Composite materials (shortened to composites) have redefined the limits of man's imagination. They have pervaded man's daily life seamlessly and helped achieve things which were believed to be impossible just a few years ago. Cheap long distance air travel, breaking of the top speed world records in car racing, the finesse coupled with incredible power in sports, and the world records in pole vault and skiing have all been made possible by the use of these composites.

Basically, composites are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The engineering definition of composites limits itself to reinforced plastics such as fiber-reinforced polymer, metal composites and ceramic composites (composite ceramic and metal matrices). The properties of the material can be tailored to requirements by adjusting the composition, method of manufacturing and adding some additives. The composite materials are often used in high-performance products that need to be lightweight, yet strong enough to take harsh loading conditions such as aerospace components (tails, wings, fuselages, propellers), wind turbine blades, racing car bodies, etc. Though these materials are resistant to harsh environments, they do undergo deterioration over time, when subjected to high temperatures, moisture for long periods of time.

There has been some research work in the area studying the effects of the ambient condition changes, but these studies are often restricted to certain application ranges of the parameter, or certain a certain composite like Kevlar. Furthermore, the study is often done only to study the effect of one parameter on the mechanical properties of the system like temperature, or moisture individually. But the interaction of the mechanical properties is not so straightforward. For instance the moisture affects the composites in different ways depending on the temperature conditions. The deterioration at higher temperatures, is through diffusion (absorption of water molecules by the composite fibers) while, at temperature below zero degrees the deterioration is through displacement of fibers, and internal stresses due to increase in the volume. Also, the rate at which the absorption takes place is dependent on the temperature and the type of composite. These complex relationships have not been studied in detail, and as such is the main goal of the proposed research.

In order to determine these relationships, the mechanical properties of the composites will be studied at two levels, global level and local level. At the global level the mechanical properties of the specimen, will be determined based on the measured strain in the system and the neutral axis (NA) of the specimen. The NA is a property which is dependent only on the condition of the specimen, and is not affected by the force applied on the structure, or the temperature of the specimen etc. At the local level, more specialized technique making use of electromechanical impedance (EMI) and Lamb waves will be used, which can detect the local deterioration accurately.

The EMI method uses special sensors made from materials like PZT which show piezo-electric effect. The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state. This interaction is precisely defined for each material and any change in the mechanical parameters of the structure will be reflected in the electrical properties that are measured.

The Lamb waves based method, uses Lamb waves which are guided plate waves that are guided between two parallel free surfaces such as the upper and lower surface of the plate. The Lamb waves are highly dispersive in nature and can travel long distances. The movement of these waves is dependent on the mechanical properties of the material. Any change in the structure will lead to changes in the parameters of these waves like the frequency shift, speed, etc. These changes can be studied and used to determine the deterioration of the specimen.

All the methods described are non-destructive techniques and may be employed on the same specimen. This allows the same sample to be tested by three different techniques, which is not possible when using the conventional destructive tests. In addition by using the same sample, any errors due to variation of the different specimen of the composite are avoided. Furthermore, the different sensors used in the study allow us to overcome any systematic errors in the measurement. The three methods used have different sensitivities to temperature and moisture, thus by using their combination we can study the individual and combined effects of temperature and moisture. This study will not only give us new information and increase knowledge on how these parameters affect the composites, but it will also give us an opportunity to compare the results with previous work, which increases the confidence in the research findings.

The added knowledge will help us change the design codes for composite structures, as they can be made more precise. In addition, the more confidence, in the behavior will allow lower safety margins which will lead to lower costs. Thus, although the research carried out is to address a basic knowledge gap, there are apparent applications of the research which will benefit humanity as a whole.