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The Design of Oil Port Accident Exercise Experiment System Based on Virtual Environment

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Abstract

Taking large scale equipments of oil storage and transportation port as research objects, in this article, we establish the oil port accident exercise experiment system under the virtual environment, which mainly includes the visual modeling construction of oil port equipment, the virtual equipment accident reasoning system and the reliability evaluation and safety evaluation system of oil equipment, in order to realize the accident reasoning, simulation, demonstration, and danger and reliability evaluation of oil equipments under the virtual environment.

Keywords: Virtual simulation, Accident exercise, Oil port safety evaluation

1. Research background and meanings

With the quick development of Chinese economy and society, oil has been the energy with maximum import demand and quick increase. At present, the oil import of China is mainly from Middle East, Africa and South America, and the transportation is mainly completed by ocean shipping. To fulfill the developmental demand of oil ocean shipping, Chinese oil special dock and oil storage business are developed quickly, and various regions establish special docks for the oil storage and transportation, and form the oil transportation port area with certain scale, which are mainly centralized in the eastern littoral from Bohai Bay to Beibu Gulf.

The shipping of oil has many characters such as large capacity, few middle tache, quick turnover, charge savings of package, barrel, storage, cleanout and disposal, few goods loss and large economic benefit and social benefit. But it has also large hidden dangers, and the security of oil storage and transportation dock comes down to the load and unload of oil ship, the acceptance and dispatch operation of oil goods, the oil storage in the storeroom, the oil pipe and other important danger sources. Because the dock stores large base oil, and oil is a sort of flammable, toxic and harmful chemical material, once accident happens, it will induce not only large fortune loss and personnel casualty, but abominable social influence and serious environmental pollution. Therefore, the safe production of oil storage and transportation dock has important meaning. In the 41st chapter of "Outline of the 11th Five-Years Plan for National Economic and Social Development", China had definitely put forward the requirement to implement supervision and alarming for important danger sources.

In the present stage, Chinese oil port storage and transportation still have many hidden troubles of security, which are mainly represented in that the security management mode of oil dock storage and transportation is not mature, and the timely danger evaluation in the process of oil dock storage and transportation and the application degrees of modern security management based on the computer technology in oil port personnel training, information sharing, production and preparation, accident emergency rescue are low. So, the security production of oil storage and transportation dock must follow the strategy of "Modern Technology to improve Safety", use modern information technology to establish the security supervision and management information system, and enhance the securities of oil load and unload, oil tank,

oil pipe and oil transportation vehicle to enhance the security production management level of enterprise through informationization.

2. Research contents of virtual accident excise system

The study of the oil port accident excise experiment system under the virtual environment takes the large scale equipment of oil storage and transportation dock as research objects, starts from the establishment of 3D entity model, establishes the high visual information carrier based on equipment component, takes equipment status parameters, accident mode and accident class as information source, studies the large equipment accident reasoning technology and simulation (demonstration) technology in the virtual environment, and forms the accident simulation system.

The design and research content of the system mainly include following aspects.

(1) High visual failure modeling technology of oil port equipment component

Adopt OO technology, take status parameters of key equipment component in oil port (including equipment figure structure, physical attribute, functional attribute, mechanical attribute and electric attribute), accident mode and accident class as character attributes, establish the 3D entity model of equipment component, and establish the high visual equipment failure model of oil port equipment components.

(2) Establish the equipment accident reasoning system in the virtual environment

Apply the accident excise technology, establish the representative accident reasoning system of oil port key equipment, and establish the representative accident process demonstration system of oil port key equipments.

(3) Establish the reliability evaluation and safety evaluation system of oil port equipment

Establish the reliability mode and safety model of oil port key equipments, and establish the reliability and security evaluation system of oil port key equipments.

(4) Establish the base of emergency rescue strategy and emergency rescue program

Establish the emergency rescue strategy decision system and emergency rescue program based on oil port storage and transportation, constitute the preventative maintenance strategy, maintenance measure and repair program after accident for oil port equipments.

(5) Research and develop 3D virtual repair system

Develop the 3D virtual repair system based on oil port key equipment for the failure orientation demonstration, accident happening process demonstration, preventative maintenance demonstration, repair process demonstration after accident and accident influence sequent demonstration.

3. Anticipated aims of system research and development

The anticipated total aim of the oil port accident excise system based on virtual environment is to offer the high visual model of oil port equipment system, realize the virtual visual reasoning of accident, offer repair strategy and repair program support for various representative accidents and demonstrate them in the virtual environment.

