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Mechanical Properties of Carbon Composites Reinforced Aluminium

Ali Anvari

University of Missouri-Columbia, USA

The main purpose of this research is to investigate and analysis the effect of temperature on the mechanical properties of carbon composites, Aluminum foam, and carbon nanotube reinforced Aluminum foam. For this analysis, fatigue behavior of Aluminum foam has been discussed, and inter-laminar shear stress between single-walled carbon nanotube reinforced aluminum foam and multi-walled carbon nanotube reinforced aluminum foam has been compared.

Application of carbon composites, particularly Carbon Nano-tube composites is broad in many industries. Carbon Nano-tube has superior mechanical properties when compared to carbon fiber due to its higher strength and Young's modulus. Carbon nanotubes have been introduced by Lijima in 1991 for the first time. Due to the excellent properties of Carbon Nano-tubes, nowadays its application is broad in many industries such as aerospace and automotive industries. Carbon nanotubes have great mechanical properties such as high tensile strength, high Young's modulus and high aspect ratio which makes Carbon Nano-tube one of the best martials for different applications. Furthermore, the electrical conductivity of Carbon Nano-tube is high. Hence, recently, for enhancing the knowledge regarding the Carbon Nano-tubes, a few studies to further analyze the mechanics and forest synthesis of Carbon Nano-tube have been published.

Carbon Nano-tubes are the crystalline shape of carbon. They have high aspect ratio due to the size of dimeter which is a few nanometers and the size of length of it which is typically about a few microns. Furthermore, they offer high flexibility and high thermal conductivity. Carbon Nano-tubes can be in the forms of Multi-Walled Carbon Nanotubes and Single-Walled Carbon Nanotubes.

In this research, ranking of the unidirectional fibers/matrix composites based on the value of inter-laminar shear stress existing between fibers and matrix due to thermal stress cycles have been determined. Thermal stress induced in composites is one of the main issues in many applications such as space structures. In this section, by applying an analytical method, it is attempted to estimate the ranking of unidirectional fibers/matrix composites exposed to thermal stress. The application of the results of this research is very broad. These results could be very advantageous in any industry using unidirectional fibers/matrix composites exposed to thermal stress such as aerospace automotive, etc.

In this study, Inter-laminar shear stress within the interfaces between the fibers and matrix, by using experimental data and applying analytical method, between Single-Walled Carbon Nano-tube reinforced Aluminum foam and Multi-Walled Carbon Nano-tube reinforced Aluminum foam is compared. In order to compare the inter-laminar shear stress of these two Nano-composites, the following procedure has been followed. The mismatch of coefficients of thermal expansion between fibers and matrix in both Nano-composites is compared. According to the results obtained, it appears that Multi-Walled Carbon Nano-tube reinforced Aluminum foam can offer lower inter-laminar shear stress when compared to Single-Walled Carbon Nano-tube reinforced Aluminum foam. The reason is, based on the evidence achieved by the mentioned analytical method, Single-Walled Carbon Nano-tube reinforced Aluminum foam, in average, offers higher mismatch between coefficients of thermal expansion and inter-laminar shear stress within the fibers and matrix interfaces. Thus, further stress concentration in these areas may result in higher crack propagation rate that can cause fracture.

Furthermore, a method to compare the thermal fatigue resistance of unidirectional Single Walled Carbon Nano-tube reinforced Aluminum foam with unidirectional Single-Walled Carbon Nano-tube reinforced epoxy has been introduced. The reason is that the application of Single-Walled Carbon Nano-tube reinforced epoxy is nowadays very common in many industries such as aerospace and automobile applications due its lightweight and high strength. In this part of the study, by using analytical method, the inter-laminar shear stress on interfaces of fibers/matrix in both Nano-composites are derived and compared. With the analysis of these results, it is determined that the risk of crack initiation and propagation due to stress concentration on interfaces of fibers/matrix, is higher within the Single-Walled Carbon Nano-tube reinforced epoxy in comparison of that within the Single-Walled Carbon Nano-tube reinforced Aluminum foam. Thus, thermal fatigue resistance of these two Nano-composites could be compared with this analysis. The results have shown that the thermal fatigue life could be enhanced by application of unidirectional Single-Walled Carbon Nano-tube reinforced Aluminum foam because inter-laminar shear stress within the Single-Walled Carbon Nano-tube reinforced Aluminum foam is less than that within the Singles-Walled Carbon Nano-tube reinforced epoxy. These results are very advantageous because replacing epoxy with Aluminum foam could decrease the manufacturing costs due to lower price of Aluminum foam.

Additionally, the comparison has shown that the inter-laminar shear stress within the interface of single-walled carbon nanotube and aluminum foam is higher than that within the interface of multi-walled carbon nanotube and aluminum foam. Hence, the probability of stress concentration and crack initiation within the interface of single-walled carbon nanotube and aluminum foam is higher than that within the interface of multi-walled carbon nanotube and aluminum foam. Furthermore, thermal fatigue lives of different single-walled carbon nanotube reinforced matrix composites have been evaluated. Moreover, interaction between carbon and molten aluminum has been analyzed.

Finally, a new relation for the thermal inter-laminar shear stress intensity factor to predict the crack initiation sites on fiber/matrix interface has been introduced. The application of Metal-Matrix Composites (MMC) is very broad in many industries especially aerospace and automotive. One of the most applicable MMC in industries is Aluminum matrix composite which contains carbon fiber and/or carbon nanotube. However, in manufacturing carbon fiber/aluminum composites or carbon nanotube/aluminum nanocomposites, carbon can react with molten aluminum. The results of this reaction can lead to develop carbide (Al_4C_3) and/or Aluminum oxide (AL_2O_3) in carbon/aluminum interfaces. Hence, on the interface of carbon/aluminum, carbon, carbide, aluminum, and aluminum oxide could be in contact with each other. The goal of this part of the study is to develop a method to identify the crack initiation site within the carbon/aluminum composites when exposed to thermal stresses. In order to achieve appropriate results in this study, the new concept of Thermal Inter-Laminar Shear Stress Intensity Factor is used. The results have shown that the probability of crack initiation on interfaces of aluminum/aluminum oxide is highest.