Keywords:
Radio frequency curing, Fiber reinforced polymer, Epoxy Resin, Composites.

Introduction:
Fiber reinforced polymer (FRP) composite has very wide applications because of its adaptability and high strength to weight ratio. As FRP are lightweight with strength, they have replaced many alloy materials in its deployment. As polymer composites are in huge demand, they need to produce faster to keep up with the demand. Curing is a crucial phenomenon in polymer composite production and curing performance of the composite is majorly based on time and energy.

Radio-frequency curing offers a selective and uniform source of heating when compared to the conventional forms of heating composites such as employing an energy and time intensive autoclaving. In this present work, a radio-frequency curing system is designed and fabricated for the curing of epoxy polymer composites. The system comprises of a radio-frequency generating copper coil which acts as a heating element by the process of induction heating and dielectric heating. The mould which holds suitable amount of matrix and reinforcements by which ASTM standard size samples are prepared. A mechanical press is then used to maintain appropriate ratios of resin to the glass fibre reinforcements.

Objectives:
The major objectives are outlined as follows:
1) To design and fabricate Radio Frequency (RF) heating system for curing epoxy resin with an aliphatic amine hardener.
2) To carry out mechanical and thermal analysis of the cured samples. Mechanical analysis will be performed to check on structural stability by evaluating parameters such as tensile strength, impact strength, by using a Universal Testing Machine (UTM). For thermal analysis Differential Scanning Calorimeter (DSC) will be used to study the heat flux, glass transition temperature, degree of cure.
3) To conduct a comparative study w.r.t conventional curing techniques like room temperature curing, oven post curing and hot plate heating to study the feasibility of RF technology.

Methodology:
The functioning and methodology can be addressed by a modular approach:
1) Design and fabrication of the RF curing system.
A trial and error method was employed to identify the optimum power levels of the RF heating system at which curing would take place without degradation. The RF source has a frequency of 13-41 kHz, in which the minimal power of 100W was used for the curing of epoxy samples.

2) Fabrication of the polymer-composite using the RF system.

3) Characterization and testing of the polymer-composite. The studies carried out by utilizing the following equipment:
   a. Thermal analysis by employing a thermal imaging camera Fluke TiX500 and a Perkin Elmer DSC4000 differential scanning calorimeter.
   b. Mechanical analysis by employing a universal testing machine and IZOD/charpy machine

4) Analysis of thermal and mechanical properties by carrying out a comparative study.

Results and conclusions:

With the results obtained, the RF curing system was aptly designed to meet the dimension of the standard samples. The curing system was fabricated by coupling a mild steel mould, 5kN mechanical press and RF heating source. This system was successfully calibrated and operated to perform the curing phenomenon.

Glass fibre reinforced samples were prepared by following the process of wet-layup. The prepared samples were cured by three processes namely room temperature, hot plate and radio frequency curing for carrying out a comparative study to evaluate the pros and cons of radio frequency heating. Radio frequency cured samples developed yielded very promising results as compared to hot plate, room temperature cured samples and its post cured derivatives.

Thermal analysis by implementing a thermal imaging camera showed the cure uniformity throughout the sample at a temperature of 90°C. DSC study showed that the showed high degree of cure with glass transition temperature of 106.67°C as compared to the theoretical limit of 110.43°C. The cure time of around 20 minutes tells us that the mass production of composite parts are a possibility to meet accelerated demands of the future.

Based on mechanical testing performed on the specimens, one can conclude that the radio frequency cured sample has very good flexural strength of 402 MPa to withstand high bending loads in its structural applications. With the testing of impact strength, results further favoured the favourability of the RF cured sample in comparison to other curing methods.

Overall, RF curing for polymer composites is a very promising method for its reduced production time and energy efficiency on comparison with conventional curing methods. Overall this work tells us the potential of dielectric heating in curing polymer composites. With the increase in demand for reinforced fibres over the years, this curing system will help in accelerating the mass production for the same.

Scope for future work:

Several aspects of radio frequency technology and design of curing system can be optimised and developed with further study. Important points among them are:

- Designing an equipment based on the dielectric properties of the epoxy resin used can help in further reduction in energy used for curing.
- Studying the cure kinetics of epoxy resin we can optimize the curing sequence of the epoxy to make sure that there in minimal residual cure present in the composite.
- Use of this technology in curing carbon composites would give a much more superior result as carbon being a conductive material would heat more rapidly due to induction heating and cure the composite.
- Use of different RF inactive material for the molds and the mechanical press would reduce the production time even more as there would be no need for a cooling cycle.