pneumatic fender and a receiving device that receives radio waves from the sensor. Using a pressure sensor and a temperature sensor as the sensor can grasp the internal pressure and the internal temperature of the pneumatic fender. Using a passive RFID tag as the identification tag eliminates the need for a battery to acquire information of the identification tag.

[0003] In this management system, the identification tag and the sensor are provided separately and individually on the pneumatic fender, causing attachment work and maintenance work to be complicated. Further, the sensor is driven by a built-in battery (paragraph 0022). The battery needs to be replaced when it is weak, causing the maintenance work to be more complicated. The battery of the pneumatic fender in use cannot be easily replaced, and thus the internal pressure and the internal temperature of the pneumatic fender cannot be grasped until the weak battery is replaced. Thus, there is room for improvement in easily and more stably grasping the condition of each pneumatic fender and improving the maintainability.

### **CITATION LIST**

#### **Patent Literature**

[0004] Patent Document 1: WO 2011/155265

### **SUMMARY OF INVENTION**

#### **Technical Problem**

[0005] An object of the present invention is to provide a management system and method that can easily and more stably grasp a condition of an individual pneumatic fender and has excellent maintainability.

#### **Solution to Problem**

[0006] A management system of a pneumatic fender according to an embodiment of the present invention to achieve the object described above includes: a pneumatic fender including a body including a body portion having a cylindrical shape, bowl-shaped end portions connected to both sides of the body portion in an axial direction, and a cap portion attached to at least one of the bowl-shaped end portions; an IC tag of a passive type installed in the pneumatic fender; a pressure sensor configured to detect an internal pressure of the pneumatic fender and a temperature sensor configured to detect a temperature of an internal space of the pneumatic fender; and a communication unit disposed outside the pneumatic fender, an individual of the pneumatic fender is specified based on identification information of the IC tag acquired by the communication unit, and a condition of the pneumatic fender is determined based on detection data from the pressure sensor and the temperature sensor acquired by the communication unit. The pressure sensor and the temperature sensor are installed on the IC tag and integrated with the IC tag. The management

system includes a calculation device to be communicably connected to the communication unit. The IC tag is activated by a transmission radio wave transmitted from the communication unit, the pressure sensor and the temperature sensor is activated, a return radio wave is transmitted from the IC tag activated in response to the transmission radio wave, and wireless communication between the IC tag and the communication unit is thus performed. The identification information is acquired by the communication unit through the wireless communication and is input to the calculation device, and the detection data from the pressure sensor and the temperature sensor when the IC tag is activated is acquired by the communication unit through the wireless communication and is input to the calculation device. By the calculation device, an individual of the pneumatic fender is specified based on the identification information input, and a condition of the pneumatic fender is determined based on each detection data input.

[0007] A management method of a pneumatic fender according to an embodiment of the present invention includes: disposing, in a pneumatic fender including a body including a body portion having a cylindrical shape, bowl-shaped end portions connected to both sides of the body portion in an axial direction, and a cap portion attached to at least one of the bowl-shaped end portions, an IC tag of a passive type, a pressure sensor configured to detect an internal pressure of the pneumatic fender, and a temperature sensor configured to detect a temperature of an internal space of the pneumatic fender; disposing a communication unit outside the pneumatic fender; and specifying an individual of the pneumatic fender based on identification information of the IC tag acquired by the communication unit and determining a condition of the pneumatic fender based on detection data from the pressure sensor and the temperature sensor acquired by the communication unit. The management method includes: installing the pressure sensor and the temperature sensor on the IC tag, integrating the pressure sensor and the temperature sensor with the IC tag, and providing a calculation device to be communicably connected to the communication unit; activating the IC tag by using a transmission radio wave transmitted from the communication unit, activating the pressure sensor and the temperature sensor, transmitting a return radio wave from the IC tag activated in response to the transmission radio wave, and thus performing wireless communication between the IC tag and the communication unit; acquiring the identification information at the communication unit through the wireless communication, inputting the identification information to the calculation device, acquiring, at the communication unit through the wireless communication, the detection data from the pressure sensor and the temperature sensor when the IC tag is activated, and inputting the detection data to the calculation device; and by the calculation device, specifying an individual of the pneumatic fender based on input identification information and determining a condition of the pneumatic fender based on each detection data input.

#### Advantageous Effects of Invention

[0008] According to the present invention, the identification information and the detection data can be acquired by performing wireless communication between the IC tag and the communication unit. Then, based on the acquired identification information and the detection data, the condition of each pneumatic fender can be easily grasped. The pressure sensor and the temperature sensor are installed on the IC tag and are integrated with the IC tag, allowing man-hours for mounting these parts on the pneumatic fender to be reduced. Furthermore, the IC tag, the pressure sensor, and the temperature sensor are activated by the transmission radio wave transmitted from the communication unit. Therefore, it is not necessary to provide a battery in these parts. That is, there is no need to replace the battery of these parts, and there is no risk of data being unable to be acquired due to a weak battery. This improves maintainability and is advantageous for stably grasping the condition of each pneumatic fender for the long term.