The anticipated function and aim are seen in Figure 1, and the concrete aims include following aspects.

(1) Establish high visual accident model

As an object, the model should not only express the figure structure of equipment, but include the physical attribute, function attribute, mechanic attribute and electric attribute of equipment, and present the equipment attributes by the obvious and convenient form.

(2) Realize representative accident reason reasoning

Classify the accident, summarize the inducing factor of accident, form the accident expert knowledge base, adopt the outline analysis method, apply the fishbone diagram description to realize the accident orientation reasoning.

(3) Realize the process demonstration of representative accident

Present the accident by the simple forms (diagram, simulation and table) to the decision-maker to realize scientific decisions. The demonstration system could bring forth the process of the equipment from normal working status to the failure status, present the terrain range influenced by the accident, calculate the economic loss and evaluate the influencing degree to the public security.

(4) Design and establish complete emergency rescue program base

(5) Virtual accident simulation

4. System structure and technical method

The system structure and technical method are seen in Figure 2, which include following aspects.

4.1 High virtual failure modeling technology of oil equipment components

Model is a necessary tool in the development process of information system, and modeling is the basic and necessary work to establish the information system. The information system could be regarded as composing by a series of ordered models which usually include function model, information model, data model, control model and decision-making model.

In the development process of this system, we need information system modeling and 3D entity modeling. To establish the failure model of oil port equipment component mainly comes down to the 3D entity modeling technology.

There are many 3D entity modeling tools, and common modeling software include Pro/E, UG, SolidWorks, 3DMax and so on (Ren, 2005), and some of them have simple function and some have complex function, and some modeling methods are based on the character, and some modeling methods are entity geometry modeling. Above modeling tools all can obtain geometric entity, and relative to the requirement of equipment accident excise system, they still lack necessary attribute information, physical character and failure character information. When applying existing entity modeling tools, we should emphasize to study many information problems such as function attribute, mechanic attribute and accident mode attribute based on the geometric model.

However, because the geometric model constructed by common 3D modeling software is usually large, and when making cartoon simulation by directly introducing virtual scene, the existing PC could not acquire smooth cartoon effect. In recent years, VRML technology (Dong, 2002, p.210-214, Feng, 2006, p.387-390, Ren, 2005 & Sang, 2001) has been applied in simulation cartoon better, and it is a good choice to adopt VRML to describe the entity geometric model, attribute information and failure information.

This system will adopt OO information modeling method, apply VRML technology (or Pro-e, 3DMax, UG and SolidWorka) entity modeling tool, establish the equipment model and system model, describe attribute information and failure information aiming at the oil port storage and transportation system and large scale equipment, and modify the equipment model according the historical data of actual operation, and finally obtain the operation rule of equipment at the reaction locale and the coupling relationship among various parameters, and these relationships will be basic proof as the reasoning deduction of accident and form the expert knowledge base.

Another research emphasis of the oil port equipment component failure modeling technology is the complementary information taking the oil port equipment coupling danger as 3D entity model. At present, the security of oil port mainly takes the hidden danger and failure mode of independent equipment part as the research object (Wu, 2005), but the oil port equipments and work flow are the organic integration connecting and coupling each other, so any failure happens to any one point or any problem occurs in any one equipment which will influence and affect the whole system instantly, and if the disposal is not timely and the control measure is not proper, the chain-reaction will always be induced and the accident will be extended. Therefore, we should fully consider the coupling problem of multiple factors and multiple type failures when establishing the oil port equipment failure mode mechanism base.

4.2 Accident reasoning system of oil port equipment

The accident reasoning is the process to deduce the conclusion from existing facts according to certain accident happening rules. At present, usual methods to analyze the accident reasoning include the reasoning method based on signal transformation, the reasoning method based on the expert system, the reasoning method based ANN, and the reasoning method based on integrated intelligent system. Above methods have their own problems more or less, especially when complex failure occurs in the system or the interference happens because of various reasons, information will lose and uncertain factors will increase, so the forward and backward reasoning is more and more favored by people.

In the research domain of safety science, usual methods in accident reasoning mainly include fault tree analysis (FTA) and event tree analysis (ETA). FTA and ETA study accident mode through system safety analysis (SSA), summarize inducing factors of accident, form the accident reasoning demonstration of fishbone diagram by the tree structure analysis method, and realize the accident orientation reasoning. In recent years, with the large-scale tendency and complication of the industrial system, the research of accident deduction technology based on fuzzy reasoning is continually deepening. The fuzzy reasoning is a sort of uncertain reasoning by fuzzy knowledge, and the thing disposed by it is fuzzy, and the concept has not specific extension, and it is hard to definitely denote whether one object accords with the concept, so the fuzzy reasoning is the expression and disposal for the uncertainty (Xiang, 2005).

