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A Closed-loop PLM Model for Lifecycle Management of Complex Product

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Abstract. Complex Product has the characteristics of variety, long life cycle, difficult to verify design, strong target-oriented and dynamic, complex operating environment and status and so on. The existing PLM （Product Lifecycle Management） system can hardly effectively meet the demand of product designing, manufacturing services and MRO （Maintenance， Repair and Overhaul/ Operation）. The complex product lifecycle management model is therefore put forward. In this model, the maintenance closed-loop, operation closed-loop and design closed-loop combine to form an intelligent triple closed-loop PLM. Based on the data collected through a variety of sensors and information systems from different stages of the product life cycle, the model can be used to research the flow of data and feedback methods across the stages and organizations. By combing the data flow, the data feedback points is supposed to be found, which enable the product life cycle data being used circularly. The result is of important guiding significance to lifecycle management of complex product.

Keywords. Closed-loop PLM; Management Mode; Data Flow;

Introduction

The development of complex products needs to realize the lifecycle data feedback, supporting the optimization design and innovative design, and providing data support for product MRO. The data related to complex product change constantly at all stages of the life cycle, especially the running process and operation environment [1]. In order to manage the lifecycle data of complex product effectively, the data in the late lifecycle stages is used to be fed back to the early lifecycle stages, guiding complex product design, processing services and MRO intelligent service, and a closed-loop PLM system model of complex product is required to be established to implement the feedback using of product data. In this closed-loop, all actors of the whole lifecycle can use, manage, and control product related data, including the information after a product delivery to the customer and until its final destiny. With this closed-loop, the data goes back to designers and production engineers, and the data flow can be closed over whole product lifecycle.

Closed-loop PLM was first proposed in the EU's Product lifecycle Management and Information tracking using Smart Embedded Systems (PROMISE) project in 2004

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[2]. It can achieve effective management of PLM activities by using product data that could compensate PLM, and dynamically optimizing each stage of the product life cycle [3]. Jun studied the principles of data exchange between the different stages of the product life cycle, proposed a framework descripted by the resource, and created process flow and logistics closed-loop models [2]. Kiritsis put forward the closed-loop management framework based on communications technology and smart products [4]. Matsokis established a body-based semantic object model that supports closed-loop PLM product data and knowledge management [5]. Combining business operations, Rostad studied the impact and benefits that the closed-loop PLM system does to the business model [6]. Georgiadis and Jun studied the place in which the closed-loop PLM is used, such as predictive maintenance and re-manufacturing [7].

In China the research is focused on phased model and application, such as design changes closed-loop[8], quality control closed-loop [9], recycling manufacturing closed-loop [10], production management closed-loop [11]. Professor Wang Xu proposed: Closed-loop PLM is an effective strategy managing product lifecycle activities information, by obtaining the data associated with the product lifecycle, and integrating, transforming and sharing these data, to manage the information flow across the organization intra the lifetime [12].

Until now, the study for the closed-loop PLM system focuses on the review and phased closed-loop system, and a large closed-loop model from product MRO to product design has not been established yet. Combined with complex products demand, PLM development status and trends, this article proposes a complex product triple closed-loop PLM system model, to manage the process of the product total life detailed and intelligently.

1. Complex Product triple closed-loop PLM Model

The complex product closed-loop PLM system model has three subcycles, shown in figure 1. It Integrates product lifecycle data, especially the active generating and automatic sensing data during the use phase, and manages these data classifiedly and uses them targeted. With effective data feedback mechanism, the data could flow among every stage and organization during the product lifecycle conveniently and correctly. Based on operation intelligent closed-loop, product data is counterproductive in operation, according to the processing environment and processing status, finishing self-adjustment and adaptation. Based on the maintenance intelligent closed-loop, product data is counterproductive in product maintenance, to analyzing product health, diagnosing troubles, and forming knowledge-based MRO service system. Based on design closed-loop, product data is fed back to product design, supporting product innovation and optimization, serving for product development better.

