Research on Process Integration Based on Functional Safety and Quality Management

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Abstract : With the increasing number of functions and high integration and complexity of vehicle electronic control systems, functional safety issues have become prominent. The functional safety standards propose relevant requirements in the management and production phases, which are strongly related to the requirements in the quality management system. This article is based on the integration of functional safety and quality management systems, integrating the two sets of methodologies from a production analysis perspective, and proposing an analytical theory that meets the requirements of functional safety and quality management, thereby saving labor and time costs and further improving the quality, safety, and reliability of automotive products.

Keywords: Functional Safety, Quality Management, PFMEA

1.Introduction

With the rapid growth of domestic production of intelligent connected vehicles and new energy vehicles, the safety of electronic control systems for electric vehicles has become increasingly important. Existing technologies such as EMC requirements, battery requirements, and motor requirements are difficult to cover the safety requirements of functional control (hardware and software) for new energy vehicles, especially pure electric vehicles. The research and application of functional safety technology has become an international consensus. The functional safety national standard GB/T 34590 was officially issued and implemented in May 2018, and was implemented in the second edition in 2023. It further specifies the functional safety requirements for automotive electronic control systems, especially intelligent driving systems, throughout the entire safety lifecycle of the vehicle, system, hardware, software, testing, and production, To become the current highest safety technology standard for major OEMs and Tier1s worldwide in the development of complete vehicles and electronic control systems.

The quality management system ISO/TS 16949 followed by the automotive industry today is an international automotive quality system jointly released by the International Automotive Task Force (IATF) and the International Organization for Standardization (ISO). This quality system is applicable to the entire supply chain of automotive components and services,

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including vehicle manufacturers. ISO/TS 16949 is a technical specification that incorporates special requirements from the automotive industry on the basis of ISO 9001. This technical specification is a quality system that can provide continuous improvement, emphasize defect prevention, and reduce variation and waste in the automotive manufacturing industry.

More and more OEMs and Tier1s are integrating functional safety and quality management systems throughout the entire R&D and production lifecycle, particularly in the second part of functional safety management and the seventh part of Production, operation, service and decommissioning, which specify quality and production aspects, which are highly related to the requirements of the quality management system. Therefore, based on the integration research of functional safety and quality management systems, the two sets of methodologies will be integrated to form a practical and feasible safety system integration analysis method.

2.Functional safety

Functional safety standards are established to manage and reduce the risks of automotive electronic systems to humans. The main purpose of this standard is to ensure that the vehicle's electronic system can maintain sufficient safety in the face of malfunctions[1]. As shown in Figure 1, ISO 26262 covers the entire lifecycle of electronic systems, including management, concept, system, hardware, software, production, and other phases, involving process management, requirement definition, safety analysis, testing and verification, and other contents[2].

