学 位 論 文 の 要 旨

A Design Method for Fault Tolerant Control System
（フォールトトレラント制御系の一設計法）

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This thesis introduces innovative design methods for fault-tolerant control (FTC) systems, enhancing the reliability and stability of multi-plant systems and advanced automotive technologies, particularly steer-by-wire applications. Traditional control theories generally assume flawless system components; however, real-world systems are prone to faults that degrade performance and potentially destabilize controllers. Addressing this gap, the research develops methods aimed at maintaining system performance and stability even in the presence of faults. The thesis provides a comprehensive review of existing FTC approaches, including active and passive methods and fault detection and isolation (FDI) techniques. Active methods involve real-time adaptation to detected faults, ensuring continued operation despite component failures, while passive methods design the control system to be inherently robust to certain faults without real-time adjustments. The review highlights applications across various domains, such as aerospace, industrial automation, and automotive systems, establishing the state-of-the-art in FTC and identifying gaps for further research. A simplified FTC design for multi-plant systems, which consist of multiple interconnected subsystems, is proposed. This design uses fault estimators to detect and compensate for faults, reducing overall complexity while ensuring stability and performance. A numerical example demonstrates the efficacy of the method, showing that the simplified FTC design can maintain system performance even when faults occur in one or more subsystems. The thesis also applies FTC to steer-by-wire systems, a technology in the automotive industry that replaces traditional mechanical and hydraulic steering with electronic controls. Despite advantages like reduced weight and increased design flexibility, steer-by-wire systems face new fault tolerance challenges due to their reliance on electronic components. An FTC design using a fault detector to maintain stability and performance under faults is proposed, supported by mathematical models and simulations.

The thesis concludes by summarizing key contributions and suggesting future research directions. The proposed methods are noted for their practical applicability and robustness, offering simpler and more effective solutions for designing FTC systems in high-reliability environments. The thesis emphasizes the need for continued research to address emerging challenges and enhance the reliability of complex control systems, contributing significantly to the field by providing practical solutions for real-world systems and paving the way for more robust and effective FTC designs with broad implications for improving safety and performance in critical applications.