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Application of material analysis and eddy current conductivity tests to aircraft accident investigation

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ABSTRACT

Material analysis, such as detection of causes of premature failure, is an integral procedure in solving both manufacturing and in-service problems. The case study presented in this paper describes the material analysis performed in the investigation of the Blaník L13 glider catastrophic accident caused by premature failure of the bottom flange of the right wing spar, which is made of Z 42 4203.62 aluminium alloy (equivalent to AW2024-T3 alloy). Characterization techniques including metallography, light microscopy, optical emission spectroscopy, hardness measurements, tensile testing, and electrical conductivity measurement were used to verify the basic material properties of the damaged flange.

Each critical part of an aircraft can be constructed from a specific aluminium alloy whose properties are based on its composition and heat treatment. These properties include electrical conductivity, which is determined by the alloy content and prior processing. An eddy current conductivity test thus allows alloys to be sorted based on the changes in their material properties resulting from different thermal processing. The analysis results of the damaged L13 glider flange were compared with the minimum specified values of mechanical and material properties of other flanges from retired L13 gliders. Different values were obtained for the electrical conductivity and material hardness, indicating that the possible cause of the flange's premature failure could be an imperfect material heat treatment, or material degradation.

1. Introduction

AnL13 Blaník is a two-seated trainer glider designed by Karel Dlouhý of VZLU, a Czech Company, in the 1950s [1]. Produced by Let Kunovice since 1956, it is the most numerous and widely used glider in the world, especially for continued pilot training and cross-country and acrobatics training.

The L13 glider was involved in a fatal accident in Austria on 12 June 2010 when a wing spar failed during flight, resulting in separation of the wing and loss of control of the aircraft [1]. Photographs of the failed flange are shown in Fig. 1.

Failure analysis is a multidisciplinary process for determining possible causes of problems under investigation. Collaboration among experts in various disciplines is required in some cases to integrate the analysis of evidence with quantitative

Abbreviations: HV2/14s, Vickers hardness by 2 kg for 14 s; IACS, International Annealed Copper Standard; NDI, non-destructive inspection; VZLU, Aerospace Research and Test Establishment.

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understanding of the causes of stress and background information on the design, manufacturing, and service history of the failed product or system [2].

The failure of the bottom flange of the L13 glider's right wing spar was found during the accident investigation. The detailed fractographic analysis mentioned in [3] confirmed that fatigue failure (the fracture surface is shown in Fig. 2) occurred. Hence, a preliminary assumption was that the fatal accident was caused by premature fatigue failure of the bottom flange of the right wing spar.

This article describes a subsequent phase of the accident investigation, which focused particularly on analysis of material characteristics of the bottom right wing flange of the glider wreckage by means of light microscopy, optical emission spectroscopy, hardness measurements, tensile testing, and electrical conductivity measurement.

The eddy current in the conductivity tests was measured and later used to verify the material characteristics. As a metal's electrical conductivity depends on factors such as chemical composition and the stress state of its crystalline structure, electrical conductivity data can be used to sort materials, monitor heat treatment of a metal, and inspect for heat damage in metallic structures [4].

The goal of this part of the investigation was to examine and verify the basic material properties of the fractured flange, with particular emphasis on material temper and mechanical properties.

2. Description of the critical area

The fatigue failure discovered in the glider wing was located in the main bottom right wing-spar flange in the area of the steel attachment fitting between wing and the fuselage, as marked in Figs. 3 and 4. Careful non-destructive inspection (NDI) of critical parts during service ensures safe and reliable aircraft operation. Considering the flange's position, early detection of the fatigue crack during NDI would have been very complicated [5].

Details of the flange's critical area are shown in Fig. 4. The fatigue crack occurred under the rivet head in the aluminium alloy spar flange in the thinnest cross-section of the steel fitting. The entire area was hidden under two layers of aluminium alloy sheets [5].

3. Material and experimental methods

The bottom wing-spar flange examined in this study was made of Z 42 4203.62 aluminium alloy (AlCu4Mg1, equivalent to AW2024-T3 alloy), and its cross section had an extruded L-shape. The nominal chemical composition of this alloy, listed in Table 1, was estimated based on the composition of the standard ONZ 42 4203 [6] aluminium alloy (AlCu4Mg1). The heat treatment designated as T3 for aluminium tempering consists of solution annealing (usually at 495 °C), water quenching (at 25–35 °C), cold working, and then natural aging (usually 4 days).

First, the flange samples for chemical and metallographic analyses were cut from the wing-spar wreckage near the fatigue failure area (Fig. 5a). After the hardness measurements were obtained, samples for tensile tests were taken from the remaining bottom right wing-spar flange (Fig. 5b). Finally, all results of the analyses were compared with those of other flanges made of the same aluminium alloy with the same temper designation (hereafter referred to as control flanges).

The chemical composition of the bottom wing-spar flange was determined using optical emission spectroscopy (OES) (spectrometer BAIRD Foundrymate) to verify that the material conformed to the industry standard. Three measurements were made on the slightly brushed surfaces of the wreckage sample and the control sample.

Traditional metallographic methods and light microscopy (inverted metallurgical microscope Olympus GX51, Olympus, reflected light method) were used to assess the microstructural quality of the metal alloy and for comparison with the

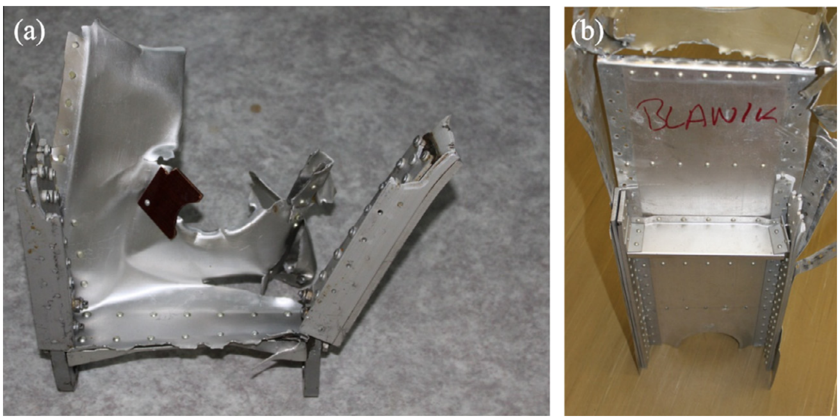

Fig. 1. (a and b) Photographs of the failed flange.