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## Description

## BRIEF DESCRIPTION OF DRAWINGS

[0009] FIG. 1 is an explanatory diagram illustrating a pneumatic fender installed on a quay in a top view.

[0010] FIG. 2 is an explanatory diagram illustrating a management system of a pneumatic fender according to an embodiment, with the fender in a longitudinal cross-sectional view.

[0011] FIG. 3 is an explanatory diagram illustrating a state in which wireless communication is performed between an IC tag and a communication unit by enlarging a portion of FIG. 2.

[0012] FIG. 4 is an enlarged explanatory diagram illustrating the vicinity of the IC tag of FIG. 3.

[0013] FIG. 5 is an explanatory diagram illustrating an IC tag in a plan view.

[0014] FIG. 6 is an explanatory diagram illustrating the IC tag of FIG. 5 in a front view.

[0015] FIG. 7 is an explanatory diagram illustrating another attachment structure of the IC tag to the fender.

[0016] FIG. 8 is an explanatory diagram illustrating a configuration of the management system in which a calculation device and terminal devices are connected through a communication network.

[0017] FIG. 9 is an explanatory diagram illustrating another embodiment of the management system, with the fender in a longitudinal cross-sectional view.

[0018] FIG. 10 is an explanatory diagram illustrating reference image data of a top view of the fender.

[0019] FIG. 11 is an explanatory diagram illustrating image data of a top view of the fender acquired by a camera device.

## DESCRIPTION OF EMBODIMENTS

[0020] A management system and method of a pneumatic fender according to an embodiment of the present invention will be described below with reference to the drawings.

[0021] As illustrated in FIG. 1, a pneumatic fender 2 (hereinafter, referred to as a fender 2) is used by being attached to an installation location such as a quay 22 or a side of a watercraft using a guy rope 2a or the like. The fender 2 includes a body 3 including a bowl-shaped end portion 5 connected to both ends of a body portion 4 having a cylindrical shape, and a cap portion 9 provided on the body 3. In this embodiment, the cap portion 9 is provided only on one of the bowl-shaped end portions 5, but it may be provided on the bowl-shaped end portion 5 at both sides.

[0022] In FIG. 1, a plurality of fenders 2 are installed at intervals, but a single fender 2 may be installed. The fender 2 may be installed in a horizontal state with the bowl-shaped end portions 5 on the left and right sides, or in a vertical state with the bowl-shaped end portions 5 on the top and bottom sides.

[0023] An embodiment of a management system 1 of the pneumatic fender illustrated in FIGS. 1 to 4 (hereinafter referred to as a management system 1) is used to grasp the condition of individual fender 2. As illustrated in FIG. 1, the management system 1 can be used not only to grasp the condition of the fender 2 installed and used at the installation location in an expanded state at a specified internal pressure, but also to grasp the condition of the fender 2 stored in a warehouse or the like, for example.

[0024] Describing the structure of the fender 2 in detail, the body 3 is formed by layering a plurality of reinforcing layers 7 between inner layer rubber 6 and outer layer rubber 8. Each of the reinforcing layers 7 constituting the body portion 4 is formed of multiple cords that are aligned to extend in parallel to a cylinder axial direction of the body portion 4 having a cylindrical shape at a predetermined cord angle. Furthermore, the cords of the reinforcing layers 7 layered adjacently have an intersecting bias structure.

[0025] The reinforcing layers 7 constituting each of the bowl-shaped end portions 5 are formed by alternately layering a cord layer formed of cords extending radially from the circular center of the bowl-shaped end portion 5 and a cord layer formed of cords extending in the circumferential direction. In other words, the multilayer structure of the reinforcing layers 7 of the bowl-shaped

end portion 5 has a so-called radial structure. In FIG. 2, a boundary between the body portion 4 and each bowl-shaped end portion 5 is illustrated by a two-dot chain line for reference.

[0026] The management system 1 includes the fender 2, a passive IC tag 11, a pressure sensor 15a, and a temperature sensor 15b installed in the fender 2, a communication unit 16 disposed outside the fender 2, and a calculation device 17 to be communicably connected to the communication unit 16. The pressure sensor 15a and the temperature sensor 15b are installed on the IC tag 11 and are integrated with the IC tag 11. In this embodiment, the IC tag 11 is embedded in the inner layer rubber 6 of the body 3. Wireless communication between the IC tag 11 and the communication unit 16 is performed, and desired information and data are acquired by the communication unit 16 from the IC tag 11.

