

Research on decision support system of ship machinery maintenance based on selective maintenance system

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Abstract

In this paper, the model of the decision support system for the ship machinery maintenance based on the mechanical selective maintenance system, the system structure, and the performance are introduced. The advanced technologies, such as equipment maintenance decision support, ASP technology, the B/S structure, web programming technology etc, are used to develop the system. The decision support system worked in the practice successful.

Keyword: Mechanical selective maintenance system. Maintenance decision. ASP B/S

1. Introduction

Since 1980s, great changes had happened to maintenance and management of shipping machinery. Those changes including getting rid of traditional managing style, trying to make advanced equipments management methods and maintenance technology adopted, introducing methods of equipment maintenance based on equipments condition inspection, keeping the levels of equipments management maintaining technology modernized have become the mainstream of the realm today.

The introduction of Planned Maintenance Scheme (PMS), the establishment and promotion of ships maintenance system(CWBT) and the primary application of selective maintenance system etc, are highlighted.

PMS is a new inspection institution of ships equipments put forward by International Association of Classification Societies(IACS) in 1989. Then PMS and its inspection methods were introduced and implemented gradually by Chinese Classification Society. After 1997, PMS was promoted by the transportation departments such as China Ocean Shipping Company, etc[1].

Meanwhile, in the late 1980s, based on the theory of the reliability-centered maintenance (RCM), a new maintenance strategy, which is conformed to the situation of our country, was put forward, that is the selective maintenance system.

Selective maintenance system is in conformity with the principle of synthetically management of equipments, and it should also be reliability centred. From machinery actual management, on base of equipment routine inspection system promotion, selective maintenance forms, including breakdown maintenance (BM), scheduled maintenance (SM), preventive diagnostic maintenance (PDM), were chosen according to equipments' characteristics of type, capability and working condition etc. Additionally, those equipments

maintained by condition are promoted selective item maintenance based double maintenance system consisted by item maintenance and major maintenance. In order to achieve the optimum purpose at the least cost and maximum synthetically efficiency within the lifespan of equipments, institutions of organization management, technologies management and capital management should be reformed. At last, a new maintenance and management system will be established gradually[6].

Not only used in general machine management, selective maintenance system is also applied in shipping machines. Similar in guiding thought and application manners, selective maintenance system and PMS conform to the requirements of relative criterions. During its promotion, most shipping companies were glad to adopt it. This item once was in the list of science and technology promotion items of Ministry of Transportation. Nowadays, many shipping companies adopt this management style in its equipments management work, laying equal emphasis on the connecting manners to PMS. However, in practice it is necessary to develop some assistant methods such as advance and practice maintenance decision support system to cooperate with it during the promotion of this new institutions. This paper will discuss the designation and development of maintenance decision support system of ship machinery which is based on selective maintenance system. The establishment of the decision model and how to make use of those advanced technologies, such as ASP technology, B/S construction, database and network programming etc, to solve some key problems will be introduced.

2 The model of maintenance decision

The ship machinery maintenance decision system is divided into tow mean sections: the information management system and the decision support system. According to the requirements of the selective maintenance system, the functions of the decision support system are as follows: The first one is to provide with the decision recommendations of the maintenance forms for different machine inconformity to the equipment performance and the operation conditions. The second function is to resolve the optimal maintenance period and to draw a maintenance program for the machines which are decided to adopt the scheduled maintenance form. For the machines which are decided to adopt the preventive diagnostic maintenance form, the decision support system has the third function to determine the maintenance items and the corresponding maintenance grade, the type and the time of maintenance, and to draw a maintenance plan as well.

The following part mainly introduces the key points of establishing the maintenance decision model associated with the preventive diagnostic maintenance form. A sketch of this model appears in Fig.1.

In the maintenance management, the equipment is divided into several “items” according to its function, construction and the maintenance pertinence. The item could be the entire equipment in the ship machinery system, or its assembly or components (see Fig. 6 for more details). In the preventive diagnostic maintenance form, the selection of the maintenance decision first takes the “item” as a unit, and then integrates it to the entire machine and the entire marine engine system.

