Chapter 1

Introduction

The vibration occurs in most of the structures, machines and dynamic systems and produces increased stresses, energy losses, wear, increase in bearing loads, induced fatigue and create passenger discomfort in vehicles, and absorb energy from the system. The reduction of noise and vibration is a major challenge in static and dynamic systems. Now-a-days machines and structures are made by light weight materials and working at higher operating speed to increase the efficiency, as a result the systems have a low inherent damping because of low mass. Therefore damping augmentation is necessary to avoid resonance or an undesirable dynamic performance. Structural sandwich construction is the developed forms of composite structures. It has been used in aerospace applications for more than 40 years. In recent years, most commercial space vehicles have also adopted this technology for many components. In addition to air and space vehicles, laminated composite sandwich structures are increasingly being used in marine, transport and civil construction applications due to their high strength to weight ratio, high bending strength, cost effectiveness, durability and low maintenance cost. When these structures are exposed to vibratory environment, they can receive vibratory energy which results high vibratory stresses, environmental fatigue of the materials and undesirable effects on the structure. Most efficient way of controlling excessive vibration and environmental fatigue is to introduce damping into structures. Several methods have been employed such as passive control, active control and semi-active control to reduce the undesirable effects of vibration of the sandwich structures. It is a common practice in passive methods to employ the viscoelastic layers in sandwich structures. However, this method would not be suitable where the adjustable changes in stiffness and damping properties are needed. The active vibration control technique could not be justified for applications when the added cost and power requirements outweigh the performance gains.

Surface damping treatments are another type of easiest damping methods which are frequently used to solve a variety of vibration problems, particularly which are used in sheet metal structural vibration problems (Baz and Ro, 1995; Nashif et al.,
1985). It can be applied to the existing structures easily and as a result it provides high damping capability. Generally it classified in two categories as unconstrained or free layer damping and constrained-layer damping treatment based on the extensional or shear deformation of the damping material. In extensional damping treatments, the damping material is coated on one or both sides of a structure, so that whenever the structure is subjected to cyclic bending, the damping material will be subjected to tension-compression deformation. On the other hand, the damping material is constrained in between two metallic layers to yield the constrained layer damping treatment. The structures are exposed to cyclic bending, and force the core or damping material to deform in shear. The shear deformation is the mechanism by which energy is dissipated. (Liu and Chattopadhyay, 2000; Stanway et al., 2003).

Alternatively, a range of semi-active damping control concepts have been evolved for various structural vibration control applications, which could offer performance gains comparable to those of the active control devices with only minimal power requirement (Spencer and Nagarajaiah, 2003; Xu, et al., 2000). These devices include controllable fluids, including electro-rheological (ER) fluid and magneto-rheological (MR) fluids. These fluids are being widely used in various semi-active vibration control applications due to their controllable rheology and damping properties with only minimal power requirement (See, 2004; Stanway et al., 1996; Xu et al., 2000). MR fluids are known to exhibit considerably higher dynamic yield strength and greater insensitivity to temperature variation and contaminants compared to the ER fluids (Wang et al., 2001; Weiss et al., 1994). In this study, MR fluid based semi active control methods have been mainly focused.

Magnetorheological (MR) fluids are a class of new intelligent materials whose rheological characteristics change rapidly and can be controlled easily in the presence of an applied magnetic field. They are stable suspensions of non-colloidal very fine ferromagnetic particles in a carrying medium exhibiting controllable rheological behavior in the presence of applied magnetic field. In the absence of a magnetic field, MR fluid is free flowing with a consistency similar to motor oil. When a magnetic field is applied, the micron-sized ferrous particles suspended in the fluid align parallel to the flux path, creating particle chains in the fluid which resist and restrict fluid movement. As a result, a yield stress develops in the fluid. The degree of change is
related to the strength of the applied magnetic field and this change can occur in less than 1 millisecond. Rapid variations in rheological properties at various intensities of magnetic field were demonstrated by Rabinow (1951). In the absence of a magnetic field, the yield stress of the MR fluid lies in the order of 2 – 3 kPa and rapidly exceeds 80 kPa under the application of a magnetic field in the order of 3000 Oe (Carlson and Weiss, 1994). With the application of varying magnetic field, these fluids are considered to yield high bandwidth control through rapid variations in the rheological properties. This forms the primary motivation of the dissertation research.

This dissertation research presents a detailed study of the dynamic properties of a fully and partially treated laminated composite MR fluid sandwich plate. The governing differential equations of motion of a sandwich plate embedding MR fluid layer, fully and partially, as the core layer and the laminated composite plate as the face layers are presented in finite element formulation. The validity of the developed finite element formulation is demonstrated by comparing the results in terms of natural frequencies derived from the present finite element formulation with those of available literatures and with the experimental measurements. The various parametric studies are also performed to investigate the effect of magnetic field, thickness of MR fluid layer, ply orientation of the face layers, location and length of the MR fluid pocket on the variation of natural frequencies and loss factor of the fully and partially treated laminated composite MR fluid sandwich plate under various boundary conditions. Forced vibration responses of MR fluid composite plates are investigated to study the dynamic response of the sandwich plate under harmonic force excitations under various magnetic fields. An optimization problem is formulated to identify the optimal locations of MR fluid pockets to yield the maximum natural frequencies at individual modes and the combination of the first five mode of transverse vibration of the sandwich plate. The optimization problem is solved by using genetic algorithm together with the finite element formulation developed for a partially treated MR fluid composite sandwich plate.