[0027] As illustrated in FIGS. 5 and 6, the IC tag 11 includes an IC chip 12 and an antenna unit 13 connected to the IC chip 12. The pressure sensor 15a and the temperature sensor 15b are connected to the IC tag 11 (the IC chip 12). The size of the IC chip 12 is very small, for example, with a vertical dimension and a horizontal dimension of 50 mm or less (equivalent to an outer diameter of 50 mm or less) and a thickness of 5 mm or less. The size of the antenna unit 13 is also very small. In this embodiment, the antenna unit 13 adopted is a dipole type and consists of a metal monofilament extending symmetrically from the IC chip 12. The length of each metal monofilament is about 10 mm or more and 200 mm or less.

[0028] In detail, the IC tag 11 includes an IC chip 12 and an antenna unit 13 connected to the IC chip 12. The IC chip 12 optionally can store tag-specific information such as an identification number A of the IC tag 11 and other necessary information. The IC tag 11 adopts commonly available specifications, and for example, an RFID tag can be used as the IC tag 11.

[0029] The IC chip 12 is located on a top surface of a substrate 14. The pressure sensor 15a and the temperature sensor 15b connected to the IC chip 12 are disposed on a back surface of the substrate 14. The antenna unit 13 (metal monofilament) protrudes and extends from the substrate 14. The antenna unit 13 is not limited to the dipole type described above, and various known types may be employed. For example, a ceramic antenna formed on the substrate 14 may be employed.

[0030] The body 3 may be brought into a contracted state by discharging air from the internal space thereof, or may be brought into an expanded state by injecting air into the internal space of the body 3 in the contracted state. Adopting the antenna unit 13 that is a dipole type and consists of a metal monofilament provides excellent bending durability, which is advantageous in avoiding damage even if the body 3 is greatly deformed.

[0031] The IC tag 11 is covered with an insulating layer 14a, and the entire IC tag 11 is electrically insulated from the outside. However, detection portions of the pressure sensor 15a and the temperature sensor 15b are not covered with the insulating layer 14a and are exposed from the surface of the insulating layer 14a. Then, as illustrated in FIG. 4, in the IC tag 11 embedded in the inner layer rubber 6 of the body 3, only the detection portions of the pressure sensor 15a and the temperature sensor 15b are exposed to the internal space of the fender 2.

[0032] As the insulating layer 14a, resins such as acrylonitrile-butadiene-styrene (ABS), polyvinyl chloride, polycarbonate, polyimide, and epoxy can be used. Polyvinyl chloride is very suitable for covering the antenna unit 13 (metal monofilament) extending long because of its excellent flexibility.

[0033] The IC tag 11 may be installed not only in the body 3 but also in the cap portion 9. However, it is easy to install the IC tag 11 in a state of being embedded in the body 3. In the body 3, the IC tag 11 is preferably embedded in the inner layer rubber 6 of the bowl-shaped end portion which is not easily deformed or subjected to an external force. If a large number of tires are installed on the outer surface of the body 3 using a chain net, the chain net and the tires become obstacles to the wireless communication between the IC tag 11 and the communication unit 16. Therefore, the IC tag 11 needs to be disposed at a position that is not covered by the chain net or the tire provided on the outer surface of the body 3. It is difficult to change the positions of the

chain net and the tire in the body portion **4**. However, the positions thereof can be slightly adjusted in the bowl-shaped end portion **5**, and from this point of view, the IC tag **11** is preferably embedded in the inner layer rubber **6** of the bowl-shaped end portion **5**.

[0034] The IC tag **11** may be installed in a state where it is embedded in the body **3** in a manufacturing process of the fender **2**. That is, by embedding the IC tag **11** in the inner layer rubber **6** in a molding process of the body **3** and then vulcanizing the body **3**, the IC tag **11** can be installed in a state where it is embedded in the body **3**.

[0035] In this embodiment, the IC tag **11** is provided at each bowl-shaped end portion **5**. In each of the bowl-shaped end portions **5**, the IC tags **11** are disposed at multiple sections (two sections) spaced apart in the circumferential direction. Further, the IC tags **11** installed in the bowl-shaped end portion **5** are disposed at positions shifted by 90° from each other in the circumferential direction.

[0036] An embedding mark **10** indicating an embedding position of the IC tag **11** is provided on the outer surface of the body **3** (the surface of the outer layer rubber **8**) corresponding to the embedding position of each IC tag **11**. In this embodiment, the embedding position mark **10** is a protruding portion. However, a form of the embedding position mark **10** is not limited as long as it can indicate the embedding position of the IC tag **11**, and it may be a recessed portion or a printed display.

[0037] The pressure sensor **15a** detects the internal pressure of the fender **2**. As the pressure sensor **15a**, various known types can be adopted as long as it can be attached to the IC tag **11**. Detection data **D1** detected by the pressure sensor **15a** is acquired by the communication unit **16**.