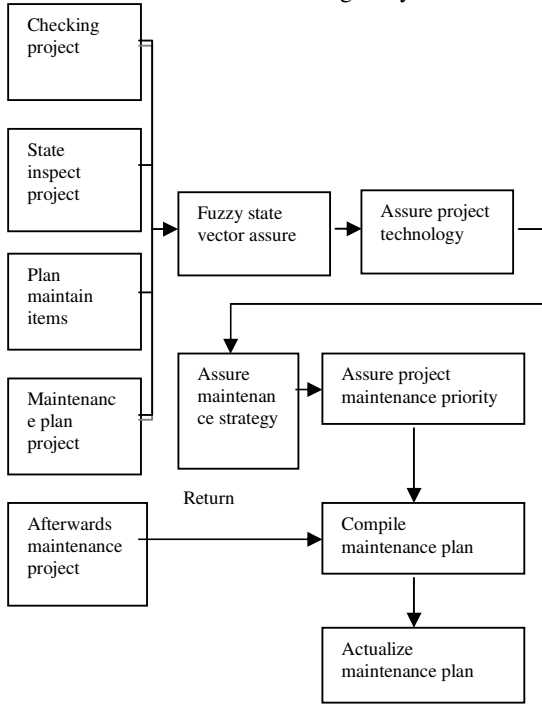


Fig.1 the model of ship maintenance decision

2.1 the method for determining the fuzzy state vector

The way to determine the equipment maintenance decision is: Firstly, fix the quantity of the technology state using the principle of fuzzy mathematics according to the running pattern of the maintenance decision; then, determine the equipment state vector according to the obtained state data from inspection, and obtain the deficiency degree of the equipment (or item), according to which to measure subjection degree of equipment item to each technology state, in order to finally determine the maintenance grade, type and the time for suggestion.

In order to describe the technology state of the equipment, this system introduces the concept of “fuzzy state vector”. Suppose each type of equipment have a series of state parameters X_1, X_2, \dots, X_n , and they are the function of the time, expressed as $X_i(t)$. The equipment function could be treated as the concourse of the normal working condition determined by n parameters X_i ; contrarily, failure or ineffective condition is the limit by which $X_i(t)$ goes beyond the concourse of the normal working condition. The ordinary working

condition deviates the good condition, but not goes beyond the utmost technology state limit, which is an intermediate state. Therefore, the equipment state could be considered as a fuzzy variable. If L is used to express the equipment technology state, then L is written as $\{l_1$ (excellent), l_2 (better), l_3 (commonly), l_4 (inferior), l_5 (poor) $\}$, which is “the fuzzy state vector” used by this system. This paper mainly will discuss the arithmetic of the equipment the fuzzy state vector in the following parts.

(1) Determining the fuzzy state vectors by evaluation made from inspecting

Since each inspection item is corresponding to the maintenance item, we can direct take a comments set of an item as the fuzzy state vector of the corresponding machine item. For example, the piston parts of the state test for comments is $(0.195, 0.585, 0.220, 0, 0)$, the fuzzy status vector of the piston part is $L = (0.195, 0.585, 0.220, 0, 0)$.

(2) Calculate the fuzzy state vector according to the state parameter obtained from the state’s monitor

The condition inspection item of the equipment is usually quantity detected by special apparatus. So we can contrast the inspecting results with the performance standard or the technical norms of the corresponding machine (or it’s assemble, parts). Let A is the perfective value for the performance, and B the limit value restricted in the standard or norm.

Because of uncertain factors exist in measuring, the result of measuring have to expression by fuzzy vector. Assuming that the result of measuring is C , than the fuzzy state vector are $\{l_1$ (excellent), l_2 (better), l_3 (commonly), l_4 (inferior), l_5 (poor) $\}$, the value of l_i was defined by Gauss-function, the formula are:

$$\begin{aligned}
 l_1 &= \text{EXP}[-(D-0.2)^2/E] \\
 l_2 &= \text{EXP}[-(D-0.4)^2/E] \\
 l_3 &= \text{EXP}[-(D-0.6)^2/E] \\
 l_4 &= \text{EXP}[-(D-0.7)^2/E] \\
 l_5 &= \text{EXP}[-(D-1.0)^2/E] \quad (1)
 \end{aligned}$$

where D is deterioration degree value

$$D = [1 - (C - A) / (B - A)]^k$$

k is exponent which is assigned $0.5 \sim 2$; E is coefficient ($= 2\sigma$, usually 0.02 , the degree value of state definition can adjust according to measuring result in case definition up can use low value).

(3) Fuzzy state vector calculate based on scheduled maintenance form

For the scheduled maintenance form, there is a fuzzy relation between time and technology state, technology state is the function of time. We can expresses fuzzy vector by $\{l_1$ (excellent), l_2 (better), l_3 (commonly), l_4 (inferior), l_5 (poor) $\}$, the value of l_i is defined by Gauss-function, the formula as

the same as formula (1). In it, deterioration degree value $D = (t/T)^k$, where t is the working time after last maintain, T is the repair period. The value of k and E are ditto.

