Research on large equipment maintenance system in life cycle

Xiaowei Xu¹,², Hongxia Wang¹, Zhenxing Liu¹, Nan Zhang¹

¹.School of Automobile and Traffic Engineering, Wuhan University of Science and Technology, Wuhan 430081, China
².Hubei Key Laboratory of Power System Design and Test for Electrical Vehicle, Xiangyang 441053, China

Abstract. In order to change the current disadvantages of traditional large equipment maintenance concept, this article plans to apply the technical method of prognostics and health management to optimize equipment maintenance strategy and develop large equipment maintenance system. Combined with the maintenance procedures of various phases in life cycle, it concluded the formulation methods of maintenance program and implement plans of maintenance work. In the meantime, it takes account into the example of the dredger power system of the Waterway Bureau to establish the auxiliary platform of ship maintenance system in life cycle.

1 Introduction
Maintainability is design attribute of the system and maintenance requirement is influential for product safety during the operation. Therefore, it is necessary to determine maintenance requirements in design phase. Maintenance advantage has been recognized in the running of the equipment, but considered insufficient in life cycle [1]. Terotechnology changes the traditional concept that maintenance only works in the operational sage, makes the maintenance work forward and considers maintainability as design principle in development phase [2,3]. What’s more, it is essential to implement selective maintenance in life cycle, including planning, design, procurement, assembly, commissioning and running, until replacement or retirement, which thereby reduces the system life cycle cost (LCC) [4,5].

With the rapid development of building industry and maintenance technology, the large equipment structure is increasingly complex, the automation technology continues to improve, and the reliability and maintainability requirements have gradually improved for marine power system. Most large equipment companies lack of complete equipment maintenance program or repair plan, as well as systematic analysis and research for equipment maintenance management. In most cases, many types of unused equipment are just renewed with little failure analysis. At the same time, equipment maintenance is not enough in effective budget control and strong support from the management layer. Furthermore, large equipment enterprises usually confuse the maintenance management and equipment monitor that directly result to maintenance schedule out of order.

Therefore, in order to avoid such phenomena as the excess or lack of maintenance, this essay attempts to convert the traditional posterior maintenance or preventive maintenance to preventive maintenance in life cycle based on prognostics and health management (PHM) [7,8]. It forecasts the running status and operating cost of large equipment equipment in life cycle, optimizes maintenance decision and formulate dynamic maintenance schedule, which conducts large equipment integrated maintenance management in life cycle[9].
2 Maintainability analysis in life cycle

2.1 The design stage
For large equipment enterprises, the investment is up to millions or billions of dollars and many parts are imported equipment. Simultaneously, it is required to import the appropriate spare parts, in the course of repair or replacement costs higher. Currently, many systems consider availability and economic at the design phase, but reliability and maintainability processed less [10].

Therefore, the maintenance concept introduced into the system planning is particularly important. According to the maintenance requirements and capital investment of planning, it conducts system design and determines the maintenance specifications, as shown in figure 1.

![Maintainability design flow chart](image)

Figure 1: Maintainability design flow chart

On the basis of maintainability management requirements, combined with the system function and life cycle cost, it defines the maintainability requirements and mission which should be coordinated with the reliability design. After the maintainability allocation and design criterion formulation, it develops the maintainability design with reliability and supportability analysis. Furthermore, it processes the maintainability assessment and judges whether to maintainability design additionally or modify the system function and cost budget.

2.2 The manufacturing stage
In design phase and assembly phase of the system, it is necessary to formulate systematic preventive maintenance program. Otherwise it may lack of standardized maintenance recommendations in operational phase, leading to system maintenance more difficult and thereby delaying maintenance tasks. As shown in figure 2, according maintenance data of various components from the equipment suppliers, combined with the specification of large equipment management, started from overall performance including reliability, feasibility and maintainability requirements, to coordinate the arrangements for the equipment maintenance within the maintenance order, MTTF, MTTR and MTBF etc.
Figure 2: Preventive maintenance formulation flow chart

In the commissioning phase, all equipment and components should be inspected to check out the technical index. Maintenance inspection is one of the most important processes. It is an evaluation of the results of various repair procedures, which starts from early phases of the project. With continuous improvement of the data quality and application of the product, maintenance inspection is implemented throughout the life cycle.

2.3 The running phase
On the basis of condition monitoring parameters, integrated with the experience or theory of the maintenance staff, the operational phase conducts prognostics and health management, optimize the maintenance program to avoid ove maintenance or excessive maintenance, reduce LCC by decreasing the loss of equipment failure or downtime. The optimization process is shown in figure 3.

Figure 3: Maintenance program optimization process

3 Life-cycle maintenance system
According to maintenance program or technical regulations developed by large equipment companies, it establishes the large equipment life-cycle maintenance system based on PHM.
As shown in Figure 5, through analyzing maintenance characteristics and technical elements about PHM of various phases in life cycle, it formulates the implementation process of the large equipment life-cycle maintenance system.

1) Design phase

From the long-term perspective, to ensure the system reliability and maintainability, it is significant to make the maintenance concept forward and carry out maintenance research and investment about PHM in the planning phase. During the design phase, in combination with the large equipment repair experience and parts maintenance manual, the maintenance design is conducted to help make the best design solutions, including the data acquisition modules, measurement systems, and overhaul channel.