[0038] The temperature sensor **15b** detects the temperature of the internal space of the fender **2**. As the temperature sensor **15b**, various known types can be adopted as long as it can be attached to the IC tag **11**. Detection data **D2** detected by the temperature sensor **15b** is acquired by the communication unit **16**.

[0039] The temperature sensor **15b** according to this embodiment includes two detection portions, and one of the detection portions detects the temperature of the internal space of the fender **2**. Then, the other of the detection portions detects the temperature of the body **3** (the inner layer rubber **6**) at the position where the temperature sensor **15b** is embedded. The temperature of the body **3** detected by the temperature sensor **15b** is also acquired by the communication unit **16** as one of the detection data **D2** (as detection data **D2.sub.1**). It is sufficient for the temperature sensor **15b** to detect the temperature of the internal space of the fender **2**. More preferably, the temperature sensor **15b** detects the temperature of the body **3** described above in addition to the temperature of the internal space of the fender **2**, as in this embodiment.

[0040] The communication unit **16** includes a radio wave transmission unit **16a** and a radio wave reception unit **16b**. The radio wave transmission unit **16a** transmits a transmission radio wave **R1** to the IC tag **11**. The transmission radio wave **R1** received by the antenna unit **13** generates power in the IC tag **11**, which activates the IC tag **11**. The IC tag **11** uses this power to transmit a return radio wave **R2** through the antenna unit **13**, and this return radio wave **R2** is received by the radio wave reception unit **16b**. Thus, wireless communication between the IC tag **11** and the communication unit **16** is performed by transmitting the return radio wave **R2** in response to the transmission radio wave **R1**.

[0041] The communication unit **16** can employ commonly distributed specifications that allow wireless communication with a passive IC tag (RFID tag). Thus, the IC tag **11** and the communication unit **16** constitute a radio frequency identification (RFID) system. In this embodiment, the communication unit **16** of a portable handy type is used. Since the passive IC tag **11** is used, the communication distance of the radio waves **R1** and **R2** between the IC tag **11** and the communication unit **16** is, for example, about one meter.

[0042] The frequency of the radio waves (**R1**, **R2**) used for wireless communication between the IC tag **11** and the communication unit **16** is mainly in the UHF band (depending on the country, range

of 860 MHz or higher and 930 MHz or lower, range of 915 MHz or higher and 930 MHz in Japan), and the HF band (13.56 MHz) may be used.

[0043] Identification information A and detection data D1, D2, and D2.sub.1 acquired by the communication unit **16** is input to the calculation device **17**. The calculation device **17** performs various computational processing using the input data. A known computer or the like is used as the calculation device **17**.

[0044] An example of a procedure for grasping the condition of the fender **2** by using this embodiment of the management system **1** will be described below.

[0045] With respect to the fender **2** installed and used at an installation location in an expanded state at a specified internal pressure as illustrated in FIG. **1**, the communication unit **16** is brought close to the fender **2**, and the IC tag **11** is activated by the transmission radio wave R1 transmitted from the radio wave transmission unit **16a** as illustrated in FIGS. **2** and **3**. When the IC tag **11** is activated, the pressure sensor **15a** and the temperature sensor **15b** integrated with the IC tag **11** are also activated. The return radio wave R2 transmitted from the activated IC tag **11** in response to the transmission radio wave R1 is received by the radio wave reception unit **16b**, and wireless communication between the IC tag **11** and the communication unit **16** is performed.

[0046] Since the distance of this wireless communication is about one meter, it is necessary to bring the communication unit **16** close to the IC tag **11**. In this embodiment, since the visible embedding mark **10** is provided on the outer surface of the body **3**, it is advantageous to stably perform the wireless communication by bringing the communication unit **16** close to the embedding mark **10**.

[0047] When the IC tag **11** is activated, the identification information A stored in the IC chip **12** is wirelessly communicated from the IC tag **11** by the return radio wave R2 and acquired by the communication unit **16**. The detection data D1, D2, and D1.sub.1 detected by the pressure sensor **15A** and the temperature sensor **15b** when the IC tag **11** is activated are wirelessly communicated from the IC tag **11** by the return radio wave R2 and acquired by the communication unit **16**.

[0048] The identification information A and the detection data D1, D2, D2.sub.1 acquired by the communication unit **16** are input to the calculation device **17**. Each identification information A and position information (installation position information) of the fender **2** on which the IC tag **11** having each identification information A is installed are associated with each other and stored in the calculation device **17**. The specification, manufacturing history, usage history, and the like of the fender **2** are also associated with the identification information A and stored in the calculation device **17**. The calculation device **17** also stores tolerance ranges for each of the internal pressure, the temperature of the internal space of the fender **2**, and the temperature of the body **3**.

