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DEVELOPMENT OF THE DAMAGE TOLERANCE CRITERIA FOR AN AGING FLEET

Alberto Monsalve
UNIV OF SANTIAGO

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Air Force Research Laboratory
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ALBERTO MONSALVE

NICOLAS VALENCIA

ALFREDO ARTIGAS

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
UNIVERSIDAD DE SANTIAGO DE CHILE,

AV. L. B. OHIGGINS 3363,
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AFOSR/SOARD
875 N Randolph St
Ste 325 Rm 3112
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14. ABSTRACT

In order to enhance the strategy for resolve the problem of the ageing fleet, it is necessary to plan this strategy using the tools of fracture mechanics and fatigue crack propagation. In this work, the measure of the fatigue life of four different aeronautic pieces is proposed. As well, a static numerical model is applied in order to analyze the points of maximum stress and maximum strain, in each sample. From this, samples will be cracked in a fatigue testing machine, measuring the crack growth rate. A composite based repair will be proposed in order to decrease the crack growth rate, computing the increase in the fatigue life due to repair. This repair will be applied by means of a structural adhesive using the appropriate conditions to cure the system constituted by the resin and the hardener. Standard methods to fabricate the repairs will be used, in accordance with ASTM and other codes. A numerical model will be applied in order to predict the fatigue life in the case of repaired samples, calibrating the model if it is necessary. Commercial software will be used for static and dynamic modelling.

The results of this work will be published in international congress of fracture mechanics or fatigue and will be published in ISI publications.

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Development of the damage tolerance criteria for an ageing fleet.

Principal Researcher	Alberto Monsalve G. Universidad de Santiago de Chile
Co researcher	Nicolás Valencia R. Academia Politécnica Aeronáutica
	Alfredo Artigas A. Universidad de Santiago de Chile

Summary

The fatigue life of different composite materials based on aluminium and glass fiber was studied. These materials were doped with different proportions of multi walled carbon nanotubes (MWNT), which are added to the epoxy resin used to fabricate the composite materials. Also, the corrosion behaviour of these materials were investigated, by means of a saline chamber in accordance with ASTM B117 standard, in order to simulate the service conditions of these materials, taking into account that they are used in aeronautical applications. The results show that it is possible to increase the fatigue life of aluminium alloys (2024 T3) repaired with composite materials doped with MWNT. Also, it is possible to detect corrosion effects due to galvanic effects between MWNT and aluminium alloys.

Motivation

Currently it's possible and it's not uncommon to find in various military and civilian operators, aging aircraft fleets carrying at least 30 or more years of service and operation. Moreover, these aircraft are reaching their limits provided by the structural design, represented by the number of flight hours identified in its design or the change in the severity of the aircraft usage. This raises and generates a phenomena in which, due to the presence of fluctuating loads, progressive and permanent change occurs in the mechanical properties of the material. This phenomena, called fatigue, begins with microstructural changes located in minor flaws, and due to the several loading cycles, it propagates, reaching the unstability and fracture. The present research evaluates the influence of a carbon nanotube reinforced polymer bonded repair as a possible solution to decrease the crack growth rate in Al 2024-T3 alloy.

Objectives

General Goal

To study the fatigue life of aluminium alloys used in aeronautics and to investigate how to increase the fatigue life applying patches of composite materials.

Specific goals

1) To study the effect of MWNT additions in the resin, in fatigue life of aluminium alloys repaired with theses composite materials.
2) To study the corrosion behaviour of the system: MWNT + epoxy resin + aluminium alloys.

Main results

Fatigue testing with 0.5 stress ratio and in 5 different load levels were carried out to four test specimens groups, which consisted in an un-repaired group as a reference, a stop-drilled group that would serve as a conventional repair, and two groups with bonded repairs; with 0.5%vol. MWNT and 1%vol. MWNT.

The results were presented in S-N diagrams (in this study, load versus number of cycles in a logarithmic scale), resulting in a fatigue life average enhancement of 163% for the 0.5%vol. MWNT patch, 200% for the 1%vol. MWNT patch and 400% for the stop-drill repair.

The best electrochemical behavior is Al 2024-T3 0% MWCNT, it presents a corrosion rate of 2.19[mpy] and a polarization resistance of 5170 [$k\Omega \cdot m^2$]. For the electrochemical test the Al 2024-T3 1% MWCNT shows a better Polarization Resistance and a lower corrosion rate than the Al 2024-T3 CAA (Chromic Acid Anodizing).

Conclusions

The main conclusion of this project is:

It is possible to increase the fatigue life of a composite material by means of carbon nanotubes which are included in the epoxy resin. These doped resin is used to repair cracked fatigue samples of 2024 T3 aluminium alloys, increasing the fatigue life of these samples.

Suggestions for future work

The main suggestions for future work are

a) To study the influence of carbon nanotubes in other composite materials, such as ARALL.
b) To study other compositions of MWNT in the mechanical behaviour of composite materials.
c) To investigate the corrosion resistance of different composite materials doped with MWNT.
d) To study the ultraviolet degradation of different composite materials doped with MWNT.
e) To study the addition of other new materials such graphene to increase the mechanical strength of epoxy resins which are used in aeronautical applications.