Research on Quality Surveillance in Digital Design Environment

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Abstract. This paper studies the definition of product quality surveillance in a digital design environment, analyzes the characteristics and new requirements of quality surveillance, and proposes the main contents of quality surveillance in these aspects, including digital design process in the aspects of quality information management, quality problem handling, digital prototype management, technical status management, data exchange and conversion. Finally, we put forward the methods of quality surveillance in digital design process.

1. Introduction

With the continuous development and application of information technology, manufacturing technology and computer technology in the field of product design and production, an informationized closed-loop system for product design and production based on digital design, digital manufacturing, digital testing, digital detection and digital applications has gradually formed, and the close integration of activities and information technology makes it possible to management of information, intelligent and scientific.

Digital design is based on the fusion of knowledge in the design process, characterized by digital modeling, simulation and optimization. It applies information technology, advanced digital manufacturing technology and modern management models to all stages of the life cycle, to make digital design with digital modeling as the core, digital manufacturing with manufacturing and production process as the core, and digital management with modern design models and business modeling as the core realized. The quality surveillance in the digital design environment can be defined as: in order to ensure that the quality requirements specified in the contract are met, make full use of the digital platform to automate, digitize, network and intelligently monitor, verify, analyze and supervise the product quality formation process and results activity.
2. Features of product quality surveillance in a digital environment

Based on the characteristics of digital design, the features are mainly analyzed in the following aspects.

(1) Visualization of quality surveillance. The traditional surveillance method is mainly based on product physical quality inspection, experience-led, and post-mortem surveillance. It lacks methods and means for real-time monitoring of process quality. In a digital environment, product quality surveillance can be carried out by using network video surveillance and online data monitoring to achieve visual quality surveillance of the entire process of product production, debugging, inspection and testing.

Through video surveillance, it can monitor key structures, automatic processing and assembly processes to realize multi-site and multi-scenario inspections. The stored video records can also be used as evidence for analyzing the causes of quality problems. Through online data monitoring, it can realize real-time monitoring of three-dimensional digital mold. Using the three-dimensional digital model, a digital prototype can be displayed on the ordinary terminal, implement real-time link with process quality feature information, and finally achieving real-time monitoring of product quality.

(2) Automation of monomer inspection. Under the traditional quality surveillance model, many key technical quality problems of products cannot be resolved. There are many problems such as inadequate process quality control, weak continuous improvement of quality management, poorly targeted corrective measures, inadequate implementation and so on. In a digital environment, we can develop intelligent inspection equipment as needed for realizing the automation of data collection and result judgment, real-time detection of changes in the level of various quality indicators of products, equipment, and processes. Through the use of big data for intelligent analysis, we can achieve real-time quality feedback and control, automated testing and inspection. In addition, it can automatically collect product processing and characteristic measurement data, and automatically compare with the theoretical data of the digital model to determine whether qualified, by using automated manufacturing and testing equipment, such as CNC processing, measuring machines.

(3) Standardization of process records. The digital design process generates a large amount of electronic technical data. These data need to be standardized, simplified, coordinated and optimized in order to achieve efficient and economical transmission and exchange. In a digital environment, the uniqueness and validity of the data are particularly important for product quality surveillance activities. It is necessary to standardize a unified record format to realize the standardization of quality surveillance, inspection, acceptance record generation and storage to ensure the traceability.

(4) Efficient of data utilization. In a digital environment, constructing a quality surveillance information system, the in-depth use of quality surveillance and inspection and acceptance data can be realized to improve the utilization rate of historical data regeneration. Digital surveillance can expand the scope of monitoring, complete more work replacing quality surveillance personnel, and can ensure the accuracy and reliability of quality data.

In addition, the quality data collected by the information system is uploaded to the server in real time. Under the setting of a hierarchical authority system, quality supervisors can query relevant information anytime, anywhere, and make quality surveillance work better and faster. Design and production personnel can also understand the various parameters of the product and the process capability of the production line through the information system, so as to make timely adjustments.

3. New requirements for product quality surveillance in a digital environment
1. The quality surveillance mode should adapt to the requirements of the digital design environment. The application of concurrent engineering theory and technology in quality surveillance under the digital design model has become possible. Collaborative manufacturing under the digital design model has become a common model. It is necessary to innovate the model of quality surveillance, establish a networked collaborative management concept, and streamline the level of quality surveillance organization, establish a flat, networked quality surveillance work system. And the use of concurrent engineering theory and technology can better promote the improvement of quality surveillance efficiency. Enterprises can build a digital quality surveillance information system to achieve efficient collaboration between quality surveillance and design, manufacturing, and quality management. Quality supervisors can participate in the product design and production process through the digital supervisory system, grasp the quality status of the product in real time, and then find problems in advance and timely warning.