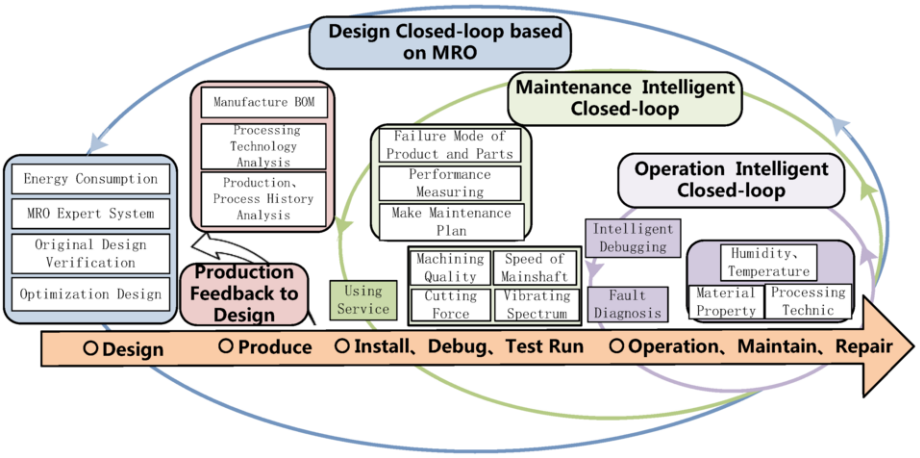

Figure 1. Complex Product triple Closed-loop PLM Model

- Complex product operation intelligent closed-loop model.

In the operation intelligent closed-loop, the product status data reacts on the running process. Depending on the operating environment and the state, the product could realize self-adjustment and adaptation. Thus, it could solve the problem of operation conditions being complex, the environment impacting on product performance greatly, the product being lack of self-adaption and self-tuning. Finally, improve the product operation stability.

- Complex product maintenance intelligent closed-loop model.

In the maintenance intelligent closed-loop, we form the knowledge-based MRO system with troubleshooting knowledge and experience and operating data, to analyze product health, diagnose troubles, provide product maintenance and repair plan. Thus, it could solve the problem of debugging difficulty, high reliability requirements, fault diagnosis being difficult, manual intervention being poor, and low failure warning capability. Finally, improve the product operation reliability and extend product's life.

- Complex product design closed-loop.

With the problem of paying little attention to operation, maintenance, repair and failure analysis when design, being lack of validation and optimization improvements of the structure of the original design, being difficult to meet single sets of custom design, high precision and high reliability requirements; being lack of process design and guidance during product use phase, we build the design closed-loop based on MRO data feedback. In this cycle, product data is counterproductive in product design, supporting product optimization and innovation.

2. Data flow of closed-loop feedback

2.1. Life Cycle Data

In order to manage and store the data conveniently, we divide product lifetime data into 4 different types: design and manufacture data, operation status data, environment status data and failure data.

Design and manufacture data includes product design and manufacturing process data. The design data constitutes the product original theoretical model, and the manufacturing data constitutes the actual model. Design and manufacturing data is provided by the companies designing and manufacturing sectors directly.

Operation status data contains all data during the operation, such as operating strength, running time, frequency, parts wear and so on. Operating-state data is collected by the sensors embedded in the product and stored and analyzed in the electronic control unit (ECU) in the product.

Environment status data is composed of the environmental status of the product, the condition data, operating temperature, humidity, voltage, current, and other properties of the object. Environment data is collected by the sensors embedded in the product collected and stored and analyzed in the ECU in the product.

Failure data is the data generated when product repair and maintenance, including the failure model, maintenance program, maintenance procedures, repair results, etc., recording every repair and maintenance infor-mation. Failure data is accumulated through the same or similar products, and expands with the products increasing and the product life cycle extending.

2.2. Data Flow Model

- Operation intelligent closed-loop data flow

ECU system module, with the function of detection is embedded in products. It acquires operational status data, extracts feature data, including information on the environment, operating information, life information of key components in real-time. After integrating and analyzing these data, it identifies the machine current work status, and early warns for non-security state. At the same time, it takes measures to deal with unexpected exception by intelligently controlling machine state of start-stop and switching operation mode. Data flow is between environment status data and operation status data, shown in figure 2.