(4) Fuzzy state vector calculate based on propose maintain form

In propose maintain form, we should distinguish the apparatus's state while we analyze it. Suppose the mark value is P (between 0~100, nearby 100 means better, nearby 0 means poor). As there is the fuzzy relation between experience and technique of maintenance man, we can expresses fuzzy vector by $\{l_1$ (excellent), l_2 (better), l_3 (commonly), l_4 (inferior), l_5 (poor) $\}$, here the value of l_i is defined by Gauss-function, the formula as the same as formula (1). But deterioration degree value $D = (1 - P/100)^k$; The value of k exponential and E coefficient are ditto.

2.2 The method of determine the project's technical grade

After the fuzzy state vector of apparatus which correspond with maintain project was made sure, we need distinguish the technical state of the project. The technical state of the project divide into: Excellent, better, commonly, inferior, poor. According to the fuzzy state vector which was made sure as before, and adopting the maximum membership degree principle, we can determine the technical grade. The maximum membership degree principle is: suppose A_1, A_2, \dots, A_n are n subsets in the universe of discourse U , for any element $x \in U$, if

$$\mu_{A_i}(x) = \max[\mu_{A_1}(x), \mu_{A_2}(x), \dots, \mu_{A_n}(x)] \quad (2)$$

then x corresponds to part of the fuzzy subset A_i . For example, if the comments of one project is (0.195, 0.585, 0.220, 0, 0). The second element is the greatest value, and then the project belongs to the technical state of Category 2, that is "better". When the project was close to the fuzzy state vector $\{1, 0, 0, 0, 0\}$, that the project in good condition. If the fuzzy state vector to close $\{0, 0, 0, 0, 1\}$, the project is in a limit state. When the vector in a fuzzy state between the two, that a state of transition in the middle. Each score corresponds to a maintenance level is proposal. For example, the "better" reviews the proposal for "Best departure from the scope of non-correct". If Comments as "inferior", then we give the suggestion is "Subject to correct maintenance". With the concept of fuzzy state vector and method as stated above, we can measure a project's technology state (Machine equipment, components or assembly.)

2.3 the arranging method of item status in each item technology grade

After determining the classification of the technology state of each item, it should further determine the priority maintenance sequence of each item, in order to provide maintenance decision support for the personnel who

make plans. We apply the ranks determined by gravity numeration. The details are: if the fuzzy state vector of an item in certain technology grade is $\{l_1, l_2, l_3, l_4, l_5\}$, the arranging factor N is calculated, and then arrange the items in order according to the values of arranging factors from small one to big one. The item whose order comes first should be first maintained. The method to calculate the arranging factor N is:

$$N = l_1 \times 5 + l_2 \times 4 + l_3 \times 3 + l_4 \times 2 + l_5 \quad (3)$$

After finishing the above work, the maintenance personnel should determine the maintenance plan under the guidance of the above analysis result.

The above part mainly introduces how to establish decision model when making maintenance decision (determining type, grade, and time) for the item which takes the form of preventive diagnostic maintenance. For the decision model of scheduled maintenance form and other decision models, the principles are similar. The details are not explained here due to limited paper length.

3 the system design and development technology

After establishing the maintenance management decision model, the realization of the system is by using such advanced technology as ASP technology, B/S structure, database, network programming etc. The key points are mainly as follows:

3.1 the system structure

The shipping mechanical maintenance decision support system are made up by 6 modules: the system instructions and operation manual, the basic parameters management, the maintenance form decision, the maintenance planning, the detection and monitor decision, the system management and so on as indicated in Fig. 2. The relationship of the modules appears in Fig.3.

