Abdul-Jabar H. Ali "A non-linear Damage Model for Fatigue Life Prediction of Fiber Reinforced Polymer Composite Lamina at Different Temperatures" University of Technology/ Mechanical Engineering Department. PH.D. Supervisor: Prof. Dr. Hussain J. Al-Alkawi and Asst. Prof. Dr. Dhafir S. Al-Fattal .2013.129p.

Abstract

A study of fatigue under constant and variable amplitude bending stress programs has been conducted on a composite material at a stress ratio (R=-1) at room temperature (RT) (30^{o}C), different temperatures 40, 50 and 60^{o}C and sequence temperatures. In this work the composite material is manufactured from polyester reinforced by E-glass fiber ((woven roving, chopped strand mat (CSM)) with different configurations of laminates $[0/90]_3$, $[CSM]_{3,}$ [0/90, ±45, 0/90], [0/90, CSM, 0/90] and [CSM, 0/90, CSM] at a constant fiber volume fraction (V_F) of about 33%.

Four groups of tests have been designed. The first group (63 specimens) was tested under tension at different temperatures ((RT) 30, 40, 50, 60^{o}C)). The second group (55 specimens) was tested under fatigue under constant stress amplitude loading to establish the S-N curve in laboratory condition (RT) 30^{o}C, while the third group (64 specimens) was tested to establish the S-N curve under different temperatures (40, 50 and 60^{o}C). The fourth group (20 specimens) was tested under fatigue at different sequence temperatures such as; ((RT) 30-50^{o}C)), ((RT) 30-60^{o}C)), (40-60^{o}C) and ((RT) 30-40-50-60-50-40^{O}C)).

The results show a little effect of temperature on tensile strength in the range of room temperature (RT) 30^{o}C to 50^{o}C for laminates reinforced with E-glass (woven roving) as [0/90, ±45,0/90], $[0/90]_3$, and [0/90, CSM, 0/90], but for laminates reinforced with E-glass chopped strand mat as $[CSM]_3$ and [CSM, 0/90, CSM], a continuous reduction in strength was observed

with increasing temperature from (RT) 30^{o}C to 60^{o}C. The highest percentage reduction in tensile strength was 23.6% at 60^{o}C for $[CSM]_3$ laminate as compared with (RT) 30^{o}C.

The results also show that the type of the fiber glass mat has strong effect on the tensile strength and on the fatigue strength at 10^6 cycles. The highest tensile strength and fatigue strength was for $[0/90]_3$ laminate compared to other laminates used in this work. The results indicate that the fatigue strength decreases with increasing temperature. The fatigue strength reduction factor (FSRF) for $[0/90]_3$ laminate at 60^{o}C was (46.7%) compared to its fatigue strength at (RT) 30^{o}C. For $[CSM]_3$ laminate at 60^{o}C, the fatigue strength reduction factor was (32%) compared to its fatigue strength at (RT) 30^{o}C.

A new proposed non-linear fatigue damage model has been established to enable the computation of fatigue damage under sequence temperature. Only fatigue tests under constant amplitude loading at constant temperature are needed to predict the fatigue life under sequence temperature. The proposed damage model for the present work is safer than Palmgren-Miner`s rule for all the tests carried out in this investigation since it takes into consideration the sequence effect, where it is a function of the tensile strength, the stress amplitude at the testing environment and the slope of S-N curve at a constant temperature under constant amplitude loading. Also, the model is a function of the number of temperature levels in each step block in program and the temperature at each level.

The results also show, for a safety design life of 10^6 cycles, the unsaturated polyester resin reinforced by E-glass fiber mat with fiber volume fraction of about 33% can be used under cyclic loading at 49% and 27.7% of

their ultimate tensile strength for laminate $[CSM]_3$ and laminate $[0/90]_3$ respectively at different temperatures in the range((RT)30-60^{o}C)).

Keywords: A non-linear Damage Model, Fatigue Life Prediction, Polymer Composite, Temperatures.