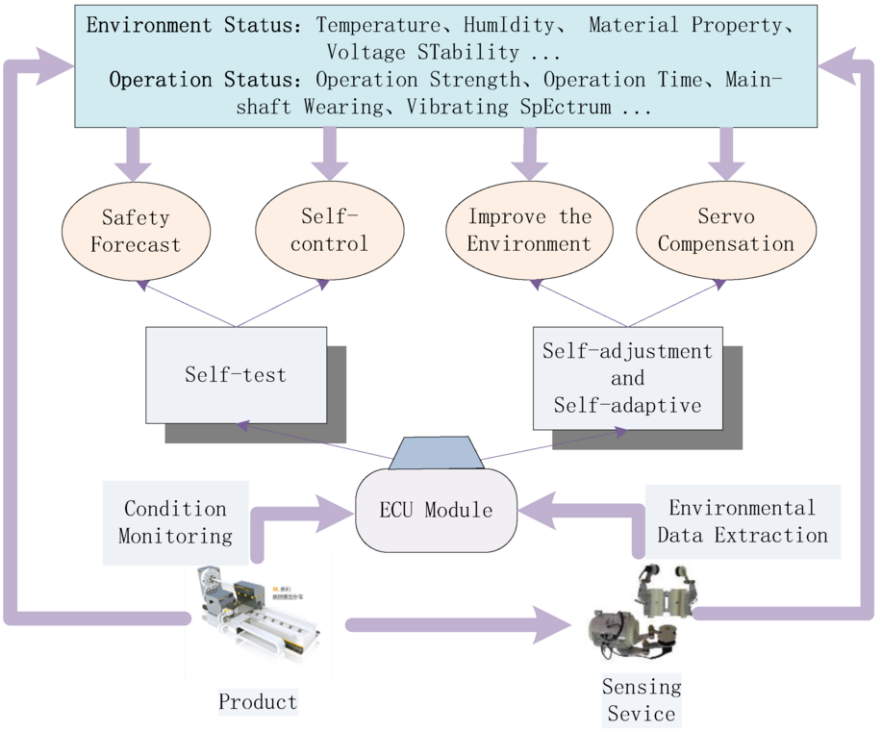

Figure 2. Data Flow of Operation Intelligent Closed-loop

ECU module monitors the operating environment of the product and obtains environmental condition data through a variety of sensors including temperature sensors, humidity sensors, vibration sensors etc. Meanwhile, it gets the operating state data, including operating strength, running time, vibration frequency and so on. ECU module takes a comprehensive analysis of the data obtained. With the result, it can determine the current status of the product, test products operation condition, make adjustments, issue accordingly instructions, and give safety warnings, automatic control, environmental improvement and servo compensation.

- Maintenance intelligent closed-loop data flow

Complex product maintenance closed-loop consists of health analysis, fault diagnosis and MRO management system. Data flow forms as a closed loop among environment status data, operation status data and failure data, shown in figure 3.