[0049] Then, the calculation device **17** specifies an individual of the fender **2** based on the input identification information A, and determines the condition of the individual fender **2** based on the input detection data D1, D2, and D2.sub.1. That is, the condition of the fender **2** is determined by comparing the input detection data D1, D2, D2.sub.1 with the corresponding tolerance ranges. As a result of the comparison, it is determined that an abnormality has occurred in the detection item out of the tolerance range, and it is determined that no abnormality has occurred in the detection item within the tolerance range.

[0050] For example, when the detection data D1 has a value lower than the tolerance range (in the case of low pressure), it can be determined that air leakage has occurred in the fender **2**. It can also be determined that air leakage occurs due to the fender **2** being often pressed strongly, and the fender **2** is used under severe conditions. When the detection data D2 and D2.sub.1 are higher than the tolerance range, it is determined that the fender **2** is in an abnormally high temperature state, and when they are lower than the tolerance range, it is determined that the fender **2** is in an abnormally low temperature state. It can also be determined that the fender **2** is in an abnormally high temperature state or an abnormally low temperature state and is being used under severe conditions.

[0051] There is a temperature difference between an above-water portion and an underwater portion of the body **3** due to the atmospheric temperature and the water temperature. However, there is no clear temperature difference in the temperature of the internal space of the fender **2** like the temperature difference between the above-water portion and the underwater portion of the body **3**. That is, the detection data D2.sub.1 is easily affected by the external environmental temperature, and the detection data D2 is less likely to be affected by the external environmental temperature than the detection data D2.sub.1. Therefore, by using the temperature sensor **15b** to detect the temperature of the internal space of the fender **2** separately from the temperature of the body **3**, it is advantageous to obtain a more detailed determination of an effect of the temperature on the durability of the fender **2** (body **3**).

[0052] It is considered that a degree of deterioration of the body **3** also varies according to a difference (temperature difference) between the detection data D2 (the internal temperature of the fender **2**) and the detection data D2.sub.1 (the temperature of the body **3**). Therefore, it is also possible to determine the effect on the durability of the fender **2** (body **3**) based on the difference between the detection data D2 and the detection data D2.sub.1. The detection data D2 and the detection data D2.sub.1 differ depending on the installation positions of the temperature sensor **15b**. Therefore, in order to determine the distribution of the detection data D2 (the internal temperature of the fender **2**) and the detection data D2.sub.1 (the temperature of the body **3**) in the fender **2**, it is preferable to install the IC tags **11** at multiple sections separated from each other.

[0053] The fender **2** installed in a horizontal state rotates in the circumferential direction, and IC tag **11** installed at one section may thus be located underwater. In this case, wireless communication between the IC tag **11** and the communication unit **16** becomes substantially impossible. Therefore, the IC tags **11** are preferably disposed at multiple sections spaced apart in the circumferential direction of the body **3**. For example, the IC tags **11** are installed at two to four sections at equal intervals in the circumferential direction of the body **3**. The fender **2** may be installed in a vertical state. Therefore, in this case, if the IC tag **11** is installed only at one bowl-shaped end portion **5**, the IC tag **11** may be located underwater. Therefore, it is preferable that the IC tag **11** is installed in each of the bowl-shaped end portions **5**.

[0054] According to this embodiment, the identification information A and the detection data D1, D2, D2.sub.1 can be acquired by performing wireless communication between the IC tag **11** and the communication unit **16**. Then, based on the acquired identification information A and the detection data D1, D2, D2.sub.1, the condition of each fender **2** can be easily grasped. The pressure sensor **15a** and the temperature sensor **15b** are installed on the IC tag **11** and are integrated with the IC tag **11**, allowing man-hours for mounting these parts on the fender **2** to be reduced. Furthermore, the IC tag **11**, the pressure sensor **15a**, and the temperature sensor **15b** are activated by the transmission radio wave R1 transmitted from the communication unit **16**. Therefore, it is not necessary to provide a battery in these parts. Therefore, there is no need to replace the battery of these parts, and there is no risk of data being unable to be acquired due to a weak battery. This improves maintainability and is advantageous for stably grasping the condition of each fender **2** for the long term.

[0055] As illustrated in FIG. **1**, when a plurality of fenders **2** are used in tandem, the severity of the fenders **2** varies depending on the installation position, and the degree of wear of each fender **2** also varies accordingly. In the management system **1**, the severity (use state) of each fender **2** and the use history of each fender **2** can be grasped. Therefore, based on the data, it is advantageous to perform appropriate rotation of the installation position such that the wear state of each fender **2** becomes uniform.