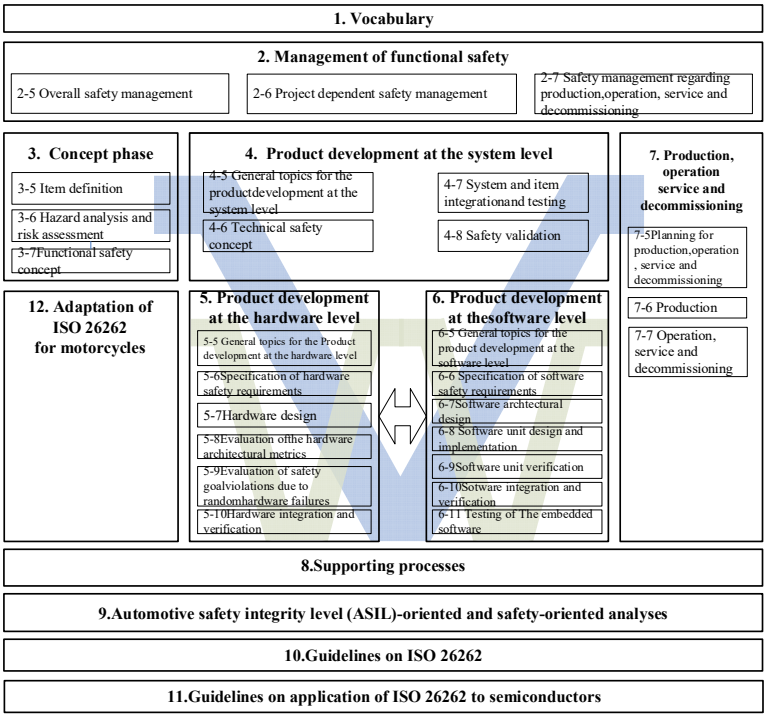

Figure 1. Overview of the ISO 26262 series of standards

Taking safety analysis as an example, the purpose of functional safety standards is to ensure that the risk of violating safety objectives due to systematic or random hardware failures is sufficiently low[3]. At each phase of functional safety, safety analysis is applied to identify hazards, as shown in Figure 2. From the conceptual stage to the production stage, safety analysis is applied in the functional safety methodology: the entire vehicle function is exported with corresponding functional failures through HAZOP analysis, safety objectives are derived through scene library and S/E/C analysis through HARA, and functional safety requirements are analyzed through FTA[4]. Combined with safety analysis at each phase, technical safety requirements are derived Hardware security requirements and software security requirements, and apply FMEDA to calculate single point failures and potential failures[5][6]. In terms of production, combined with safety analysis at each stage and P-FMEA related to the production line, derive safety requirements related to production operation and maintenance.

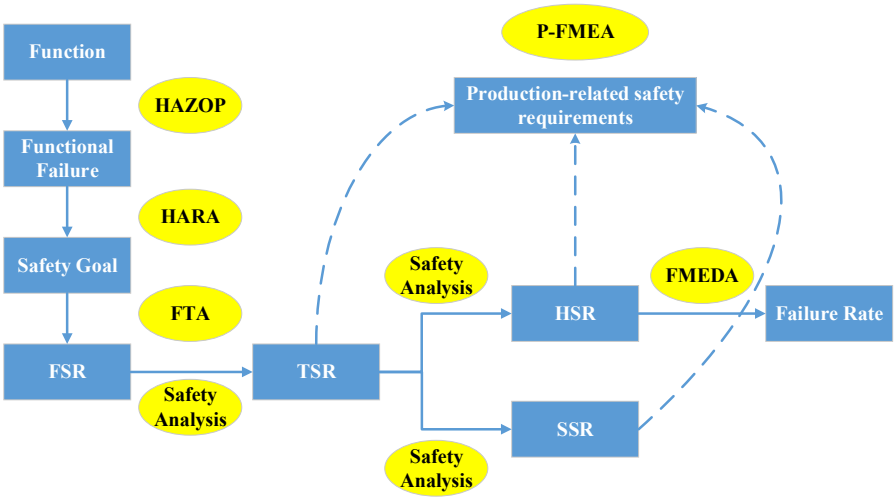

Figure 2. Analysis methods for Functional Safety at each phase

In summary, safety analysis methods have been applied in all phases of functional safety methodology. At the same time, functional safety and quality management can also be combined in the process, so it is necessary to combine the two in the process and development methods.

3.Quality management

The quality management ISO/TS 16949 is a global standard developed for the automotive manufacturing industry, with the goal of improving the quality level of the entire automotive supply chain through effective quality management systems. This system is combined with the ISO 9001 quality management standard and focuses on special processes and requirements related to automotive manufacturing[7].

The focus of ISO/TS 16949 includes process stability, defect prevention, continuous improvement, and supply chain management. This standard emphasizes the shared

commitment of global automotive industry manufacturers to quality, providing them with a framework to ensure that their products meet customer expectations and regulatory requirements[8].

Figure 3. PDCA Cycle of Quality Management

As shown in Figure 3, the quality management system requires organizations to establish, implement, maintain, and continuously improve an effective quality management system. This includes the formulation of quality policies, the setting of quality objectives, the preparation of quality manuals, and a series of documents and procedures to ensure that the entire organization is committed to quality. The standard requires organizations to implement advanced quality management methods in product development and production processes, including product planning, design and development, and production process validation, to ensure that products meet customer requirements and regulatory standards[9]. It encourages organizations to measure and evaluate the effectiveness of their quality management system through the use of data, statistical techniques, and other analytical methods. This helps organizations identify problems in a timely manner, take corrective measures, and continuously improve their quality management system.

4.Functional safety and quality management system integration

The quality management ISO/TS 16949 is a global standard developed for the automotive manufacturing industry, with the goal of improving the quality level of the entire automotive supply chain through effective quality management systems. This system is combined with the ISO 9001 quality management standard and focuses on special processes and requirements related to automotive manufacturing[10].