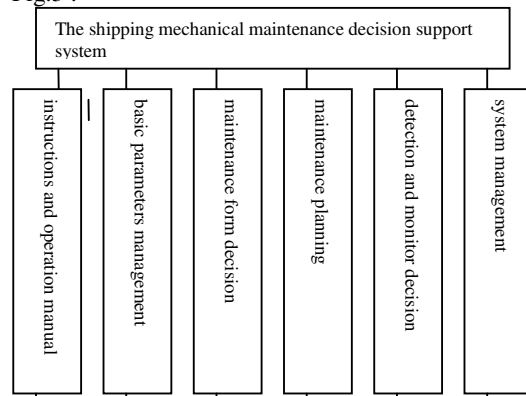


Fig .2 .system modules structure

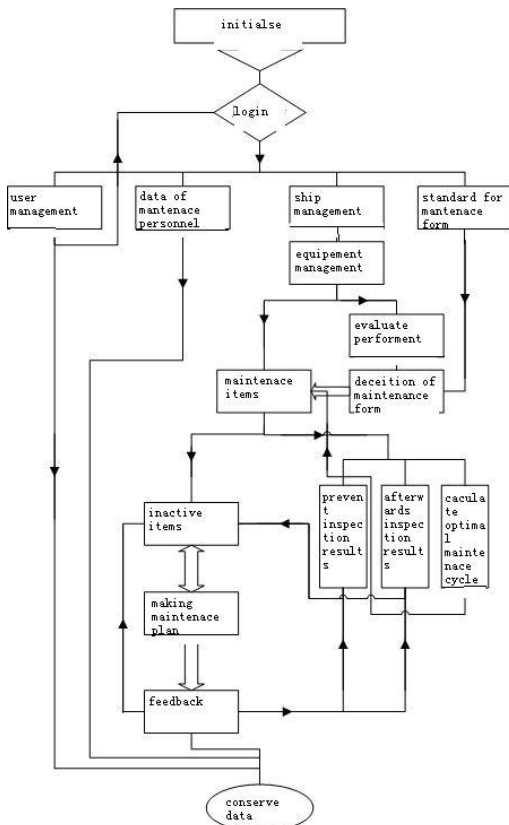


Fig. 3. structure of system flow

The operation mode of inspection and maintenance in the system is shown in Figure 4. It includes the inspection plan, implementation of the inspection, the evaluation of the inspection result, the decision-making and planning of the repair and maintenance work, the implement of the repair and maintenance work and the maintenance inspection and so on. All the above constitute a whole work cycle. Keeping on doing the work cycle, the ship would be kept in safety.

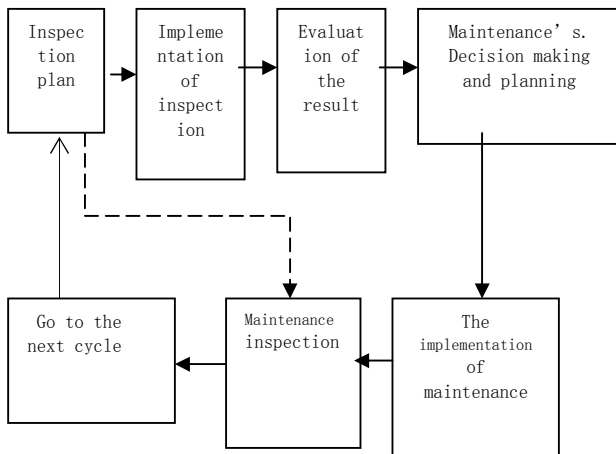


Fig.4 shipping inspection and maintenance running model

3.2 The development technology of the system

The system adopts B/S structure (Browser/Server). Under this structure, user's interface is thoroughly realized by WWW. Only a small part of logic is realized in the head,

the rest is realized in the server, forming the 3-tier structure. This structure is the first choice in management system software at present. Owing to the use of B/S structure, the system structure becomes very simple (see table 5), only needing SQL SERVER 2000 and IIS server. To the client, as long as the user access to the server, he can use this system with the browser. Not only the local area network system demonical can be used but also the enterprise network that can be able to access to the outside world can be used too. Internet users are able to use the system and give full play to the B/S structure advantage.

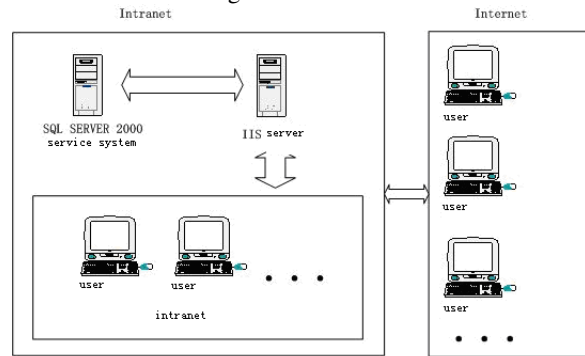


Fig. 5. structure of system frame

ASP (Active Server Pages) is used in the development of the system. ASP is developed by Microsoft and it is a kind of server-side scripting environment. It is a very popular open-end Web server application. [3,5] SQL Server 2000 is used in database system and it is the latest version of Microsoft's large-scale database server. Its performance indicators has the trend in catching up with Oracle database in every aspects^[4]. At the same time, with the use of the production of Fireworks 2004 in making Pictures and So think DHTML Menu 4.1 combination of ASP technology to produce the menu, makes the interface more beautiful and the operation more simple. [2]

