Engineering Technology Trends Vol 3 Issue 6 2025

ORIGINAL RESEARCH ARTICLE

Omniscient Pte.Ltd.

Open Access

Discussion on Common Issues in the Maintenance of the Boeing 737NG Flight Control Cable System

Zhen Liu*

Engineering Technology Branch of China Southern Airlines Co., LTD, Zhengzhou, Henan 450014, China

***Correspondence to:** Zhen Liu, Engineering Technology Branch of China Southern Airlines Co., LTD, Zhengzhou, Henan 450014, China , E-mail: liuzhena@csair.com

Abstract: This paper aims to systematically examine the common issues encountered in the routine maintenance, scheduled inspection, and troubleshooting of the flight control cable system of the Boeing 737NG. It first outlines the basic configuration and operating principles of the 737NG cable system, and then provides an in-depth analysis of typical failure modes—including cable wear, corrosion, abnormal tension, pulley seizure, loosened fittings, and improper lubrication—focusing on their causes, inspection methods, and potential risks. On this basis, targeted preventive maintenance strategies, recommendations for the application of advanced inspection technologies, and optimization measures for personnel training are proposed. The study indicates that by strengthening refined, life-cycle-oriented management of the cable system, strictly implementing maintenance manual procedures, and actively introducing predictive maintenance concepts, the reliability of this critical system can be significantly enhanced, thereby providing solid assurance for the safe and efficient operation of the 737NG fleet.

Keywords: Boeing 737NG; flight control system; cable; maintenance; wear; corrosion; tension

Introduction

Since entering commercial service in the late 1990s, the Boeing 737NG series has become a mainstay aircraft for short- and medium-haul routes worldwide due to its economic efficiency, reliability, and well-established maintenance system. Although fly-by-wire control systems have been widely adopted in large commercial aircraft, the 737NG still employs a hybrid flight control system centered on mechanical cables with hydraulic assistance. This design not only ensures redundancy and fail-safe capability but also preserves control feel and pilot familiarity. However, mechanical systems are inevitably subject to wear and aging. As a key component connecting the cockpit to the aircraft control surfaces, degradation of the flight control cable system can adversely affect handling qualities and even compromise flight safety [1]. Historically, failures of cable systems have led to serious accidents, underscoring the critical importance of maintenance. At present, with the increasing age of the 737NG fleet, challenges in cable system maintenance are intensifying, and the limitations of traditional periodic inspection models are becoming evident. Therefore, an in-depth study of maintenance issues related to the 737NG cable system can assist maintenance personnel in accurately addressing faults and provide support for airlines in formulating more scientific and efficient preventive and predictive maintenance strategies.

1. Overview of the Boeing 737NG Flight Control Cable System

1.1 Basic System Configuration

The flight control system of the Boeing 737NG mainly consists of three subsystems: the primary flight control system (ailerons, elevators, and rudder), the secondary control system (leading-edge/trailing-edge flaps and spoilers), and the horizontal stabilizer trim system. Among these, the primary flight controls and the horizontal stabilizer trim system rely extensively on cables for signal transmission and force transfer. Specifically, the aileron control system originates from the control columns in the cockpit and transmits pilot inputs through a series of torque tubes, quadrant assemblies, and cables, ultimately connecting to the aileron power control units (PCUs) on the left and right wings. In this system, the cables primarily function to convey pilot command inputs. The elevator control system adopts a similar configuration, in which pitch commands from the control columns are transmitted via a complex cable network to the elevator PCUs located near the base of the vertical stabilizer. Rudder control is achieved through yaw inputs applied by the pilot via the rudder pedals; these inputs are transmitted through pedal cranks, quadrants, and long-span cables running along the fuselage to actuate the rudder PCU. Of particular importance is the horizontal stabilizer trim system. Commands from the trim wheels or the autopilot are transmitted through an independent, high-tension cable system to drive the horizontal stabilizer trim actuator (jackscrew) located in the aft fuselage, thereby achieving longitudinal trim of the aircraft. Failure of the cables in this system would directly result in loss of pitch control, with potentially catastrophic consequences.

1.2 Structure and Materials of the Cables

The flight control cables used on the 737NG are typically aviation-grade multi-strand stainless steel aircraft cables, with common constructions such as 7×7 and 7×19. In this notation, “7×19” indicates a cable composed of seven strands, each containing nineteen individual wires. This configuration provides high tensile strength while maintaining good flexibility and fatigue resistance. The outer surface of the cables is usually coated with a corrosion-resistant layer, and in specific areas, polytetrafluoroethylene (PTFE, Teflon) sleeves are applied to reduce friction. Both ends of the cables are connected to various types of terminal fittings through swaging or casting processes, such as ball ends and clevis fittings. These terminals facilitate articulation with quadrants, bellcranks, or other connecting components, ensuring smooth force transmission and adequate freedom of movement.