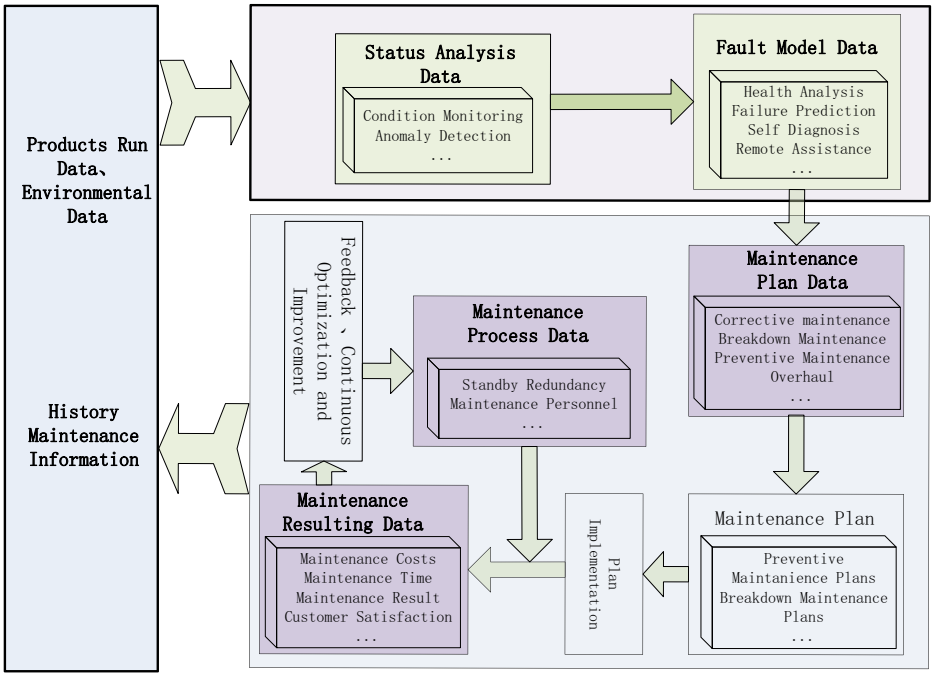

Figure 3. Data Flow of Maintenance Intelligent Closed-loop

Combined with historical status, operating states and environmental factors of complex products, product status characteristics is extracted to analyze the state, evaluate the current health state, and diagnose fault. After locating the fault sources and fault location, these data is used to match failure maintenance strategy, and then maintenance mode is determined. Later, the fault is repaired in accordance with a maintenance program. In the repair process, spare parts, maintenance personnel and other data is provided to support it. After the repair, the data generated during the maintenance is analyzed to evaluate the process and the results, including maintenance costs, time, customer satisfaction, etc. Meanwhile, data gets feedback to optimize and improve repair and maintenance continuously. At last, product failure data get feedback on products running, continue enriching the contents of failure data, and provide data to support future maintenance.

- (3) Design closed-loop data flow

Because complex product has complex structure and high reliability, potential failure mode and effects analysis (FMEA) should be considered in the design phase. Traditional d-FMEA only considers the feed forward process from the design stage to the using stage [13], it is difficult to verify the correctness of the original design, and it can hardly achieve a comprehensive optimization results. Through design closed-loop based on MRO data feedback, it is possible to offer engineering design services for key processes of complex parts. In this cycle, the design is optimized from both product design and engineering aspects. Data flow is among the design and manufacture data, operation status data, and failure data, shown in figure 4.