2. The quality surveillance methods should be adapted to the requirements of the digital design environment. Digital technology is widely used to gradually realize the network of product information data, so that the data can be generated at one time and transmitted and used many times, which greatly improves the sharing and reuse of information data. Moreover, information technology and management methods such as product comprehensive data environment, project management, cost monitoring, technical status control, and parts network ordering system can be used to improve the effectiveness of product quality surveillance. Enterprises need to build a digital surveillance platform to conduct real-time monitoring and online analysis of critical data and important information generated in the process of digital design and manufacturing, including video surveillance records of critical processes, product quality trend analysis, product quality judgment, online acceptance, and online processing of quality issues and simulation of quality surveillance based on digital prototypes. It needs to use digital surveillance concepts, methods and tools based on digital prototypes for product quality verification, etc.

3. The quality surveillance objects and key points should be adapted to the requirements of the digital design environment. In the digital environment, product quality surveillance needs to be extended from the physical quality to the quality of digital products in the digital design process, including 3D model quality, modeling tools, 3D model lightweighting, and model management. It is necessary to strengthen the design quality surveillance with the virtual prototype as the object, so as to realize the transition from the compliance index surveillance of the traditional physical prototype to the demand achievable surveillance of the virtual prototype. The virtual prototype is a simulation of the physical prototype in terms of appearance, function, performance, etc. Compared with the traditional physical prototype-based design and simulation mode, the virtual prototype-based system design and simulation mode require that the virtual prototype system model has a high reliability, a model that lacks sufficient credibility is meaningless, and may even have serious misleading consequences, which can lead to significant losses and waste.

4. The timing of quality surveillance should be adapted to the requirements of the digital design environment. In order to support the parallel working mode of digital design, for the design process of product processing, assembly, inspection, it needs fully considering about the three-dimensional expression, structure and multimedia features of the digital design process in terms of quality
surveillance timing. Such as the links between process descriptive text and different information of views, features and annotations, the efficiency and synergy of information transmission between designers and workshop workers, the textual process description information, supporting resources, three-dimensional process models and inspection requirements involved in each process. We can determine the key node of digital quality surveillance by analyzing these features.

4. Main contents of quality surveillance in digital design process

The key tasks of quality surveillance in digital design process mainly include digital design process information management surveillance, digital design process quality problem handling surveillance, digital prototype management surveillance, technical status management surveillance, data exchange and conversion surveillance, etc.

4.1 Quality information management surveillance in digital design process

(1) Quality information management requirements. The quality information involved in the digital design process includes: recommendations made in technical reviews, problems found in virtual assembly, problems found in virtual testing and simulation, problems found in digital product inspection, problems found in configuration audits, etc. Enterprises need to collect, transmit, process, store, and use quality information in the digital design process to implement closed-loop management.

(2) Quality information process. In the digital design environment, the quality information flow is formed through the processes of information collection, analysis and processing, feedback, or exchange. It made PDM, database and other network resources as the medium, using quality control tools such as FRACAS. And it is produced along with the concurrent engineering design process, flows through all stages of design, process, manufacturing, procurement, and testing.

The information management platform PDM should integrate the information of each stage of the parallel design process and the corresponding departments for information collection, processing, data change control, version management and release, etc. This includes quality problem records, corrective actions and plans, and related standards, monitoring data entry, quality tracking and comprehensive quality management, etc. With the unified management of PDM, the crossover and duplication of information among various departments are reduced, and the efficiency of information transmission and the availability of information are improved.

4.2 Handling surveillance of quality problems in digital design process

(1) The scope of quality problems in the digital design process. The quality problems of the digital design process mainly include: the digital prototype design error of affecting the product schedule, causing the interface design modification with other units, causing the product performance index to drop, and causing production rework; due to technical reasons, it causes experiments based on simulation results to carry out related work errors in simulation analysis of failed or damaged products; quality problems caused by functional defects reflected after the information management platform goes online; quality problems caused by technical reasons that affect the use of the information software after delivery.

(2) Requirements for handling quality problems in the digital design process. After the quality problem occurs, the enterprise should organize technical personnel in digital prototype design and
product simulation analysis to confirm the phenomenon of the quality problem, analyze and determine the cause of the problem. Test according to the original design method, simulation method and operation method, and formulate and implement corrective measures. The corrective measures confirmed by verification shall be implemented in the digital design, process, simulation or test documents. And in the following key stages of the comprehensive inspection of quality problems and organize the necessary review, including product digital prototype production before the factory, digital prototype delivery, before the simulation based on the design of the test and so on.

