Research on PDA-based hull damage detection and plugging device

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Abstract. With the rapid development of the shipping industry, the water traffic safety situation is still severe, and the shipping safety issue has received extensive attention from all walks of life. Water traffic accidents such as ship collisions, groundings, fires, and self-sinking events will bring serious consequences such as economic losses, marine pollution, and casualties. Based on PDA, this project designs a set of airbag system specially for passenger ships. Compared with the traditional manual plugging technology that relies on the experience and judgment of the crew, this project is more comprehensive and intelligent. Modern ships should move towards a safer and more intelligent direction, so as to truly ensure the safety of shipping channels.

Keywords: ship safety; PDA; algorithm design; shipping.

1. Introduction

1.1 Project Background

With the development of the water transportation industry, the shipping industry has gradually played an irreplaceable and important role in serving the economic and social development and smoothing international trade. Today, with the rapid development of my country's shipping industry, the safety situation of water traffic is still severe, and the issue of shipping safety has received extensive attention from all walks of life. Water traffic accidents such as ship collisions, groundings, fires, and self-sinking events will bring serious consequences such as economic losses, marine pollution, and casualties. Among the major shipping traffic accidents, the consequences caused by ship collisions are the most serious, and the accident rate of shipwrecks is extremely high. Therefore, the protection measures for ships after ship collisions and other maritime traffic accidents are the main concerns in the shipping industry. One, this product can provide a strong guarantee for the safety of passenger ships [1].

1.2 Research objectives and content

The research goal is to use fast, self-detonating inflatable airbags to provide buoyancy to prevent ships from rolling over or sinking [2]. The research content is to use the electronic sensing control equipment to process the information data of the ship's inclination degree and the water intrusion degree obtained from the gravity inclination sensor and the water sensor, and to decide whether to issue an instruction to open the corresponding airbag [3]. When the igniter is detonated, Push out the main body of the airbag, and the airbag enters the damaged compartment and is filled with gas to generate buoyancy to correct the attitude of the ship [4].

1.3 Research significance

This project is a set of airbag systems specially designed for passenger ships. Compared with the traditional manual plugging technology that relies on the experience and judgment of the crew, this project is more comprehensive and intelligent. Modern ships should move towards a safer and more intelligent direction, so as to truly ensure the safety of shipping channels, achieve the stability of the international shipping logistics supply chain and the high-quality development of the shipping industry [5].

2. Development and Application of PDA

2.1 PDA and its operating system development

The early application of PDA is reflected in personal consumption, but in recent years, with the development of microelectronic technology and optoelectronic technology, the mobile computer system represented by PDA has become increasingly popular, and its demand has shown a trend of increasing temperature [6]. PDA is a handheld machine suitable for the palm, most of which are mainly pen-type handwriting input [7]. Operating systems such as Windows CE and its subordinate Windows Mobile have been widely used in various types of PDAs, and provide a wealth of embedded development toolkits, which are convenient for developers to develop and research on the corresponding platform. PDA has the characteristics of portability, durability and simple operation, which meets the requirements of field operations. Based on the above characteristics, PDAs have been widely used in various industries, such as warehouse management systems and logistics control systems in logistics systems, mobile workflow systems in large enterprise management, mobile data query and entry in public security systems, and catering service industry [8].

PDA has a special operating system, friendly interface, and strong practicability. Judging from the current market, although PDA operating systems are highly competitive, they have their own characteristics, including Palm operating system, Linux operating system, Windows CE operating system, etc., as well as various operations derived from these systems as the kernel. System [9].

2.2 Status of PDA-based hull detection system

In foreign countries, there have been successful cases of applying the PDA-based hull detection data acquisition system, but its price is relatively expensive, and the operation interface is not convenient for domestic direct use, which brings certain difficulties for promotion [10]. Domestically, similar to industries such as medical treatment, electric power, railway transportation, and field geological survey, the application of PDA in shipbuilding industry, especially in ship hull inspection, is still in its infancy. In addition, most of these applications in the initial stage only import the detection data into the PDA, and compare with the relevant standards to conclude that the data is still input by handwriting, so the automation and information of data collection have not been truly realized [11]. In the process of hull accuracy inspection, a large amount of data is included and the requirements for data management and accuracy are very strict. In the existing detection system, the field detection data is input into the PDA for management, although the detection efficiency is improved to a certain extent, but the connection between the detection instrument and the PDA is not realized.