3.3 The function and use of system

The following work can be done through this system: Information management on ship, Information management for device, Information management for maintenance personnel, Setting the standard way of decision-making, The determine of evaluation of equipment and maintenance methods Maintenance/repair items and to be revised project management, Maintenance/inspection plan, Maintenance/inspection program feedback, The management of state of repair projects and after maintenance, The best maintenance cycle, and user management for scheduled maintenance projects and so on.

After successful landing, the user should put in the message of the ship, then manage each device, because the equipment belongs to the fixed points of the ship, and the ship and equipment is one-to-many relationship. In machinery and equipment maintenance decision support system, the inspection/maintenance projects to identify and test / maintenance programs of the entire system is the key to running effect. Ship inspection /

maintenance projects are in accordance with the categories - equipment - equipment or assembly division, each device corresponds a number of specific project. The principal is shown in Fig. 6.

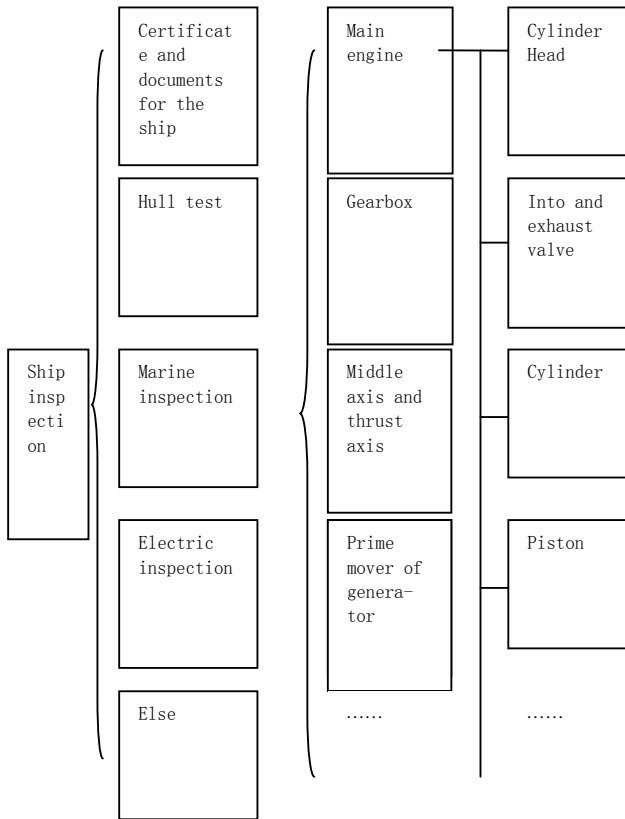


Fig. 6 principle of division of the project

In the process of determining the maintenance/inspection program, it is necessary to indicate the type of maintenance/inspection program (for example, there are annual inspection and special inspection in the marine maintenance/inspection program.), maintenance/sub-item test (the concrete content in maintenance/inspection program: for example ,cylinder, cylinder head ,into and exhaust valve and their gears, piston rod, guide, link, crosshead, crankshaft and all bearings, the fasteners of crankshaft-box door abduction, explosion-proof facilities, scavenging system, safety facilities, booster and cooler, clutch, reversing agency, machine with pump and cooler and so on are included in the inspection of the main engine), maintenance/inspection requirements, the standard and methods for maintenance/inspection. the quantitative evaluation method for the effect of single maintenance/inspection, the possible default and its reason, solutions and so on.

The assessing method of Maintenance and quantitative can pass through the system in maintenance mode-assisted decision-making module to complete. System can use the "maintenance mode decision-making module", according to the entry of the evaluation criteria for performance evaluation of the devices. The system will be assisted for the maintenance of each item to choose the right way of maintenance. At the same time, scheduled maintenance methods used for maintenance projects, equipment maintenance cycle entry and the last

time to repair, maintenance cycle can use the system to provide the decision-making of the "optimum scheduled maintenance cycle". For the preventive diagnostic maintenance projects, it is necessary to enter state inspection methods, criteria and method of the degradation degree calculating.

