



Failure analysis of bolted joints: Effect of friction coefficients in torque–preloading relationship

D. Croccolo*, M. De Agostinis, N. Vincenzi

DIEM, University of Bologna, Viale Risorgimento, 2, 40136 Bologna, Italy

ARTICLE INFO

Article history:

Received 14 June 2010

Received in revised form 16 September 2010

Accepted 17 September 2010

Available online 29 September 2010

Keywords:

Tightening test

Friction coefficient

Bolted connections

Preloading force

ABSTRACT

The aim of this study is to provide an experimental methodology useful to determine the friction coefficients in bolted joints and, therefore, to relate precisely the tightening torque to the preloading force. The components under investigation are clamped joints made of aluminium alloy and used in front motorbike suspensions to connect steering plates and legs, or legs and the wheel pin: static failures of clamps occurred during the tightening, because of the bending stress introduced by the preloading forces. Some specific specimens have been appropriately designed and realised with the same process of the actual components. The bolt torque is given by a torque wrench whereas the preloading force has been evaluated by means of a strain gauge. The overall friction coefficient and the torque coefficient (nut factor) have been calculated. Experimental tests have been carried out by applying the Design of Experiment method in order to obtain an accurate mathematical model that involves the significant friction variables and their interactions. Then, results of present study have been applied to actual components: the tightening torque has been precisely related to the preloading force by means of the friction coefficients definition and the tensile state of clamps have been evaluated both experimentally (strain gauges) and numerically (FEA) in order to shed light on the failures which occurred during the tightening.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Threaded fasteners are widely used in mechanical and structural applications because of their easiness to assemble and disassemble for maintenance and repair purposes. Both the level and the stability of the clamp loads, which are created by the tightening process, will govern the safety and reliability of bolted joints. In most of production applications, the fastener tension (preloading force) is achieved by using a torque wrench applied to the head or to the nut. The tribological aspects of the tightening phase are critical to define the actual torque–tension relationship [1,2]. The tightening torque is mostly consumed during the process of overcoming two friction components: the underhead (or bearing) friction due to the sliding of the fastener head on the flanges and the thread friction between the male and female thread. The residual torque component produces the fastener tension by generating the joint clamping force. Inaccuracies in determining the friction components may lead to an overestimation or underestimation of the bolted joint performances. The torque–preloading relationship is often simplified by using a constant K (Eq. (1)), known as torque coefficient (or nut factor): some authors and Standards [3–5] provide an approximate value of 0.20 for the nut factor, but warnings against using it for critical joints should be

Abbreviations: DOE, Design of Experiment; FEM, finite elements method; ANOVA, Analysis of Variance; F -tests, Fisher's tests.

* Corresponding author. Tel./fax: +39 0512093413.

E-mail address: dario.croccolo@unibo.it (D. Croccolo).