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Characterisation of the sliding friction response of peel-ply textured surfaces

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Abstract

The present paper reports on effects of texture, contamination by aircraft operating fluids, and contact pressure on the sliding friction response of polymer surfaces. This study provides essential data necessary for the design of friction-based energy absorption devices. Their functionality is ought to integrate into structural elements of aircraft fuselages made from carbon fibre reinforced plastics. The paper specifically addresses epoxy resin surfaces of continuous fibre reinforced composite material currently applied in aircraft industry. Peel-ply was utilised to achieve the characteristic surface texture. A pin-on-flat type test apparatus was designed and used to determine the friction coefficient as a function of the initial surface texture, the contamination by five different aircraft operating fluids, as well as the contact pressure. The sliding friction results obtained in this study indicate a significant influence of both, the surface texture and the state of contamination.

Keywords: Sliding friction, B. Physical properties, D. Physical methods of analysis, A. Prepreg

1. Introduction

Research and technology projects on aircraft fuselage pursue the application of lightweight materials to achieve improved structural efficiency. Especially thermoset carbon fibre reinforced plastics (CFRPs) comply with the designer's need for excellent specific material properties. Structural designs applying such composite materials need to satisfy the authorities airworthiness code for an 'equivalent level of safety' [1] compared to current metallic fuselage designs.

Due to plastic deformation capacity of state-of-the-art metallic fuselage designs, those certification requirements are achieved almost naturally by the design's intrinsic energy absorption capabilities. In contrast to metallic materials, thermoset CFRPs exhibit brittle fracture behaviour when loaded beyond their elastic limits. Thus, energy absorption by large deformation of structural elements is unsatisfactory limited. A current countermeasure is to attach energy absorption elements to the structural elements. Since the attached elements only act in crash landing scenarios, they are considered dead weight in standard aircraft operation scenarios. Thus, they negatively affect the mass balance. However, integrating the energy absorption functionality into the structural elements appears beneficial with respect to the mass balance. When considering CFRPs, energy absorption principles such as fibre breakage, matrix cracking, and friction are utilisable.

In most engineering applications, sliding friction is subject to minimisation as it causes energy loss and material loss [2] in mechanical devices such as bearings or bushings. In contrast, the purpose of energy absorption devices is to transform a maximum of kinetic energy into some other kind of energy e.g. friction energy. Where friction energy (E_F) is the amount of dissipated energy, removed from the work put into a device by the frictional force (F_F) acting along a sliding distance (S). This relation can be expressed with equation 1. In order to estimate the amount of kinetic energy transformed into friction energy, the sliding friction response needs to be characterised with respect to the static and the kinetic coefficients of friction.

$$E_F = F_F \cdot S \tag{1}$$

When composite materials are investigated in friction applications, they are commonly paired with metallic surfaces [3]. Therein, the possibility to tailor the composite properties using special fillers with different volume fraction, shape, and size is of special interest [4].

With respect to literature about metal-on-metal friction as well as metal-on-polymer friction, limited data is available about polymer-on-polymer friction, especially for thermoset polymers. Bartenev and Lavrentev [5] present data showing the friction coefficient of a polymer-on-polymer pair being higher than for friction on metallic surfaces. It was found that for rigid polymers, the friction coefficient depends upon the nature of the rigid surface.

Myshkin et al. [6] extensively discuss effects immanent to polymer-on-polymer friction. Therein, polymer properties are reviewed with respect to their application as tribological materials.

Currently, one publication is known covering textured epoxy resin surface in a tribological investigation. Schn [7] has explored reciprocal sliding for composite on composite contact in order to model bolted joints and predict the corresponding failure load. The initial coefficient of friction recorded was 0.65 and 0.74 after wear in.

However, integrating energy absorption attributes based on sliding friction into CFRP aircraft fuselage structural elements

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