ABSTRACT

Hybrid aluminium - glass fiber laminates are a class of light weight materials used in structural applications as a substitute for metals in areas like aerospace and automobiles. These laminates consist of glass fiber reinforced plastic (GFRP) sandwiched between thin aluminium sheets. Although many studies have been carried out on such hybrid metal fiber laminates, published information with respect to mechanical properties is very limited. The first chapter of the thesis gives an introduction to various types of hybrid laminates, literature review and the aim and scope of the present investigation.

In this work, hybrid aluminium - glass fiber laminates with different metal thickness and fiber volume fraction combination have been fabricated using hand layup technique and tested under tensile loading. The fabrication and testing details are given in the second chapter. Further, the effect of metal thickness and fiber volume fraction on the tensile modulus, yield strength and ultimate strength as well as the extent of debonding of aluminium layer are discussed in this chapter. Scanning electron microscopic observations on the fractured specimen for finding out the failure modes in the hybrid laminate and Finite element analysis using ANSYS for understanding the stress-strain behavior of the hybrid laminates in the linear elastic region are also presented in the second chapter. Formation of analytical expressions based on rule of mixtures for determining the tensile properties of
the hybrid laminate such as elastic modulus, yield strength and ultimate strength for various aluminium (metal) thickness and fiber volume fractions are dealt in the third chapter and comparison between the analytical and the experimental results are also presented.

Laminate properties under tensile loading, predicted based on the rule of mixtures, compared well with the experimental results. While an increase in the elastic modulus and yield strength has been observed on increasing the metal thickness fraction, a reverse trend in ultimate strength is observed as the thickness is increased. However, all the three properties increased with an increase in fiber volume fraction. Debonding is found to depend primarily upon the thickness of aluminium layer. Fiber volume fraction appears to have very little effect on the debonding of aluminium layer. The hybrid laminates have exhibited significant improvements in specific tensile properties such as specific stiffness and specific strength when compared with pure GFRP and monolithic aluminium respectively. It has been found that the ANSYS results compared well with the experimental values. Scanning electron micrographs on the fractured hybrid specimens have shown that the GFRP failure is a combination of fiber fracture, fiber pullout and fiber matrix debonding.

These hybrid laminates, when used in demanding applications such as aerospace and automobile structures as a substitute for monolithic aluminium, are frequently subjected to impact forces from various sources and their impact performance therefore assumes more significance.
Hybrid Laminates with varying aluminium thickness fractions, fiber volume fractions and fiber orientation in the layers of GFRP have been studied for their impact performance by conducting impact tests under low velocity impact. The fourth chapter deals with the experimental methods in determining the impact performance of the hybrid laminates in terms of metal thickness, fiber volume fraction and fiber orientation. Also, a discussion on the scanning electron micrographic observations of the damaged/fractured specimens and a study of the impact load-time history under various impact loading conditions elucidating the failure modes and sequences in the hybrid laminates are presented in the fourth chapter.

It has been found that the specific cracking and perforation energy for the hybrid laminates increased with an increase in the fiber volume and aluminium thickness fraction. The specific cracking and perforation energy of cross ply hybrid laminate is found to be higher than that for unidirectional hybrid laminate. When compared with aluminium, both UDHL and CPHL have higher specific energy values.

The damage depth and the damage area has been measured for both type of laminates and on comparing, it is observed that the damage depth and damage area for cross ply hybrid laminate (CPHL) is lower than that of unidirectional hybrid laminate (UDHL) for the same impact energy. The internal damage area in the FRP layer is found to be lower than the damage area in the outer aluminium layer.
Chapter five gives a brief outline of how the research findings contributes to the designing of new laminates for structural applications or similar purpose.

Chapter six summarizes the important conclusions of the present studies and gives direction for future work.

From the studies, it is apparent that while the fiber volume fraction in the GFRP layer of the hybrid laminate accounts for higher and better tensile/impact properties, the metal thickness fraction plays an important role in the debonding of aluminium layer during tensile loading.