4.3 Management surveillance of digital prototype in the process of digital design

1) Data management requirements. Digital prototype data should be managed in the PDM system, and data security authority management mechanism should be established to regularly back up the data. All data and documents that related to the daily work process of the digital prototype should have multiple machine archives and multiple storage media backups. It should be implemented to avoid the catastrophic loss of data caused by natural or human factors.

2) Requirements for review of digital prototypes. The digital prototype should be reviewed synchronously with the design stage, and the organization should prepare and provide working reports of the digital prototype models at all stages of the design, the whole machine and each sample section according to the requirements of the review. The basis for the digital prototype review includes technical solutions and digital quality assurance Outline, etc. The digital prototype submitted for review shall meet the requirements of digital design standards and specifications, and shall pass inspection. The digital prototype evaluation preparation items include digital prototype, digital prototype display environment, related demonstration projects, digital outline, digital prototype design quality analysis report, digital prototype correctness acceptance inspection report, digital prototype standard acceptance inspection report, interference inspection analysis report, quality characteristic calculation analysis report, and human-machine assembly feasibility verification simulation report, etc.

4.4 Technical status management surveillance of digital product

Technical status management surveillance is the focus of quality surveillance in the digital design process. Digital design technical status management surveillance includes these four aspects: technical status identification surveillance, technical status control surveillance, technical status record surveillance, and technical status audit surveillance.

1) Surveillance on the technical status identification of digital products. In order to ensure the uniqueness, traceability and relevance of technical status items in the digital design process, the technical status items should be identified. The data formed by the technical status management should be included in a single product data source managed by the product data management system. When the digital product is checked in, it needs to be marked according to the technical status labeling requirements, and the correctness of the digital product is checked by physical audit. Digital products are divided into states of editing, pre-release, approval, release, official release, and filing according to the degree of completion. In the digital design, the state and control of the data must be set in time according to the degree of completion of the data. Achieving effective control of digital product versions through the implementation of the approval process.

2) Surveillance on the control of technical status changes of digital products. The technical status
change control surveillance of digital products should pay more attention to these four aspects.

1) Implementing the principles and methods of the main model when changing to ensure that the solid model of the part is the only data source for drawing and assembly.

2) The method of changing the data model first and then generating the two-dimensional pattern through the digital product is adopted to ensure the consistency of the product data model and the two-dimensional pattern.

3) The files and documents on all different media related to the change object should be changed at the same time and be consistent.

4) Changes to lower-tier components should be coordinated with higher-level components.

3) Documentary surveillance of the technical status of digital products. The documentary requirements for the technical status of digital products generally include: recording and reporting the proposed changes of digital product technical status documents; recording and reporting the results of digital product technical status audits, including non-conformances and final handling; recording and reporting all deviations from the license and concession status of the digital product technical status items; recording and reporting the implementation status of approved changes; provide all changes to each digital product technical status item, maintaining traceability to the initially identified functional baseline, design baseline, and digital prototyping baseline.

4) Review surveillance of the technical status of digital products. Generally, the physical and technical status review is carried out when product data is checked in, when product data is approved, when a baseline is established, or when a product is delivered. It is mainly to check the integrity of the baseline and product data, and to check the completeness of the product data and the correctness of the logo, and the consistency of the product with the final baseline.

4.5 Data exchange and conversion surveillance in digital design process

In the context of concurrent engineering and collaborative design, digital products, as the basis of the entire product development process, face a large number of data exchange scenarios. High-quality digital product data can be accurately expressed by intermediate files, and can be accurately recognized and accepted by downstream software. It is directly applied and does not need to be repaired, modified or even remodeled. Product data conversion includes product data exchange and data transmission. Data exchange refers to the exchange or sharing of product data between software systems in accordance with the agreed data format during the entire product life cycle. Data transmission refers to the process of using a network or storage medium to achieve data transmission.

1) Data exchange. Data exchange should ensure that the data is correct and effective during the exchange process. It can provide complete security mechanisms and measures to ensure the integrity and safety of the data during the exchange process. And, the product data exchange process should be tracked and recorded to ensure the traceability of the data exchange.

2) Data transmission. Data transmission methods include network transmission and storage medium transmission. Product data transmission should provide perfect security mechanisms and measures to ensure the integrity and safety of the data in the transmission process, measures should be taken during the product data transmission process, such as check codes, to ensure data consistency. The product data transmission process should be tracked and records to ensure the traceability of data transmission.

3) Data inspection. Both parties of product data transmission should check whether the data and the
information or status recorded in the product data transfer record sheet are consistent, whether the data is correct and effective, whether the data is complete and consistent before and after data transfer, and the consistency of CAD model data before and after conversion.

(4) Real-time data collection. In the process of product design and production, all kinds of automated testing equipment are used to continuously conduct online testing of product related parameters and technological processes, and real-time collection of product quality data. It ensures that various performance indicators meet quality standards.

