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Effect of riveting process parameters on the local stress field of a T-joint

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ABSTRACT

Rotorcraft airframes are complex structures designed to satisfy different goals; fatigue life represents one of the most critical issues, which must be guaranteed throughout the design and the construction phase. In this scenario riveted joints play an important structural role especially because of the variable loads they are subjected to. Their fatigue behaviour is strictly influenced by the local stress fields left very near to the holes during riveting manufacturing operations. Therefore, with the aim to improve design awareness, the effects of the different parameters involved during the riveting process are herein investigated. The effects of the squeeze force, the clearance, the rivet length and the clamping angle in the stress field of the joints are considered by means of numerical models. Detailed finite elements models (including rivet forming formation) are validated through experimental tests. These models are aimed at obtaining an accurate stress–strain field in the most stressed zone including the residual stress in the holes. Finally, using the literature fatigue data of Al8090-T81 and the Crossland multiaxial fatigue criterion, the influence of the riveting parameters on the fatigue strength is evaluated for optimisation purposes.

1. Introduction

The whole rotorcraft frame is composed of many parts, which are obtained by different technological processes: Extruded, laminated and hydroformed sections, tubes, sheets, forged and machinated components. These components are jointed together in subsystems. They are subsequently connected to form large assemblies and are, finally, turned into a complete rotorcraft structure. For example, in a classical helicopter frame there are three main subassemblies: cockpit, cabin and rear tail. In the classical metallic design, these parts are arranged in order to be disassembled for repair or replacement. To facilitate the assembly and disassembly operations, bolts or rivets are mainly used in the joints.

From a structural point of view, rivets and bolts transfer the flight loads among the components: Their critical role requires particular attention in the design phase. In fact, joints are perhaps the most common source of failure in aircraft structures and it is, therefore, important that all the design aspects are taken into account during the structural analysis. Failures may occur for different reasons (manufacturing issues, fatigue, fretting due to slippage, stress corrosion, etc.) involving not only the static strength but also the fatigue life. As far as the peculiarity of the rivets in relation to the bolts is concerned, they are permanent fasteners characterised by a low cost and a low assembly time but also by a lower strength.

The maximum static strength submitted on the rivets and on the hole (bearing loads) is the guiding criteria during the fastener design process. The detailed procedure is presented in the military handbook MIL-HDBK-5 J [1]. However, since fatigue loads are the most common cause of failure, fatigue tolerance evaluation is ruled and highlighted by the Certification Specification for Large Rotorcraft CS-29 [2]. Paragraph 571, CS-29 shows three fatigue methods that must be used to design fatigue critical components: safe-life, flow tolerance and fail-safe. The rivets are designed using classical safe-life methodology, notwithstanding, the joints, on which they are used, can be also designed using the fail-safe or flow tolerance approach [3]. In fact, the major failure mode of a joint is not rivet failure but is related to fatigue cracks, which nucleate in the rivet holes and which propagates over the component. Therefore, considerable research efforts have been made to study this phenomenon shared by all kinds of joints that contain a hole. Accordingly, the main aim of this work is to analyse the effect that variations in the riveting process parameters have on the local stress filed in the holes of a T-cleat joint used in rotorcraft frames and to then finally relate these values to the fatigue life of the joint.

A brief literature review of the principal factors expected to be involved and to have a significant influence on the fatigue analysis and fatigue life of rotorcraft riveted joints is reported in Section 2.

In order to carry out an accurate simulation of the local stress field in the holes of the joint, a detailed simulation of the components and of their complete manufacturing process is fundamental; this information is obtained with a detailed 3D non-linear finite element (FE) model of the joint, reproduced in full detail and including the riveting process, reported in Section 3.

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