[0056] When the fender **2** is stored in a warehouse or the like, the fender **2** is stored in an expanded state at a predetermined internal pressure. In determining the condition of the fenders **2**, wireless communication between the IC tag **11** and the communication unit **16** is performed by the above-described procedure. Then, an individual of the fenders **2** is specified, and the condition of the



fender **2** is determined based on the detection data **D1**, **D2**, **D2.sub.1**. Air leakage of the fender **2** over time can be easily grasped based on the detection data **D1**. For the fender **2** whose internal pressure is lower than the reference value due to the air leakage, it is advantageous to quickly perform operation of replenishing air.

[0057] The IC tag **11** illustrated in FIG. **7** is covered with coating rubber **6a** and embedded in the body **3** of the fender **2** that has already been manufactured. Specifically, the IC tag **11** is bonded to the inner layer rubber **6** and entirely covered with the coating rubber **6a**. However, the detection portions of the pressure sensor **15a** and the temperature sensor **15b** are not covered with the coating rubber **6a** and are exposed to the internal space of the fender **2**. The coating rubber **6a** is bonded to the inner layer rubber **6**. The same kind of rubber as the inner layer rubber **6** may be used for the coating rubber **6a**.

[0058] If the fender **2** that has already been manufactured is large (for example, the outer diameter of the body portion **4** is two meters or more), workers can enter and exit the inside of the fender **2** through the cap portion **9**. Therefore, as illustrated in FIG. **7**, the IC tag **11** can be attached afterward to the fender **2** that has been already manufactured with the IC tag **11** embedded in the body **3**. When the IC tag **11** is attached later to the body **3** in this manner, the management system **1** can be applied to the fender **2** that has already been manufactured.

[0059] As illustrated in FIG. **8**, the calculation device **17** may be configured to be connected to desired terminal devices **21** via a communication network such as the Internet. For example, various pieces of information (data) are transmitted from the calculation device **17** to the terminal devices **21** of relevant parties such as a control room of an operating company (user) of the fender **2**, a sales company of the fender **2**, or a manufacturing company, which are located remotely from the location where the fender **2** is used. The information to be transmitted to each of the terminal devices **21** is, for example, the detection data **D1**, **D2**, **D2.sub.1** of each fender **2** acquired by the communication unit **16** and the determination result of the condition of the fender **2** by the calculation device **17**. According to this configuration, the relevant persons having these terminal devices **21** can grasp the internal and external states of the fender **2** while being remotely located to the place where the fender **2** is used.

[0060] In another embodiment of the management system **1** illustrated in FIG. **9**, a drone **18** and a camera device **19** are further added to the foregoing embodiment. The communication unit **16** and the camera device **19** are installed on the drone **18**. Other configurations are substantially the same as those in the foregoing embodiment, and the various specifications described above can also be applied. The camera device **19** can be optionally provided. However, providing the camera device **19** is advantageous in grasping the condition of the fender **2** in more detail. In FIGS. **9** to **11**, the boundary between the body portion **4** and each bowl-shaped end portion **5** is illustrated by a two-dot chain line for reference.

[0061] In this embodiment, the calculation device **17** is located at a location remote from the place where the fender **2** is used, and the communication unit **16** and the calculation device **17** are configured separately and independently. The communication unit **16** and the calculation device **17** may be integrated and installed on the drone **18**.

[0062] The camera device **19** acquires image data **M** of the fender **2** from the airspace above the fender **2**. As the camera device **19**, various known digital cameras and the like that acquire the image data **M** of still images or moving images can be adopted. The image data **M** acquired by the camera device **19** is input to the calculation device **17**.

[0063] The drone **18** can employ known specifications that allow the drone **18** to fly to a desired position and hover in a fixed position while installed with the communication unit **16** and the camera device **19** described above. The drone **18** is equipped with a GNSS receiver **20**, and the position coordinates of the drone **18** are grasped in real time by the GNSS receiver **20**. Inputting the position coordinates of the desired position into a control unit of the drone **18** allows the drone **18** to fly to the desired position by automatic control operation.

[0064] The calculation device **17** has already received reference image data **Mc** that indicates the fender **2** in a sound condition without twisting and without any unnecessary deformation as illustrated in FIG. **10**. The reference image data **Mc** may be image data actually photographed from the airspace above the fender **2** or data prepared from design data or the like. For example, an output means such as a monitor is connected to the calculation device **17**.

[0065] An example of a procedure for grasping the condition of the fender **2** by using the embodiment of the management system **1** as illustrated in FIG. **9** will be described below.