The oil port equipment accident reasoning system will comprehensively utilize the example reasoning (Wu, 2005), forward and backward reasoning (Nie, 2005) and fuzzy reasoning technology to analyze the parameter association in potential accident according to the early failure alarming information of equipment, and find out the possibility which will induce the accident of equipment, and use the virtual visual method to deduct the happening and development process of accident, and accordingly arrange proper equipment examining and maintenance plan, constitute relative anti-accident measure and program, and finally realize the real-time maintenance for equipments.

4.3 Virtual simulation system

The virtual simulation system is a sort of technology which utilizes the computer software to simulate actual locale and objects to implement scientific experiment, and it is the necessary measure to implement analysis, design, experiment and evaluation for many complex system (engineering or non-engineering). According to the applied object, it could be divided into the model simulation and view simulation.

The research and development hotspots of virtual simulation technology mainly include OO simulation, DIS (distributed interactive simulation), intelligent simulation, visual simulation, multimedia simulation and virtual reality simulation (Zhao, 2007). The virtual visual technology, simulation technology and virtual reality technology are more and more concerned in the domain of equipment safety by people, but present foreign and domestic researches still have not apply the virtual simulation technology combining visual technology, simulation technology and virtual reality technology in accident diagnosis and orientation, accident development process demonstration, accident statues expression and accident damage evaluation for oil port equipments.

The oil port equipment virtual simulation system takes the Windows NT ADAMS (automatic dynamic analysis of mechanical system) 10.0 as the original version, comprehensively utilizes the visual simulation technology, multimedia simulation technology and virtual reality simulation technology to realize the oil equipment and liquid transportation (3D) virtual scene, places different equipments in the virtual scene according to the distribution of oil port establishment (equipments), and establishes living 3D system through particularly describing the attributes of equipments and visual interactive interface. For the software construction, the system is composed by basic simulation demonstration units which have complete network interface and could realize the connection with the main control platform, the association with multiple personnel and the cooperative demonstration.

4.4 Reliability evaluation and safety evaluation system of oil port equipment

The project of oil port safety evaluation relates to many aspects such as the intrinsic harm of goods, the berthing and unberthing work, the loading and unloading work, and the storage work. Oil products generally possess many characters such as flammability, explosion hazard, volatility, static charge accumulation, diffusion and fluidity, heat dilatability, toxicity, oxidant contact hazard and high acid, so the project of oil storage and transportation dock generally possess many potential dangerous factors such as fire, explosion, poisoning asphyxia, chemical burn, electric harm, mechanical harm, object shocking, high falling, collapse, drowning, ship collision, poison harm and yawp harm. In addition, in the dock work process, many potential dangers such as cable breaking, oil pipe breaking and personnel dropping and being smashed still exist.

At present, the evaluation methods used in oil port storage and transportation dock mainly include advance danger analysis method, safety checking table method, important danger source differentiation method, fault tree analysis method, work condition danger evaluation method, large accident consequence analysis method, liquid leaking model evaluation method and some safety evaluation methods combing quantitative analysis with qualitative analysis. According the time stage of safety evaluation, the evaluations include oil port safety prevaluation, oil port checking and accepting safety evaluation, oil port storage and transportation actuality safety evaluation and oil port special safety evaluation.

The safety evaluation content of the system is mainly to establish the reliability evaluation model and danger evaluation model of oil port key equipments. Combining the Weibull distributed information of oil port equipment life, we utilize Monte Carlo simulation method to simulate the accident happening frequency in certain term, establish the reliability evaluation system of oil port equipment through building the reliability block diagram (RBD) of key equipments. We take many key equipments and work flows such as oil ship loading and unloading work, oil tank accepting and dispatching flow and oil pipe as research objects, take oil port overall arrangement, overall plane collocation, oil dock loading and unloading technology, berthing ability, fire fighting establishment, electric safety, anti-thunder and anti-static, special equipments, oil port loading and unloading machines, dock engineering quality and structure safety, dock affiliated establishment, safety management, labor and sanitation and emergency rescue as main contents of safety evaluation, consider the influencing degree of accident consequence degree (including induced social influence, economic loss and environmental influence) based on the reliability evaluation system, and establish the accident danger evaluation model of oil equipments.

