**CHAPTER - 7**

**CONCLUSIONS**

**Static Analysis and Optimization:**

- By prescribing the different values of the lower and upper bounds on each of the shape design variable, a different optimum shape is obtained, each time. Therefore, a thorough investigation is made with three different cases to arrive at the global optimum shape of the structures by prescribing the movement directions of the shape design variables in different directions with strain energy minimization as objective. It is observed that the global optimum shape is obtained when the shape design variables move in both the horizontal & vertical directions simultaneously.

- In strain energy minimization, the maximum percentage reduction in deflection and strain energy is observed when the shape design variables move in both the horizontal & vertical directions simultaneously.

- The strain energy minimization leads to considerable increase in the stiffness (rigidity) of the structure. Such rigid structures with increased stiffness have higher resistance against
deformation and may therefore be considered structurally more efficient.

- A thorough investigation is made with three different cases to arrive at the global optimum shape of the structures by prescribing the movement directions of the shape design variables in different directions with stress leveling index minimization as objective. It is observed that the global optimum shape is obtained when the shape design variables move in both the horizontal & vertical directions simultaneously.

- In stress leveling index minimization, the maximum percentage reduction in deflection and stress leveling index is observed when the shape design variables move in both the horizontal & vertical directions simultaneously.

- The stress leveling index minimization leads to more uniform distribution of stress intensities throughout the structure. The stress leveling enables the use of structural material more efficiently.

**Free Vibration Analysis and Optimization:**

- By prescribing the different values of the lower and upper bounds on each of the shape and thickness design variable, a different optimum shape is obtained, each time. Therefore, a thorough investigation is made to arrive at the optimum shape of the structures by prescribing the movement directions of the
shape design variables in both horizontal and vertical directions (i.e. X,Y directions) simultaneously. The upper and lower bounds as well as the initial and optimum values of the design variables are provided for both the cases.

- **Minimization of Volume** (keeping frequency constant) leads to reduction in weight of the structure since the density of the material being constant. Volume or weight minimization is considered more important in the aerospace industry, where structural designs are more often based on weight consideration, rather than on cost and fabrication considerations.

- **Maximization of fundamental frequency** (keeping volume constant) ultimately leads to considerable increase in the stiffness (i.e. rigidity) of the structure. Such rigid structures have higher resistance against deformation and may therefore be considered structurally more efficient.

- By maximizing the difference between the forcing frequency and the natural frequency of the structure subjected to certain geometric constraints, resonance can be avoided and the structure can be safeguarded against failure.

- **Combination of shape as well as thickness variables** used in the optimization process results in greater reduction in volume or weight of the structure and significant increase in the fundamental frequency of the structure, compared to the case, when only shape or thickness variables are used.
Some of the optimum shapes presented are not practical but are included to show how shape and thickness changes can substantially alter the volume and fundamental frequency. However, manufacturing constraints etc. can be imposed to produce more practical optimum designs.

**Dynamic Analysis and Optimization:**

- Laminated composite plates fixed and simply supported along all the four edges subjected to triangular and rectangular impulsive loads are investigated for various types of fiber orientations. It is observed that fiber orientation plays a vital role in distribution of stresses and deflections.

- By properly orienting the fibers in a laminated composite plates, the maximum deflections can be reduced to an extent of about 90% and maximum stresses can be reduced to an extent of about 85%. This implies considerable saving in material can be achieved by properly orienting the fibers.

- It is observed that the peak deflection, stress, velocity and acceleration are minimum in 90/-60/45/-60/90 orientation (all the cases) and maximum in 0/0/0/0/0 orientation. (most of the cases) Hence, 90/-60/45/-60/90 is the most robust orientation with respect to various response parameters.

- Design of composite laminated plates based on these studies will not only save the material but also evolve robust design.
**SCOPE FOR FURTHER STUDY**

- Buckling analysis of prismatic and axisymmetric shell structures may be investigated. Structural optimization of prismatic and axisymmetric shell structures can be carried out to maximize the critical buckling load or to minimize the weight/volume subjected to certain constraints.
- The stability characteristics, post buckling and general nonlinear behavior of optimized shells may be investigated.
- The use of topological optimization in which the optimal layouts of plate and shell structures are determined should be considered as a prelude to shape optimization of the type described in this research work. Thus, a two-phase optimization is envisaged.
- Multi objective problems may be considered in which there are several objective functions to be minimized and/or maximized.
- The analysis of laminated composite plates can be extended to various types of shell structures. Parametric optimization of laminated composite plates and shells made of different materials and thicknesses can be carried out for various boundary conditions, load cases and fiber orientation.
- Plates of various shapes, Single and Three-cell box girder bridges, Doubly curved shells such as Elliptic paraboloids, Hyperboloidal shells, Conoids, Cone-Cylinder combinations, Bells, Free form shells, Stiffened panels may be investigated.