4.1 The challenge of system integration

Functional safety and quality management, while different in terms of focus, have some things in common. First, both focus on the concept of continuous improvement. Combining these two systems creates a more comprehensive quality management system that enables continuous improvement at all stages of product design, production and maintenance. Second, both focus on risk management, but with different emphases. Functional safety ISO 26262 has introduced full life cycle risk management for automotive electronics systems, while quality management

ISO/TS 16949 focuses more on process and supply chain risk management. By combining the two, risk can be managed at a full range, full life cycle level and product reliability and safety can be improved.

However, successfully integrating these two systems will not be a simple task. One of the challenges is ensuring consistency between the requirements of the two standards. This may involve modifying and adapting the organization's processes, documentation, and training programs to ensure that the requirements of the converged system are met. Another challenge is to maintain clarity and operability in a converged system. Because the two systems each have complex requirements and procedures, merging them can lead to information overload and confusion. Therefore, organizations need to think carefully about how to integrate these requirements so that they are easy to understand and implement for all stakeholders.

The integration of functional safety and quality management systems will create a more integrated management system. This system can provide a unified approach at all stages of the automotive manufacturing and supply chain, thereby more efficiently meeting the requirements of both standards. By integrating elements of risk management, continuous improvement, and quality control, organizations can achieve higher levels of safety and quality. Integrated systems can also bring economic benefits. By simplifying the management system, organizations can reduce redundancy and duplication and reduce administrative costs. This not only makes the organization more competitive, but also helps to improve the efficiency and sustainability of the entire automotive industry.

4.2 Production phase integration

As shown in Figure 4, the two methodologies are combined based on functional safety and quality management system production related content. On the one hand, in the production planning, trial production and production level of functional safety, it is necessary to sort out safety-related needs, and sort out the planning process and production accordingly. On the other hand, the PFMEA in the quality management system needs to be analyzed and supplemented with electronic and electrical related failures to form the PFMEA analysis that integrates functional safety.

Figure 4. Production analysis of functional safety and quality management integration

Production-related safety requirements are mentioned in the functional safety system, hardware, and software phases. Ensuring functional safety during Production, operation, service and decommissioning consists of two main aspects: the first relates to the activities undertaken during the development phase to ensure adequate system architecture design and the definition of appropriate safety-related special features; The second aspect relates to

activities to ensure that functional safety is achieved or maintained during the production and operation phases, such as based on specific safety-related special features. As shown in Table 1, identify the insulation characteristics that need to be tested under specified conditions in the special features, as follows:

Table 1. Insulation Characteristics in Special Features

Characteristics	Specification	Process	Measuring Tool	Control method/Frequency
Insulation characteristics under specified test conditions	Meet the requirements of 4.3.1.15 in Q/JLY 7111091C-2021, with an insulation resistance of ≥ 100M Ω. After testing, the functional status of the components meets the A-level requirements.	Insulation withstand voltage test	Safety regulations detector	Project Phase: 100% Inspection of Manufacturing Process Mass production stage: MES control percentage testing of the first inspection sample

As shown in Table 2, the PFMEA analysis of insulation and voltage resistance is presented. PFMEA in the automobile production line is mainly used to identify the potential failure mode and impact of the automobile manufacturing process, analyze the failure causes, and guide the team to formulate preventive measures or control measures based on the failure causes, so as to prevent the occurrence of defects or curb the escape of defects[11]. However, currently PFMEA is mainly aimed at traditional processes, and its guiding significance for failure analysis of automotive electronics and control, especially increasingly complex control software, is weak. Such as software calibration, brushing, and mismatch with development stage parameters will cause security problems[12]. On this basis, the combination of the two can analyze the failure that may occur in the production line of different functions of the vehicle, find out solutions and safety requirements, form an experience database and solidified in the enterprise data, so as to directly call the experience demand database and analyze and update it in time.

Table 2. Analysis of Insulation Characteristics

Insulation withstand voltage	Unable to start test	Production line: affecting production efficiency	MES system control
	insulation failure	Production line: product rework Customer: The heater is not working	MES system control, unable to enter the next station
	insulation failure	Production line: product rework Customer: The heater is not working	MES system control, unable to enter the next station

5.Summary

In the automotive industry, functional safety and quality management are key elements that complement each other, but the pursuit of superior safety and quality cannot be compromised. By integrating functional safety ISO 26262 with quality management ISO/TS 16949, a more comprehensive and efficient quality management system can be achieved to improve the

safety, reliability and quality of automotive products. This convergence helps to meet not only industry standards but also growing customer expectations, creating a more integrated management system that can further improve the quality, safety and reliability of automotive products and drive the automotive industry towards a more sustainable and competitive future.

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