1.3 Operating Principles of the System

The operating principle of the cable system is essentially based on force transmission and synchronized displacement. When the pilot moves the control devices in the cockpit, the resulting mechanical displacement is transmitted precisely and with minimal delay through the cables to the remote control surface actuators. To ensure that the cables do not become slack or excessively stretched during transmission, multiple turnbuckles and tension regulators are incorporated into the system. In addition, fairleads and idler pulleys distributed along the entire cable routing are used to change cable direction, reduce bending radius, and guide smooth cable operation [2].

The overall system design follows strict redundancy principles. For example, the primary flight control system typically employs dual or triple independent cable circuits. Even if one circuit fails, the remaining circuits can still provide basic control capability, thereby establishing multiple layers of protection for flight safety.

2. Analysis of Common Issues in the Maintenance of Flight Control Cable Systems

During routine maintenance of the 737NG, a wide range of issues have been observed in the cable system. These issues can be broadly categorized into several typical failure modes.

2.1 Cable Wear

Wear is the most common form of cable damage and is primarily caused by repeated friction between the cable and pulley grooves, fairlead holes, or the edges of structural components. In particular, when pulley bearings are damaged, pulley grooves become rough, or foreign objects are present, wear can accelerate significantly. In addition, repeated bending of the cable over pulleys can lead to fatigue wear of the internal wires. In the early stages, wear manifests as burrs or broken outer wires on the cable surface. As wear progresses, the effective load-bearing cross-sectional area decreases, resulting in a significant reduction in cable strength. If not detected in time, this condition may cause sudden cable failure under flight loads, leading to loss of control. According to the Aircraft Maintenance Manual (AMM), when the number of broken outer wires exceeds specified limits (e.g., the allowable number of broken wires within one lay length), the cable must be replaced. Cable wear frequently occurs in concealed areas, such as inside fairlead holes passing through bulkheads or on the backside of pulleys, which are difficult to access through visual inspection alone. Therefore, auxiliary inspection tools, such as borescopes, are often required to ensure effective detection.

2.2 Corrosion

The Boeing 737NG operates globally in a wide range of climatic environments. Moisture, salt spray, and industrial pollutants are all factors that can induce cable corrosion. Although the cables are made of stainless steel, the passive oxide layer on the surface may be degraded during long-term service, particularly in the presence of crevices, water accumulation, or galvanic coupling with dissimilar metals. Corrosion causes the cable surface to become rough and may generate pitting, which similarly reduces its mechanical strength [3]. More critically, corrosion products (rust residues) increase the coefficient of friction between the cable and pulleys, leading to higher control forces and even control jamming. In extreme cases, severe stress corrosion cracking (SCC) may result in catastrophic failure without obvious prior warning. Early signs of corrosion are often difficult to detect and may be mistaken for ordinary contamination; therefore, thorough cleaning is required before an accurate assessment can be made.

2.3 Abnormal Cable Tension

Abnormal cable tension includes both excessive and insufficient tension. Insufficient tension is typically caused by loosened turnbuckles, structural deformation of the airframe, or temperature variations, whereas excessive tension may result from incorrect adjustment or system binding. Low tension can lead to slack and cable whipping during control operation, adversely affecting control precision and response time, and in severe cases may cause the cable to disengage from the pulley groove. Excessive tension, on the other hand, accelerates wear of both the cables and pulleys and imposes additional stress on associated structures, thereby reducing their service life. For the horizontal stabilizer trim system in particular, cable tension is a critical parameter that directly affects trim efficiency and accuracy. Cable tension is normally measured using a dedicated tensiometer and compared with the standard values specified in the AMM.

2.4 Failures of Pulleys and Guiding Devices

Pulley bearings may seize or rotate poorly due to inadequate lubrication, water ingress, or contamination by foreign matter. Guiding devices, such as fairleads, may fail to properly guide the cable as a result of improper installation or structural deformation. Pulley seizure directly increases resistance to cable movement, causing the pilot to perceive heavy control forces. Moreover, seizure points become localized sources of concentrated wear, significantly shortening cable service life. Failure of guiding devices may allow the cable to rub directly against sharp structural edges, resulting in rapid abrasion or severing.

2.5 Loosening of Fittings and Excessive Free Play

Cable terminal fittings, quadrant attachment bolts, bellcrank hinges, and other connection points may loosen or develop excessive clearances under long-term vibration and cyclic loading. Loosened fittings introduce additional backlash, causing nonlinear responses between control input and output. This degrades handling qualities, particularly during critical phases such as precision approaches. Excessive free play may also lead to localized stress concentration, accelerating component fatigue.

2.6 Improper Lubrication

Lubrication of the cable system is a critical maintenance task, but only approved aviation lubricants (such as Mobilgrease 32 or equivalent) may be used. The use of incorrect lubricants (e.g., general-purpose grease), as well as insufficient or excessive lubrication, can all lead to adverse effects [4]. Incompatible lubricants may chemically interact with cable coatings or sealing materials, resulting in material degradation. Insufficient lubrication accelerates wear, whereas excessive lubrication can attract dust and debris, forming an abrasive compound that further increases wear and may contaminate adjacent sensors or electrical equipment.

