Samih kahtan Jawad Al najjar. Fatigue Cumulative Damage and Life Estimation of Metal Matrix Composite Material Under Low Temperatures Conditions. University of Technology Mechanical Engineering Department. Ph.D. Supervisors: Dr. Hussain J. Al-Alkawi, Dr. Dhafir S. Al-Fattal. 2015. 136*p*.

ABSTRACT

Carbon fibers have been considered as so important reinforcements for aluminum alloys in manufacturing advanced composite materials. Composite materials have been used in automobile, ships aircraft, sports goods and so on. This thesis is concerned with the study of fatigue test behavior of carbon fiber reinforced aluminum (CFRA) composite material with constant volume fraction (V_f = 60%). Three samples of different laminate arrangements and orientations were employed, namely S_1 and S_2, which included both woven and unidirection carbon fibers, and S_3, which contained only unidirection carbon fibers. While, (3003) Aluminum alloy was employed as the matrix material. The tensile and fatigue tests were carried out at room temperature (RT), 0 °C, -15 °C and -30 °C using an environmental test chamber. . Experimental tests were carried out either at longitudinal (0°) or transverse (90°) directions of composite specimens.

The results of tensile tests indicated that low temperatures have a significant effect on the mechanical properties, i.e., tensile and modulus. It was found that the ultimate tensile strength for sample S_1 reduced as the temperature decreased for both directions, while S_2 didn't effect by low temperatures in transverse direction but the strength was reduced at -30 °C by 10% compared to RT in longitudinal direction. It was also observed that for S_3, the ultimate tensile strength was reduced at -30 °C for both directions. The modulus of elasticity of the three samples was increased as the temperature reduced.

Fatigue test was performed under constant and variable amplitude bending stress at stress ratio (R = -1). The fatigue behaviour under constant amplitude stresses was studied. The ultimate strength was found to vary in a proportional manner with the fatigue endurance limit at low temperatures. It was found that for the S_1, the fatigue strength (fatigue endurance limit at 10^7 cycles) of -15 °C has increased by (25.5%) in transverse direction while (1.8%) in longitudinal direction as compared to RT. In sample S_2, fatigue strength value at -15°C was lower than the other low temperatures in transverse direction, but in longitudinal direction a reduction was observed by -9.6% with respect to RT. In sample S_3 , an increment in fatigue strength was about (28%) for both directions as compared to RT.

Fatigue test at variable amplitude loading was carried out at RT, -15 °C and -30 °C to obtain the effect of low temperature on the fatigue damage behavior.

A proposed cumulative non-linear damage model was presented. This model included the effect of loading sequences and working conditions. A comparison between the proposed model and the experimental data was carried out. Satisfactory predictions have been obtained from applying the proposed model developed in this work. A finite element model was used to simulate the experimental results of constant amplitude

fatigue test. ANSYS program version 11 was used to simulate the applied stress, life and deformation (deflection), and a good agreement between the experimental data and numerical analysis was obtained.
Keywords: Carbon fiber. Fatigue. Cumulative damage.