5. Conclusions

To design and study the oil port accident exercise experiment system in virtual environment could realize the accident simulation of oil port equipment. In this article, we take the oil port key equipments (oil tanker, oil storeroom, transportation pipe and so on) as objects, take the representative accident mode of oil equipment as information source, take the high visual equipment model as information carrier, study the oil port equipment accident excise technology in the virtual environment, and realize the virtual support environment and platform of accident analysis and danger evaluation.

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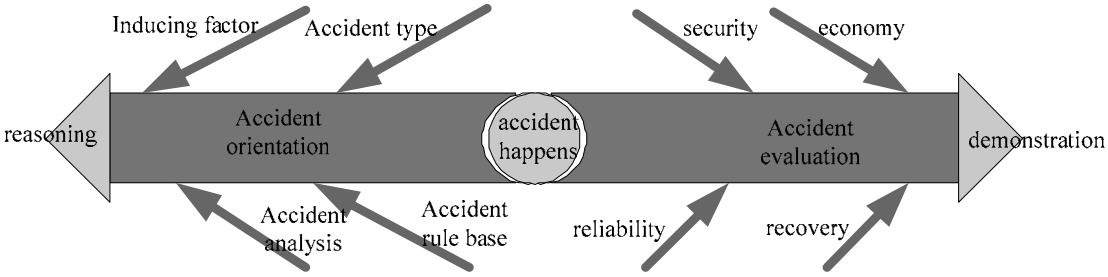

Figure 1. Total Aim of System

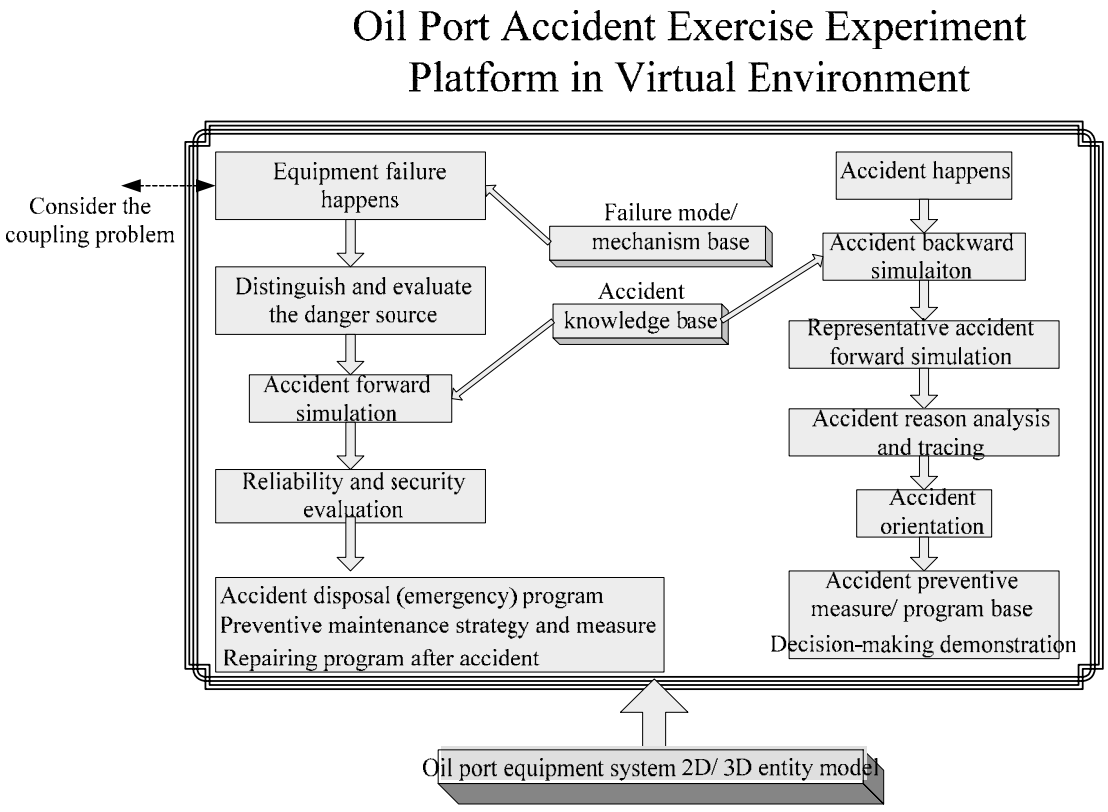

Figure 2. Technical Method