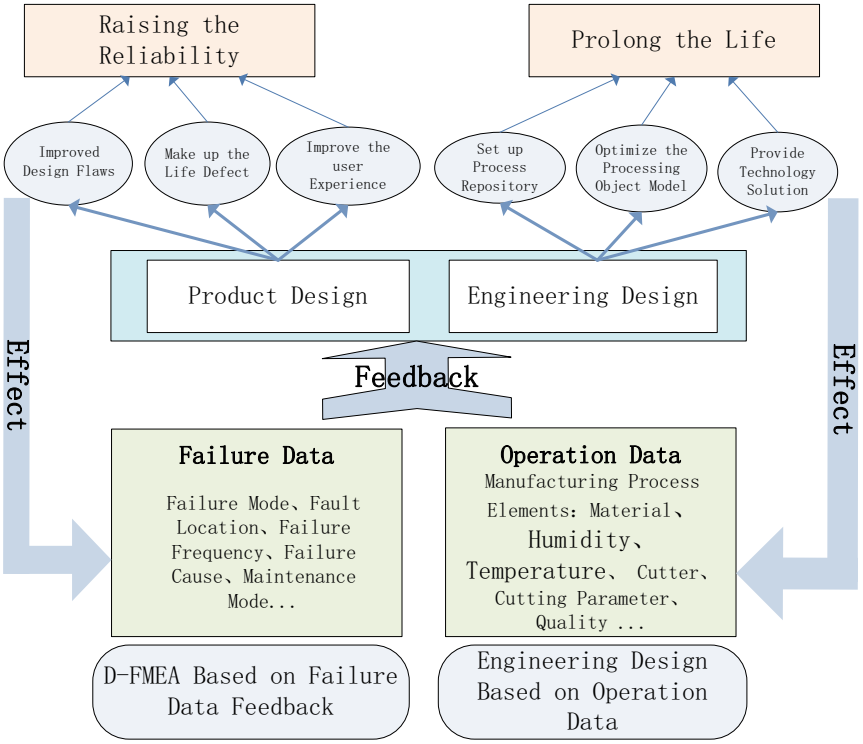

Figure 4. Data Flow of Design Closed-loop

By failure data analysis, failure parts and reasons are found. In the next time the product being designed, new methods and techniques are used to improve design flaws, make up life and enhance the user experience. Product performance is largely depended on the operating environment and the objects. Running mode is also different because of different environmental and objects. Operation data is analyzed, product optimization operation model is built and product processing library is formed. This could offer different technology solutions for different processes running and objects.

3. Conclusion

Complex products closed-loop PLM system can manage the product data, and make full use of the lifecycle data to reflect the operation status, provide repair and maintenance services, get feedback to product design. It will be increasingly applied by firms.

In this paper, we present a closed-loop PLM system for complex product. The closed-loop PLM system includes three cycles: operation intelligent closed-loop, maintenance intelligent closed-loop and design closed-loop, which cover the total lifecycle. And finally, we elaborate the circulation mode and circulation pathways across stages and across organizations of each closed-loop data. In fact, it is a new model to manage and use product lifecycle data efficiently.

Acknowledgments

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References

[1] Research on Major Technical Equipment Manufacturing Industry Development, China's Productivity Development Research Report on 2007-2008, 2009.
[2] Jun H B, Kiritsis D, Xirouchakis P. Research issues on closed-loop PLM. Computers in Industry, 2007, 58(8): 855-868.
[3] Jun H B, Shin J H, Kiritsis D, et al. System architecture for closed-loop PLM. International Journal of Computer Integrated Manufacturing, 2007, 20(7): 684-698.
[4] Kiritsis D, Bufardi A, Xirouchakis P. Research issues on product lifecycle management and information tracking using smart embedded systems. Advanced Engineering Informatics, 2003, 17(3): 189-202.
[5] Matsokis A, Kiritsis D. An ontology-based approach for Product Lifecycle Management. Computers in in-dustry, 2010, 61(8): 787-797.
[6] Røstad C C, Myklebust O, Moseng B. Closing the product lifecycle information loops//18th International Conference on Production Research, Fisciamo, Italy. 2005.
[7] Georgiadis P, Athanasiou E. The impact of two-product joint lifecycles on capacity planning of remanufacturing networks. European Journal of Operational Research, 2010, 202(2): 420-433.
[8] Wang Xiaocui. Engineering Change Process Control Based on PLM. Jinan: Shandong University, 2009.
[9] Liu Jingjun, Sun Quan, Zhou Jinglun. Research of Product Quality Close Loop Management System. Microcomputer Information, 2006, 22(18): 140-140.
[10] Ma Demin. Research on Compatibility Mechanism of Manufacturing/Remanufacturing Closed-loop Supply Chain System. Information Technology & Standardization, 2008, 3: 42-46.
[11] Wang Ming. Design and Implementation of Production Management System Based on Universal Software Development Platform. Xi'an: Xidian University, 2007.
[12] Wang Xu, Li Wenchuan. New Concept for Manufacturing Industry——Closed-loop Product Lifecycle Man-agement. China Mechanical Engineering, 2010 (14): 1687-1693.
[13] Chang Kuei-Hu, Wen Ta-Chun. A novel efficient approach for DFMEA combining 2-tuple and the OWA operator. Expert Systems with Applications, 2010, 37(3): 2362-2370.