[0066] As illustrated in FIG. **9**, the drone **18** is flown from a measurement base located, for example, on land or on a ship, and moved into the airspace above and near the fender **2**. For example, based on the position information of the fender **2** grasped in advance, the GNSS receiver **20** installed on the drone **18** is used to move the drone **18** to the airspace above the fender **2** by automatic operation. In performing wireless communication between the IC tag **11** and the communication unit **16**, the drone **18** continues to be positioned in the airspace above and near the IC tag **11** by automatic operation, and the separation distance between the IC tag **11** and the communication unit **16** is maintained at about one meter. Alternatively, the drone **18** can be positioned in the airspace above and near the IC tag **11** by operation from a drone operator based on the image data **M** acquired in real time by the camera device **19**. In this embodiment, when the embedding mark **10** is provided on the outer surface of the body portion **4**, the communication unit **16** can be easily brought close to the IC tag **11** using the embedding mark **10** as a sign.

[0067] With the drone **18** (the communication unit **16**) positioned in the airspace above and near the IC tag **11**, the IC tag **11** is activated by the transmission radio wave **R1** transmitted from the radio wave transmission unit **16a**. The return radio wave **R2** transmitted from the IC tag **11** in response to the transmission radio wave **R1** is received by the radio wave reception unit **16b**, and wireless communication between the IC tag **11** and the communication unit **16** is performed.

[0068] The procedure for grasping the condition of the fender **2** is the same as in the foregoing embodiment, but in this embodiment, as illustrated in FIG. **9**, while the drone **18** is in the airspace above the fender **2**, the camera device **19** acquires image data **Mr** of the fender **2**. As illustrated in FIG. **11**, it is preferable to acquire the image data **Mr** that covers the entity of the fender **2**. The timing of acquiring the image data **Mr** may be before or after performing wireless communication between the IC tag **11** and the communication unit **16**.

[0069] The acquired image data **Mr** is input to the calculation device **17**. The calculation device **17** determines the external state of the fender **2** based on the difference between the input image data **Mr** and the preset reference image data **Mc**. For example, each external shape (contour) of the fender **2** of the reference image data **Mc** illustrated in FIG. **10** and the acquired image data **Mr** illustrated in FIG. **11** are compared. The calculation device **17** determines that an abnormal deformation has occurred in the fender **2** when the degree of deformation of the fender **2** of the image data **Mr** relative to the fender **2** of the reference image data **Mc** exceeds a preset tolerance range, and determines that no abnormal deformation has occurred when the degree of deformation is within this tolerance range. Superimposing the fenders **2** on the reference image data **Mc** and the image data **Mr** allows the degree of deformation of the fender **2** to be easily calculated by the calculation device **17**. As a result, it is advantageous to grasp the damage or the like of the fender **2** early.

[0070] Alternatively, the arrangement of the fender **2** at the attachment location, such as the quay **22**, of the reference image data **Mc** and the image data **Mr** are compared. The calculation device **17** determines that an abnormal displacement has occurred in the fender **2** when the degree of displacement of the fender **2** of the image data **Mr** relative to the fender **2** of the reference image data **Mc** exceeds a preset tolerance range, and determines that no abnormal displacement has occurred when the degree of displacement is within this tolerance range. As a result, it is advantageous to grasp the attachment abnormality of the fender **2** or the like early.

[0071] According to this embodiment, in performing wireless communication between the IC tag

**11** and the communication unit **16**, the drone **18** is moved into the airspace above and near the IC tag **11**. Therefore, the worker does not need to move close to the IC tag **11** to bring the communication unit **16** close to the IC tag **11**, making the work much lighter. Even when the fender **2** is large (for example, the outer diameter of the body portion **4** is two meters or more), this wireless communication can be easily performed.

[0072] Further, by providing the camera device **19**, the external state of the fender **2** can be grasped by comparing the reference image data  $M_c$  and the image data  $M_r$ . That is, it is advantageous to grasp the condition of the fender **2** in more detail by using the image data  $M_r$  as well as the detection data **D1**, **D2**, and **D2.sub.1** by the pressure sensor **15a** and the temperature sensor **15b**. In this embodiment, when the calculation device **17** is connected to the desired terminal device **21** via a communication network as illustrated in FIG. **8**, the image data  $M_r$  of each fender **2** acquired by the camera device **19** can also be transmitted from the calculation device **17** to the terminal device **21**.

## REFERENCE SIGNS LIST

[0073] **1** Management system [0074] **2** Pneumatic fender [0075] **2a** Guy rope [0076] **3** Body [0077] **4** Body portion [0078] **5** Bowl-shaped end portion [0079] **6** Inner layer rubber [0080] **6a** Coating rubber [0081] **7** Reinforcing layer [0082] **8** Outer layer rubber [0083] **9** Cap portion [0084] **10** Embedding mark [0085] **11** IC tag [0086] **12** IC chip [0087] **13** Antenna unit [0088] **14** Substrate [0089] **14a** Insulating layer [0090] **15a** Pressure sensor [0091] **15b** Temperature sensor [0092] **16** Communication unit [0093] **16a** Radio wave transmission unit [0094] **16b** Radio wave reception unit [0095] **17** Calculation device [0096] **18** Drone [0097] **19** Camera device [0098] **20** GNSS receiver [0099] **21** Terminal device [0100] **22** Quay [0101] **A** Identification information [0102] **D1**, **D2** Detection data [0103] **M** Image data