(5) Data analysis and judgment. Digital quality surveillance forms a product quality database through real-time monitoring of product quality data. Analyzing and comparing it with standard data of product simulation models according to different product quality data types such as count values and measured values, it can performs quality control and improvement to make the quality characteristics of products are more in good condition to prevent falling into unqualified range.

5. Ways and methods of quality surveillance in digital design process
In the digital environment, many methods of quality surveillance have changed. The full life cycle of the product can gradually transition to paperless, which makes the quality surveillance elements such as the technical status of electronic drawings and key quality characteristics more intuitive. Based on digital technology, you can more fully and reasonably use the quality statistical management tools by adding effective and reliable boundary conditions, and discard the complexity and ease of manually inputting the computer in the traditional design model.

At the same time, the effective collection of quality data in the digital environment can ensure a single source of data for the simulation process, and the implementation of the quality surveillance process based on digital prototype simulation is simpler and more reliable. Through the use of product quality data, the generation of non-conforming products can be effectively controlled. In the inspection and acceptance process, it can also achieve accurate and effective quality traceability, accurately locate the source of product materials and components, identify the causes of quality problems, clarify responsibilities, and then complete the traceability and solve the quality problems.

5.1 The form of quality surveillance in digital design mode
The forms of quality surveillance in the digital design process generally include: quality data surveillance, process surveillance, and inspection and acceptance.

(1) Quality data surveillance. The hierarchical relationship and data attributes between the items, nodes and related objects of the product structure tree should be based on the product data management attributes, version management and change management standards, and the expression should be standardized and unique. The definition of effectiveness of the product design process quality data shall comply with the standard provisions of product configuration management in data management and be supervised and managed in accordance with the standards. Mass data will be generated in the product design process, and the big data processing method will be used to process the data in depth, and the trend of product quality problems will be mined from the mass data, while the repeatability of historical quality problems will be weakened to ensure the efficient recycling of data.

(2) Process surveillance. In the digital design mode, we must strictly follow the digital prototype model provided in the product design stage, refer to the relevant standards and specifications of product
quality requirements, and monitor product quality in real time. In the process of product manufacturing, network video monitoring and online data monitoring are used to achieve quality surveillance of the entire process of product production, debugging, inspection and testing. Digital methods are used to automate data collection and result judgment. The whole process of product manufacturing quality surveillance and data of inspection and acceptance should be in-depth used which can improve the utilization rate of historical data. Standardization of a unified recording format can ensure the standardization of data generated by quality surveillance and inspection and acceptance records, laying the foundation for traceability of quality problems.

(3) Inspection and acceptance. On the basis of the virtual prototype test acceptance, during the product joint test and joint debugging and system inspection and acceptance, it is necessary to accurately understand the working status of each component, especially the receiving and sending of messages, data, and instructions, so as to master the information process and discover in time 3. The location information "clogging point" provides a basis for quickly troubleshooting and improving the efficiency of inspection and acceptance. Different types of products require different monitoring technologies, such as message-based monitoring and link layer monitoring.

5.2 Quality surveillance method under digital design mode

(1) Electronic document review and approval. Electronic document review is the review and approval of product quality assurance documents, various test and appraisal reports, conclusions, outlines specifications and so on. These key points are included: review and approve the quality plan of the approved product, supervise the preparation of the design work network plan and clarify the requirements of the key nodes of digital design, implement the phased quality control, and the completeness, accuracy, reasonableness and feasibility of the relevant documents.

(2) Review participation. Quality supervisors should participate in the design review, process review, and product quality review prior to the transfer of the design process in a digital collaborative environment.

(3) Experiment participation. Quality supervisors should participate in relevant tests involving key technologies and major and serious quality problems of virtual prototypes or products, and participate in identification and finalization tests. According to the standard specifications in the digital design mode, monitoring technologies, including message-based monitoring and link layer monitoring are adopted to supervise the quality of relevant experiments in the process of design production and use.

(4) Digital prototype management and review. According to the requirements of the definition of digital prototypes at various stages of design, the purpose, structure and standard requirements of the digital prototype should be clarified. Its assembly process should meet the requirements of digital product assembly quality control requirements. It conduct digital prototype management according to the relevant product data management standards, and implement quality control of product data management; digital prototype review and design review are carried out simultaneously, and digital prototype models and work reports are provided in accordance with the review standards.

(5) Online inspection. Online inspection is a planned and focused quality inspection activity carried out by quality supervisors on the design (production) process on the digital quality surveillance platform according to product quality. Its purpose is to understand quality trends in time, discover quality problems in time, and do product quality prediction and prevention work. Through the search of file
records, product acceptance records, product quality companion cards and other documents, understand and master the quality dynamics, and take targeted measures to solve them.

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