The most important thing is that these systems only manage the data simply, and do not process and feedback the detection data in various aspects, and do not achieve seamless integration with the follow-up precision management work [12]. Only by combining on-site inspection work with in-office precision management work can an efficient precision management system be designed and realized, providing maximum assistance for on-site segmented loading. Therefore, it is very necessary to study a PDA-based auxiliary detection system for ship hull accuracy [13].

2.3 Analysis of Coordinate System Conversion Algorithm

The process of similar transformation is the process of matching the elements of the new coordinate system with the original coordinate system after translation, rotation and scaling, and keeping the mesh shape unchanged [14]. The advantage of this model is that the meaning of the conversion parameters is relatively clear and the calculation is simple. The disadvantage is that it is only suitable for coordinate conversion between local coordinate systems in a small range, and does not consider the local deformation and error accumulation between the two coordinate systems, and the conversion accuracy is low. These deficiencies can be improved by combining similarity transformation with regression approximation. In this system, only two-space rectangular coordinate conversion is required, and the conversion range is small, and does not involve large-scale coordinate

transformation (such as the space geodetic coordinate system), so the conversion accuracy is not considered [15].

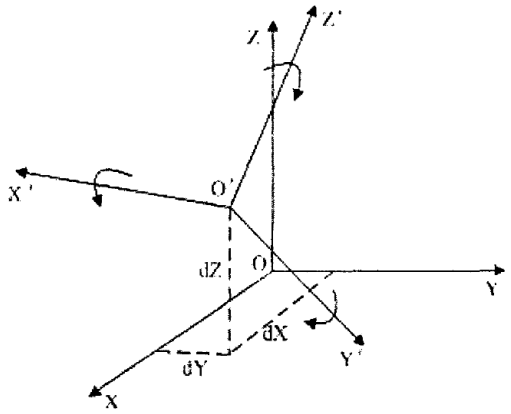


Figure 1. Coordinate system conversion example

After a series of steps above, the conversion relationship from the original Cartesian coordinate system O-XYZ to the target Cartesian coordinate system O-X'Y'Z' transformation can be obtained as follows:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} dX \\ dY \\ dZ \end{bmatrix} + \begin{pmatrix} 0 & \varepsilon_z & -\varepsilon_y \\ -\varepsilon_z & 0 & \varepsilon_x \\ \varepsilon_y & -\varepsilon_x & 0 \end{pmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + (1+k) \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Rewrite the formula and find the error before and after the transformation, and get the error equation of the i pair of common points:

$$\mathbf{e_i} = \begin{pmatrix} V_x \\ V_y \\ V_z \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & X & 0 & -Z & Y \\ 0 & 1 & 0 & Y & Z & 0 & -X \\ 0 & 0 & 1 & Z & -Y & X & 0 \end{pmatrix} \begin{pmatrix} dX \\ dY \\ dZ \\ k \\ \varepsilon_x \\ \varepsilon_y \\ \varepsilon_x \end{pmatrix} + \begin{pmatrix} X - X' \\ Y - Y' \\ Z - Z' \end{pmatrix} = \mathbf{c_i t} + \mathbf{p_i}$$

For n pairs of common point errors can be expressed as:

$$\mathbf{E} = \mathbf{Ct} + \mathbf{P}$$

The error sum of squares is obtained from the above formula:

$$S(\mathbf{t}) = \sum_{i=1}^{n} \mathbf{e}_i^{\mathbf{T}} \mathbf{e}_i = \mathbf{E}^{\mathbf{T}} \mathbf{E}$$

In order to obtain the value of t when s(t) is the smallest, take the first and second derivatives of s(t) with respect to t to get:

$$\frac{dS(\mathbf{t})}{d\mathbf{t}} = 2\mathbf{C}^{\mathrm{T}}\mathbf{Ct} + 2\mathbf{C}^{\mathrm{T}}\mathbf{P}$$

$$\frac{d^2S(t)}{dt^2} = 2C^{\mathbf{T}}\mathbf{C}$$

Therefore t is the value that minimizes S(t), the least squares solution of the seven-parameter method.