3. Optimization of Maintenance Strategies and Technological Outlook

3.1 Strengthening Preventive Maintenance

In response to the increasingly evident aging issues of the 737NG cable system, strengthening preventive maintenance remains the most practical and effective countermeasure at present. The primary requirement is to ensure that all maintenance activities strictly comply with the Boeing AMM and the job card procedures issued by the airline's engineering department, eliminating any form of simplification or omission. During every scheduled inspection, regardless of check level, inspection, cleaning, lubrication, and tension adjustment of the cable system should be regarded as non-negotiable core tasks. Furthermore, a detailed cable system service history should be established for each aircraft in the fleet. Each critical cable should be tracked individually, with records of inspection results, identified defects, corrective actions, and replacement history. This data-driven management approach facilitates the identification of common issues associated with specific aircraft or operating routes and provides an empirical basis for optimizing maintenance programs. Finally, an environment-adaptive maintenance strategy should be implemented. For aircraft operating in harsh conditions such as high humidity or high salinity, inspection intervals for cables in relevant areas should be proactively shortened, and enhanced anti-corrosion measures should be applied to mitigate risks in advance.

3.2 Exploring Predictive Maintenance

Building upon preventive maintenance, the transition toward predictive maintenance represents the future direction for improving maintenance efficiency and safety margins. This shift requires moving beyond traditional visual inspections and actively introducing advanced non-destructive testing (NDT) techniques. For instance, magnetic particle testing (MT) and eddy current testing (ET) can penetrate beneath the cable surface to detect internal broken wires, microcracks, and corrosion damage, enabling identification of defects at an incipient stage. In the long term, with advances in the Internet of Things (IoT) and miniaturized sensor technologies, it is feasible to consider integrating distributed sensor networks along critical cable routing paths. Such systems could enable real-time monitoring of key health indicators, including cable tension, strain, vibration frequency, and temperature. By correlating real-time data with historical records and theoretical models, and leveraging big data analytics and artificial intelligence algorithms, an intelligent health management system could be established. This would allow accurate prediction of the remaining useful life of the cable system and early warning of potential failures, ultimately transforming maintenance from a reactive approach into proactive health management.

3.3 Enhancing Personnel Skills and Safety Awareness

Regardless of how advanced the technologies and strategies may be, their effective implementation ultimately depends on human execution. Therefore, improving the professional competence and safety awareness of maintenance personnel is fundamental to ensuring the quality of cable system maintenance. Airlines should regularly organize specialized training programs focused on flight control cable systems. Such training should not only cover system architecture, operating principles, and standard procedures specified in the AMM, but also provide in-depth explanations of typical failure mechanisms, techniques for identifying concealed defects, and methods for preventing common human errors. At the same time, case-based safety education should be institutionalized. By analyzing domestic and international incidents caused by negligence in cable maintenance, maintenance personnel can gain a profound understanding of the critical responsibility inherent in their work and firmly establish a professional ethos characterized by reverence for life, adherence to regulations, and respect for professional duties. In addition, promoting the use of illustrated standardized work instructions and electronic inspection checklists can effectively reduce operational errors caused by memory lapses or overreliance on experience, thereby ensuring the standardization and consistency of maintenance activities.

Conclusion

Although the flight control cable system of the Boeing 737NG is technically mature, its maintenance is of vital importance. This paper has identified six major categories of common issues encountered in the maintenance of this system, analyzed their causes, manifestations, and potential risks, and pointed out that these problems largely stem from environmental factors, wear, maintenance omissions, and human-related factors. To address these challenges, aviation maintenance organizations must move beyond traditional mindsets and establish an integrated framework that combines preventive maintenance, predictive maintenance, and personnel capability development. By strictly adhering to maintenance manuals, utilizing advanced inspection technologies, establishing data-driven decision-making mechanisms, and enhancing the overall quality of maintenance teams, failure rates can be reduced and safe, reliable fleet operations can be ensured. With the ongoing advancement of intelligence and digitalization in the aviation industry, new opportunities are emerging for the health management of traditional mechanical systems. Integrating technologies such as the Internet of Things and artificial intelligence into cable system maintenance processes represents a promising direction for future research and practical application.

References

[1] Yang Yi. Key Points in the Maintenance of Flight Control Cables on Boeing 737NG Aircraft [J]. Journal of Civil Aviation, 2018, 2(05): 104–105.

[2] Zhang Yuqing. Failure Analysis of a Rudder Control Cable Fracture Incident [J]. Journal of Civil Aviation, 2024, 8(02): 122–125+113.

[3] Yi Siyun, Yang Zhaojun. Analysis of Typical Failures in CESSNA 172 Aircraft [J]. Journal of Civil Aviation, 2025, 9(01): 107–110+150.

[4] Li Chaoyong, Lu Haowei, Zeng Yan. An Analysis of Common Failures and Maintenance Strategies of Aircraft Hydraulic Systems [J]. Mechanical Industry Standardization & Quality, 2023, (11): 43–46.