ABSTRACT

Polymer matrix composites have superior mechanical, damping and weathering properties than the conventional materials. Attempts are being made to replace the conventional automobile steel front suspension spring with the polymer matrix composite spring. This will result in superior vehicle handling characteristics, maintenance and cost saving on suspension components such as hydraulic dampers. The objective of the present study is to develop composite elliptic spring elements which can serve as an efficient and viable alternative to steel helical coil spring.

The study comprises of (i) Development of formulation for the design and analysis of elliptic spring elements (ii) Optimization of spring material composition by experimentation studies and (iii) Evaluation of fatigue performance and fatigue damage progression by acoustic emission technique (AET).

The theorerical formulation for the calculation of static mechanical properties of the spring elements has been developed. The influence of spring element varaibles such as major axis/minor axis ratio, width, thickness, volume fraction of fibres (V_f) and laminate configuration on the spring properties are studied. Based on these studiess, the geometric parameters and laminate configuration of the spring element were optimized. Several composite elliptic spring elements were fabricated and tested for stiffness. Theoretical and experimental stiffness values agree well.

While fabricating the test samples, the epoxy resin was cured with two different curing agents and toughened with CTBN synthetic elastomer. The amount of curing agent added

to the epoxy was also varied. The influence of these variables on the toughness and flexural properties was studied using work of fracture method. The maximum work of fracture values were obtained for 9% piperidine cured/15% CTBN modified epoxies. The microscopic features of the fracture surface were studied using optical and scanning electron microscopy. New fractographic features, highlighting the stress whitening concepts have been observed and analysed. Similar studies were carried out for composite samples, having varying volume fraction of fibres and CTBN content. Phase separation at 18% CTBN concentration was confirmed through T_g and optical microscopy studies. Phase separation of rubber particles in the epoxy matrix was found to deteriorate the mechanical properties of the matrix

The damping properties of different matrices and composites were studied using dynamic mechanical analysis (DMA). The effect of CTBN addition and other matrix variables on tan δ (loss factor) of resultant matrices have been evaluated. The influence of fibre addition on the damping properties have been evaluated in order to optimize the fibre volume fraction.

The fatigue and acoustic emission studies have been conducted on different types of spring elements (variables: matrix composition and laminate configuration) to evaluate the stiffness reduction The fatigue behaviour of the spring element and fatigue damage progression were assessed in real time using AE technique. The fatigue properties of spring elements having UD rovings were found to be inferior compared to the one with WRM/UDR type configuration.

The fatigue studies were experimentally conducted upto 6.0x 10^5 cycles and extrapolated upto 1million cycles. The best fatigue performance obtained was 22% stiffness reduction at the end of 1 million cycles at a displcement of 25 mm. Sensing of AE signals revealed that the composite materials are active during the fatigue tests right from the start. The analysis of AE signals indicated the predominant emission of burst type signals. Continuous type signals were also observed during a particular phase of fatigue tests. Fatigue stiffness reduction and acoustic emission signal characteristics were correlated for the better understanding of fatigue damage growth in the spring element. Also, free vibration studies on the actual spring element were carried out to determine the loss factor.

The thesis is concluded highlighting the major findings and special feaatures of the present study.