After the completion of the initial work setting, system can go in for decision-making to determine the deterioration index of corresponding maintenance projects according to the working hours of equipment, the equipment inspection information and the test results of the repair items. So the maintenance priority of the various maintenance projects will be determined. Managers can examine the current state of the management real-time. At the same time, under the order of priority in accordance with the maintenance / inspection, combined with the actual situation, managers will rectify the corresponding item on the project automatically or manually. After dealing with the repair project amendments, managers can easily work out maintenance / inspection program.

When the maintenance / inspections are completed according to plans, it is necessary to fill out maintenance feedback which directly affects the information of the maintenance and repair projects, at the same time to update testing records. Fig. 7 shows the feedback interface of maintenance project. After the completing the above-mentioned work, it enter the next cycle of maintenance activities.

船舶维修信息反馈表

姓名	拖轮1-2004-5-1	制表人	greener	制表日期	2004-5-3
维修开始日期	2004-5-1	维修结束日期	2004-5-2	维修地点	大连
维修负责人	管伟	设备台时	20	维修单位	中远船坞
维修工时	20	维修费用	500		

维修项目	修复情况	修复日期	质量评分	维修情况简要说明
缸盖和活塞	已修复	2004年5月2日	70	良好1
11	已修复	2004年5月2日	100	良好
螺索	已修复	2004年5月1日	80	良好

Fig. 7 maintenance feedback

4. Applications and analysis of the effects

The present system is suitable for ship maintenance and repair management. The system in operation has been welcomed by the shipping companies. The systems are convenient to the management and maintenance of machineries, increase efficiency, promote the management level, improve the reliability of the equipments and better scientific planning use of maintenance resources.

The system has been adopted in a company for the maintenance management of three passenger-cargo vessels. In recent years (2003-2006) the test results make the quantitative evaluation. It showed that after applying the system, the test results of the technical state of the passenger-cargo vessels gradually develop in a positive direction.

In the process of the ship repair and maintenance information management system and the implementation

of the decision-making system in the company, the emergence of the substandard number and the use of maintenance costs are shown in table 1. The table showed that in recent years, the failed state of the passenger-cargo vessels took place in a downward trend, and maintenance inspection costs of the equipments also decrease. Therefore, the implementation of the system can effectively improve the technology state of equipments of the ships.

Table 1 the number of the tested substandard accidents and the maintenance costs from 2003 to 2006

The name of the ship	times of tested substandard accidents /maintenance costs	2003	2004	2005	before the June of 2006
(ship 1)	substandard accidents /times	4	3	3	1
	the cost of inspections and repairs / ten thousand Yuan	400	350	340	160
(ship 2)	substandard accidents /times	3	4	2	0
	the cost of inspections and repairs / ten thousand Yuan	310	280	260	120
(ship 3)	substandard accidents /times	2	2	1	0
	the cost of inspections and repairs / ten thousand Yuan	300	270	260	130

5. Discussion

By developing maintenance decision support system of shipping machinery, the promotion of selective maintenance of marine machines is strong supported, the activities and maintenance decisions are science and information based. The summary of characteristics of this system as follows:

(1)The model constructed by principle of the largest degree of membership and fuzzy synthetic evaluation method makes the decision support system performances well in applicability, and satisfied results are achieved.

(2)The frame is simplified, operation of users is easier and quicker and developing costs is lowered down by applying B/S construction to information system of equipment maintenance management. By applying the most popular ASP technology at present and using powerful function database of SQL Server 2000, the system runs faster. Because codes are deposited in the server, so the security of the system is improved.

(3)Functions, such as information management of ships, equipments and maintenance persons, decision of equipment maintenance form chosen, management of maintenance items and maintenance plans, information management of inspection etc, are realized. The purpose to improve managing and equipment reliability, save maintenance cost has been achieved.

References:

- [1] China Classification Society . Guide for PMS Inspection of Marine Machinery . China Communications Press,2002
- [2] Hainle , Java Script Full Manual . Beijing: : Tsinghua University Press,2004
- [3] Li Xiaoli , Zhang Wei . Network Application System Development and Examples by ASP and SQL Server. Beijing: Post & Telecom Press,2004
- [4] Liu Rui. Microsoft SQL Server2000 Collection. Beijing: China Railway Publishing House,2004
- [5] Xuan Xiaoping, Dan Zhenggang, Zhang Wenyi. Navigation of ASP Database development by Examples . Beijing: Post & Telecom Press,2003
- [6] Yan Li, Zhu Xinhe, Yan Zhijun etc. Strategy and Application of Selective Maintenance of Transportation Machinery . Dalian : Dalian Maritime University Press,2001.11

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