3. Research based on marine airbag equipment

The current functions of marine airbag equipment are mainly for flotation, wave prevention, and convenient salvage, which can reduce the impact of waves on salvage and salvage work, improve the salvage and salvage environment [16]. Floating, can effectively prevent overturning and delay the sinking time. At present, the specific applications of airbag equipment in the hull mainly include the following:

3.1 Ship anti-rollover and anti-sinking system

This air bag system is mainly a method to prevent the ship from overturning or sinking by providing buoyancy with fast, self-detonating and inflating air bags [17]. The key to the technology is to use the electronic sensing control equipment to process the information and data of the ship's inclination and the degree of water ingress obtained from the gravity inclination sensor and the water sensor, and to decide whether to issue an instruction to open the corresponding airbag. When the igniter is detonated, Push out the main body of the airbag, and the airbag enters the damaged compartment and is filled with gas to generate buoyancy to correct the attitude of the ship [18].

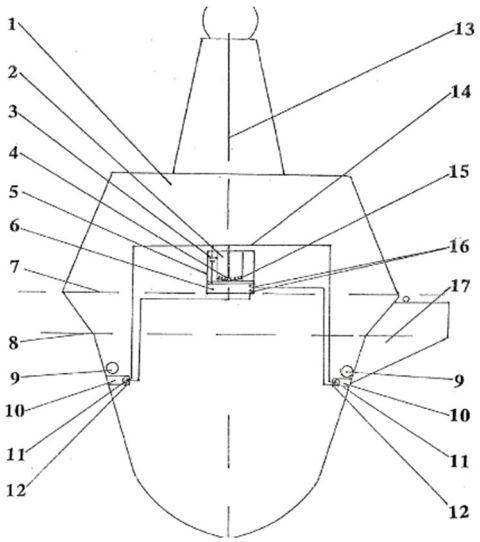


Figure 2. Distribution of airbags on the side

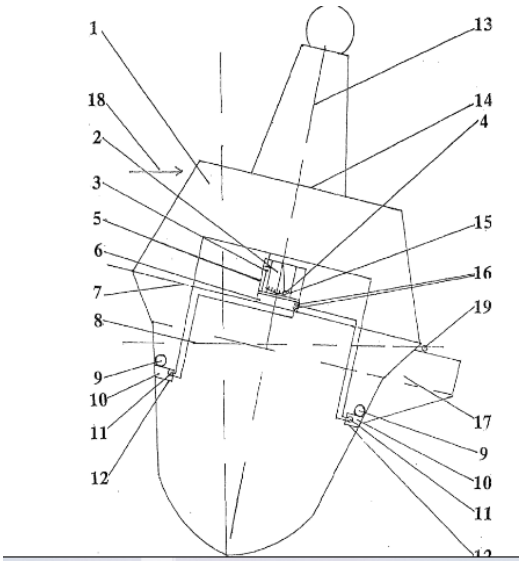


Figure 3. Simulation of the situation of ship rollover

3.2 Ship plugging system

The airbag structure for plugging can finally realize the plugging from the outside to the inside, which is different from the traditional plugging method. Leaks inside the hull [19].

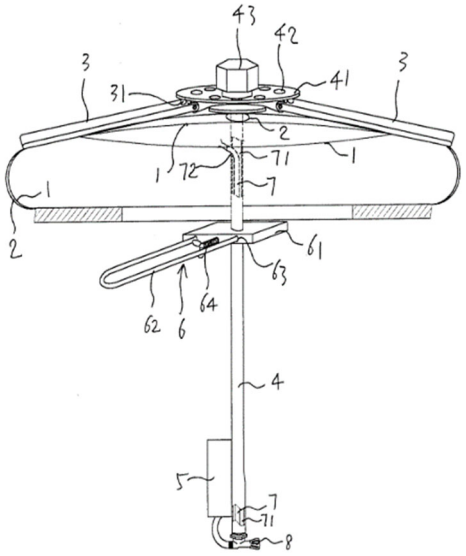


Figure 4. Structural design of a plugging airbag

To sum up, airbag equipment can play a positive role in ship anti-sinking and anti-rolling, which can slow down the sinking time of the ship and improve the salvage and salvage environment. However, there are still many problems that cannot be ignored in the practical application of the airbag: the external anti-overturning airbag needs to be installed in multiple rib positions, which takes up too much space on the hull; the existing plugging airbag needs to be specially installed, which will lead to a decrease in the strength of the hull[20]. In addition, the airbag self-starting detection system is still not mature enough, and the airbag cannot be guaranteed to start at the right time, which also causes the current situation that marine airbags are not widely used.

