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Fatigue strength and weight optimization of threaded connections in tie-rods for aircraft structures

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Abstract

Tie-rods are connecting elements used in an aircraft and they basically consist of a straight tube and two screwed in adapter ends. In order to optimize the tie-rod in terms of weight reduction a detailed knowledge of its fatigue strength is important. However, the complex load and contact distribution within the threaded connection between tube and adapter end make a secure and efficient fatigue design challenging. Moreover, the connection is realized with a thread insert to assure smooth adjustability of the adapter ends, which further increases the complexity of a fatigue strength assessment.

Thus, cyclic fatigue tests with a load ratio of $R = 0.01$ are performed to investigate the influences of thread insert length and position on the fatigue life of three different configurations. The experimental results are explained by Finite Element analyses using a detailed Finite Element model of the threaded connection. Finally microscopic examinations as well as the Finite Element analyses are utilized to further optimize the threaded connection in terms of reduced weight and high fatigue strength.

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Keywords: Tie-rod; aircraft; threaded connection; thread insert; cyclic fatigue test; Finite Element simulation

1. Introduction

Tie-rods are commonly used connecting elements in an aircraft and attach, e.g., galleys, lavatories or storage bins to the fuselage structure. The specific design of tie-rods varies depending on the installation purpose and manufacturer. In this paper the threaded connection of interior tie-rods from RO-RA Aviation Systems is investigated. Fig. 1 shows a schematic sketch of such tie-rods with a straight tube and two adapter ends, which are screwed into the tube in order to adjust the length of the complete assembly. The threaded connection between the tube and the adapter end consists of two parts: a threaded sleeve and a screw insert in order to maintain a smooth-running connection to the adapter end. The sleeve is firmly attached to the tube. Such tie-rods are subjected to tension and compression loads with variable amplitude and must meet the high requirements of the aeronautic industry. Structural components in aircrafts in general have to be designed for a certain service life and therefore a detailed knowledge of their fatigue behavior is of great importance [1]. Furthermore, tie-rods have to meet weight requirements because of their large number in an aircraft. Previous fatigue tests carried out in the test facilities of the Institute of Structural Lightweight

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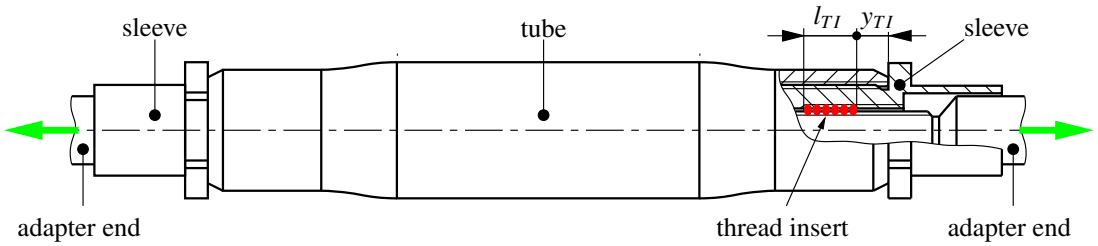

Fig. 1. Sketch of considered tie-rod to test influence of thread insert length and position on the fatigue life (not to scale)

Design have shown that the threaded connection between tube and adapter end is a critical failure location. Therefore, we performed detailed investigations in order to optimize the threaded connection in terms of both, increased fatigue strength and reduced weight.

Numerous influences on the fatigue life of threaded connections have already been investigated [2–4], considering the threaded connection as a standard bolt and nut. They also include conclusions regarding general threads but for the estimation of the fatigue life of threaded connections including thread inserts no explicit information was found in literature.

An analytical approach to calculate the fatigue strength based on nominal or local stresses is presented by the FKM guideline [5]. For threaded connections the FKM guideline refers to existing guidelines such as the VDI guideline 2230 [6], which is only valid for fastening threads. Therefore, both guidelines [5, 6] are also not applicable for the threaded connection given in tie-rods. Another approach is to apply the local concept in combination with Finite Element simulations to estimate the fatigue life of threaded connections [3, 7, 13]. Material properties such as the cyclic stress-strain curve and the strain life curve are inevitable input parameters for the local concept [4]. For the given tie-rod components these detailed material informations were not available to the authors. Additionally, the situation of two threads (one between tube and sleeve and the other between sleeve and adapter end) in close vicinity and their possible interdependence make a secure and accurate fatigue life estimation challenging.

Therefore, the influence of thread insert length l_{TI} and position y_{TI} (see Fig. 1) on the fatigue life is investigated experimentally by cyclic fatigue tests. Three considered configurations are listed in Table 1. Subsequently, the samples of the fatigue tests are analyzed by microscopic examinations of the crack location. Results of the fatigue tests were also compared to Finite Element simulations of the threaded connection.

Table 1. Three configurations to investigate the influence of the thread insert length and position.

	l_{TI} in mm	y_{TI} in mm
Configuration 1 (cfg1)	15	1
Configuration 2 (cfg2)	10	1
Configuration 3 (cfg3)	10	6