## Claims

**1.** A management system of a pneumatic fender, the management system comprising: a pneumatic fender comprising a body comprising a body portion having a cylindrical shape, bowl-shaped end portions connected to both sides of the body portion in an axial direction, and a cap portion attached to at least one of the bowl-shaped end portions; an IC tag of a passive type installed in the pneumatic fender; a pressure sensor configured to detect an internal pressure of the pneumatic fender and a temperature sensor configured to detect a temperature of an internal space of the pneumatic fender; and a communication unit disposed outside the pneumatic fender, an individual of the pneumatic fender being specified based on identification information of the IC tag acquired by the communication unit, and a condition of the pneumatic fender being determined based on detection data from the pressure sensor and the temperature sensor acquired by the communication unit; the pressure sensor and the temperature sensor being installed on the IC tag and integrated with the IC tag, the management system comprising a calculation device to be communicably connected to the communication unit, the IC tag being activated by a transmission radio wave transmitted from the communication unit, the pressure sensor and the temperature sensor being activated, a return radio wave being transmitted from the IC tag activated in response to the transmission radio wave, and wireless communication between the IC tag and the communication unit being thus performed, the identification information being acquired by the communication unit through the wireless communication and being input to the calculation device, and the detection data from the pressure sensor and the temperature sensor when the IC tag is activated being acquired by the communication unit through the wireless communication and being input to the calculation device, and by the calculation device, an individual of the pneumatic fender being specified based on the identification information input, and a condition of the pneumatic fender being determined based on each detection data input.

**2.** The management system of a pneumatic fender according to claim 1, wherein the IC tag is

embedded in the body.

3. The management system of a pneumatic fender according to claim 2, wherein the IC tag is disposed at multiple sections spaced apart in a circumferential direction of the body.
  4. The management system of a pneumatic fender according to claim 2, wherein an antenna unit constituting the IC tag is a dipole type and consists of a metal monofilament.
  5. The management system of a pneumatic fender according to claim 2, wherein an embedding mark indicating an embedding position of the IC tag is provided on an outer surface of the body corresponding to the embedding position of the IC tag.
  6. The management system of a pneumatic fender according to claim 2, wherein the temperature sensor is configured to detect a temperature of the body at a position where the temperature sensor is embedded, and the temperature of the body detected by the temperature sensor is also used as the detection data from the temperature sensor.
  7. The management system of a pneumatic fender according to claim 1, wherein the communication unit is mounted on a drone.
  8. The management system of a pneumatic fender according to claim 7, wherein a camera device is mounted on the drone, image data acquired by the camera device is input to the calculation device, and the calculation device determines, based on the image data input, a condition of the pneumatic fender.
  9. A management method of a pneumatic fender, the management method comprising: disposing, in a pneumatic fender comprising a body comprising a body portion having a cylindrical shape, bowl-shaped end portions connected to both sides of the body portion in an axial direction, and a cap portion attached to at least one of the bowl-shaped end portions, an IC tag of a passive type, a pressure sensor configured to detect an internal pressure of the pneumatic fender, and a temperature sensor configured to detect a temperature of an internal space of the pneumatic fender; disposing a communication unit outside the pneumatic fender; and specifying an individual of the pneumatic fender based on identification information of the IC tag acquired by the communication unit and determining a condition of the pneumatic fender based on detection data from the pressure sensor and the temperature sensor acquired by the communication unit; the management method comprising: installing the pressure sensor and the temperature sensor on the IC tag, integrating the pressure sensor and the temperature sensor with the IC tag, and providing a calculation device to be communicably connected to the communication unit; activating the IC tag by using a transmission radio wave transmitted from the communication unit, activating the pressure sensor and the temperature sensor, transmitting a return radio wave from the IC tag activated in response to the transmission radio wave, and thus performing wireless communication between the IC tag and the communication unit; acquiring the identification information at the communication unit through the wireless communication, inputting the identification information to the calculation device, acquiring, at the communication unit through the wireless communication, the detection data from the pressure sensor and the temperature sensor when the IC tag is activated, and inputting the detection data to the calculation device; and by the calculation device, specifying an individual of the pneumatic fender based on the identification information input and determining a condition of the pneumatic fender based on each detection data input.
  10. The management method of a pneumatic fender according to claim 9, comprising installing the IC tag while being embedded in the body in a manufacturing process of the pneumatic fender or later installing the IC tag embedded in the body in the pneumatic fender that has already been manufactured.
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