3.3 Using the positioning technology with radio frequency identification technology (RFID) as the core

This damage detection system mainly includes a split liquid level sensor, a database system, a signal converter, a Zigbee wireless communication system, a terminal receiver and a background server. The signal is processed and analyzed by the database processing system, and converted into information that can be received by the Zigbee communication system, and the received hull damage system is transmitted to the terminal receiver in the bridge through wireless communication technology. Process the signal. Finally, the detection of the damage signal of the hull is completed. Among them, the main flow chart of damage detection and positioning is as follows:

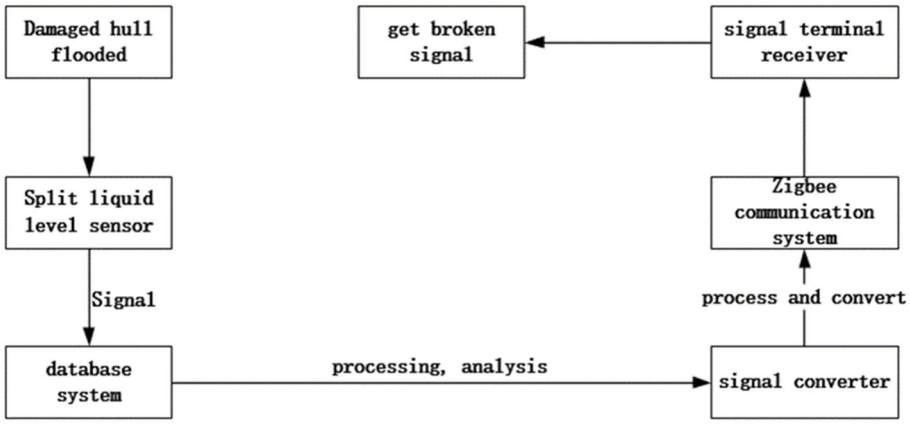


Figure 5. Flow chart of damage detection and location

At present, most of the positioning technologies on the market include infrared positioning technology, ultrasonic propagation positioning technology, GPS positioning technology and WI-FI positioning technology. Infrared positioning technology is only suitable for short-distance propagation, and is easily interfered by environmental factors such as walls and lights, and the positioning accuracy in short-distance positioning is low; although the positioning distance of ultrasonic propagation positioning technology is large, it is affected by non-line-of-sight propagation. It has great influence and strict requirements on environmental factors, so it is not suitable for positioning in ship cabins; GPS positioning technology is the most widely used positioning technology at present, but due to its large coverage and the positioning of small objects indoors The accuracy is low, so it is not suitable for this project. Although the WI-FI positioning technology has high positioning accuracy and low cost, the usual receiver and transmitter only allow the positioning of the area within a radius of 90m, and it is easy to receive interference from other signals. Therefore, after analyzing the existing positioning technology, this project decided to adopt the positioning technology with radio frequency identification technology (RFID) as the core, because the radio frequency identification technology (RFID) has the characteristics of high security, strong environmental adaptability and non-line-of-sight communication. , and this technology is widely used in information collection, information management and other fields, so this project plans to use this technology to locate the damaged position of the hull after damage. That is, after the terminal signal receiver receives the damage signal, the RIFD technology is used to determine the specific location of the damaged bulkhead, so as to achieve the purpose of blocking the cabin and leaks in time. This RFID positioning system consists of readers, tags, communication networks and background servers. The system composition is as follows:

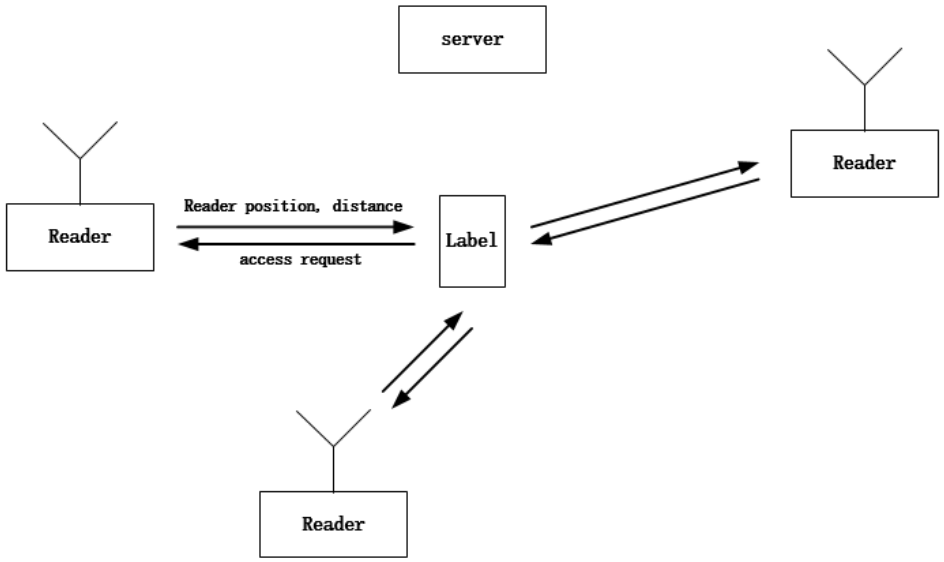


Figure 6. Composition of RFID breach location system

Among them, each reader stores the information of its own position, and can send it to the tag entering the hull area by means of radio frequency. Through radio frequency communication between the tag and the reader, the pseudorange of the radio transmission can be measured, and its own position information can be calculated accordingly, and then reported to the reader. The communication network can transmit the information received by the reader to the background server, and the background server can also control each reader through the network. After the installation of the system is completed, the label on the hull can determine its own position through radio frequency, and upload it to the background server through the communication network. The background server collects the tag information and provides network services for the location of the tag, and finally can

locate the exact location of the damaged hull. According to the severity of the hull collision, the damage on the bulkhead of the general ship can be divided into three situations: small holes, small and medium holes, and large cracks. The split-type liquid level sensor signals when three different holes appear are stored in the data processing library respectively. When a ship collides, the type of hole in the bulkhead can be judged according to the difference in signal size, so as to take corresponding sealing measures. blocking measures.

3.4 Adopt electromagnetic ejection skeleton design

Considering various factors such as the flow of water in the cabin environment after the hole enters the water and the navigation of the ship, in order to make the airbag device stably block the hole in the cabin, we must effectively fix the airbag device. The traditional single airbag is not only unable to maintain stability in water, but also easily deformed under the action of water pressure, and cannot well achieve the function of plugging leaks. To solve this problem, we designed a rod device based on electromagnetic ejection as the internal skeleton of the airbag. The electromagnetic ejection skeleton is mainly composed of a central shaft, a movable telescopic disk, a connecting rod and a fixed plate at both ends; the central shaft is the core shaft member, and the interior is hollow design, and the central shaft is equipped with a telescopic disk, a connecting rod and a fixed plate; It is assembled on the central shaft and connected with the connecting rod to control the opening and contraction of the entire skeleton; there are six connecting rods in total, which are connected with the first layer of air bags to support and control the air bags; the fixing plates are installed at both ends of the central shaft , cooperate with two fixed shafts to fix the whole frame inside the cabin.

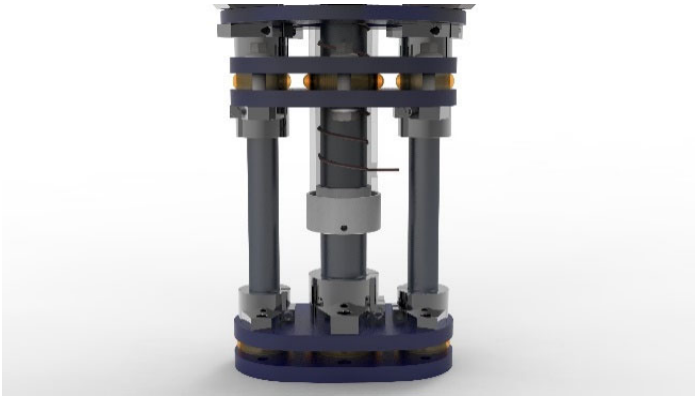


Figure 7. The current loop formed by the central shaft and the fixed rod

4. Conclusion

The multi-layer leak-stopping airbag device designed in this project mainly includes two parts: the electromagnetic ejection skeleton and the two-layer airbag device outside the skeleton. The electromagnetic ejection skeleton can not only provide internal support for the airbag, but also use this skeleton to reasonably arrange the entire airbag device in the appropriate position of the cabin to be installed. It is fixed at a certain position in the cabin to maintain stability, so that the airbag device can be in a reasonable position when it is working, so that the airbag can block the cracks and cracks in the cabin. Through the multi-layer airbag device outside the ejection frame, we can effectively block it. The hole in the cabin and the double-layer design can effectively solve the problem of large deformation of the airbag caused by external water pressure. The inflated airbag can also occupy a certain volume to provide buoyancy for the hull. The production cost of this project is low, which can guarantee the safety of goods and personnel on board, and has high economic benefits.

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