2) Manufacturing phase

In the procurement phase, sensors, measurement equipment, maintenance resource and interchangeability of the data acquisition modules should be taken into account. At the assembly stage, firstly, test equipment, installation location, maintenance tools and overhaul channel should be considered. Secondly, combined with the CWBT, the statutory inspection rules or the recommendations of equipment manufacturers, it develops the initial equipment maintenance program. During the commissioning phase, taken the management modes and maintenance concept of each equipment company into account, through the optimization of the maintenance force, the maintenance window and the maintenance resources, it arranges reasonable maintenance tasks and develops a detailed repair plan.
3) Operational phase
In the operational phase, on the basis of condition monitoring parameters, integrated with the experience of the maintenance servicemen, it conducts prognostics and health management. From the prospect of security, economy and integrity, it determines the maintenance item, time and organizational measures for implementation. Afterwards, it develops dynamic rolling maintenance program based on the maintenance program optimization system. At last, in replacement and decommissioning phases, it is important to summary the optimization process of the system and enriches knowledge of the system database about PHM.

4 Application analysis
For the newly-built Waterway Bureau dredger -long whale II, which is self-propelled and trailing suction, it establishes the ship maintenance program optimization system in life cycle based on PHM. In figure 6, the optimization system is divided into three subsystems, including the shipboard monitoring and management subsystem, the maintenance center management subsystem and the ship-to-shore radio communication subsystem. The shipboard monitoring and management system monitors the major equipment and conducts the maintenance or maintain of the ship. The subsystem carries out the data acquisition, transmission and monitoring independent. The maintenance center management subsystem receives the online real-time data of the shipboard monitoring subsystem and completes functions of condition monitoring, health assessment, failure prediction, maintenance management and emergency dispatch. The ship-to-shore radio communication subsystem is the approach to connect the shipboard monitoring and management subsystem and the maintenance center.
management subsystem. It completes the ship-shore wireless communications and data transmission.

Figure 6: Dredger maintenance program auxiliary platform

5 Conclusion
First of all, through analyzing the maintenance characteristics of the various phases in life cycle, it can be found maintenance is essential in each phase of the system. It is important to change the traditional maintenance concept, research on the maintenance system in life cycle, instead of considering maintenance only in the running phase.

Secondly, it is difficult to formulate a comprehensive maintenance program based on the traditional maintenance concept. Therefore, it is significant to establish the auxiliary platform of ship maintenance program based on PHM by means of data acquisition and processing, condition monitoring, health assessment, failure prediction and comprehensive security analysis of many ship equipments.

In brief, it helps much more to formulate the ship maintenance program with technology means than only personal experience and reform the traditional posterior maintenance and the scheduled maintenance by maintenance work during the life cycle.

Acknowledgements
This work was supported by the National Natural Science Foundation of China (NSFC) (Grant No. 51505345), the Science and technology research project of Education Department of Hubei Province(Grant No. Q20151105) and the Hubei Key Laboratory of Power System Design and Test for Electrical Vehicle(Grant No. HBUASEV2015F005).
References
[1] Barone Giorgio, Frangopol Dan M. Reliability, risk and lifetime distributions as performance indicators for life-cycle maintenance of deteriorating structures[J]. Reliability Engineering and System Safety, 2014, 123: 21-37
[2] Gerardo Alvarez. Maintenance role in a plant life-cycle [C]. The 17th European Maintenance Congress. European maintenance 2004, Barcelona, Spain: 2004: 43-51
[3] Mitropoulou Chara Ch., Lagaros Nikos D., Papadrakakis Manolis. Life-cycle cost assessment of optimally designed reinforced concrete buildings under seismic actions[J]. Reliability Engineering and System Safety, 2011, 96(10): 1311-1331
[4] Yongkang Ge. Reform idea of equipment maintenance structure in life cycle [J]. Equipment management and maintenance, 2013(1): 7-8
[5] Sheng Zhu, Jukun Yao, Xiaoming Wang. New features and technical system of maintenance and development for equipment life cycle [J]. Journal of Academy of Armored Force Engineering, 2012, 26(6): 1-5
[6] Ran Yu, Jianlan Li. The Decision-making Model for the Maintenance Time in Equipment Full Life Cycle Based on Reliability [J]. Mechanical Science and Technology for Aerospace Engineering, 2013, 32(4): 573-576
[7] Sheppard John, Kaufman Mark, Wilmer Timothy. IEEE standards for prognostics and health management [J]. IEEE Aerospace and Electronic Systems Magazine, 2009, 24(9): 34-41
[8] Ma Ning, Lü Chen. Research on PHM architecture of aircraft [J]. Journal of Huazhong University of Science and Technology (Natural Science Edition), 2009, 37: 207-209
[9] Xiaowei Xu, Shidong Fan, et al. Research on PHM Technology Application of Ship Maintenance Program Optimization [C]. 2013 IEEE International Conference on Prognostics and Health Management, Gaithersburg MD United States, 2013.6.
[10] A. Coulibaly, R. Houssin, B. Mutel. Maintainability and safety indicators at design stage for mechanical products [J]. Computers in Industry, 2008, 59: 438-449