Aerospace structures are different from other structures due to the difference in the required properties for an aerospace application. The primary motivation of this kind of structure lies in its lightweight nature, need for enough strength to withstand different loading conditions, durability, high performance, etc. The choice of materials for the aerospace structures is mainly metals, alloys, ceramics, and composites. The use of composites is increasing rapidly for aerospace structures due to its lightweight nature, high specific strength, tailoring properties to meet the design needs, fatigue and corrosion resistance, etc. The structural analysis and modelling of different aerospace structures to obtain a particular level of performance depend on a deep understanding of the material properties, and structural and geometric characteristics. So, to achieve a reliable structure, variability among the material and its effect on analysis and design should be addressed. In this thesis, we explore the modelling and analysis of uncertainty and its effect on different structures which have aerospace applications. In particular laminated composites, sandwich composites and periodic structures are considered. Computational methods which need less CPU time are also explored to facilitate efficient uncertainty quantification.

In search of the effect of uncertainty on the failure curves of laminated composites, we have considered a random variable based modelling approach to obtain the most conservative Tsai-Wu failure envelopes considering material as well as ply angle uncertainty. The uncertainty analysis is performed using Monte Carlo simulation (MCS). Meso-scale elastic constants of the carbon/epoxy composite material are considered as uncertain with 5% coefficient of variation (COV). The innermost points of the stochastic realizations of failure curves form the most conservative modified Tsai-Wu failure envelopes, and these curves are used as constraint functions to perform the weight optimization problem using particle swarm optimization algorithm. Later, AS4/8552 carbon epoxy laminated composite with material and ply angle uncertainties is considered to analyze the effect of uncertainties on the failure strength properties, and their probability distributions are also obtained. For uncertainty influenced design, three ranges of failure curves ($\mu - 3\sigma$, μ, $\mu + 3\sigma$) (μ = mean, σ = standard deviation) are chosen as constraint functions to observe the effect of uncertainty on the design of composite structures. Also, a new heuristic directional bat algorithm (dBA) is explored for the constrained minimum weight composite laminate design optimization problem.

We also focus on the modelling aspects of spatial variability of material and geometric parameters for sandwich composite beam structures. The elastic and geometric properties of the sandwich beam are considered as a non-Gaussian random field, and MCS along with the computationally efficient time-domain spectral element method (TSEM) is proposed considering a higher order sandwich panel theory which can capture the core compatibility. Further, a stochastic time domain spectral element method (STSEM) is proposed for both Timoshenko and sandwich beams. Discretization of the non-Gaussian random field is performed using expansion optimal linear estimation and optimal linear estimation. The analysis shows the effect of different variability and their impact on the various response characteristics of beam structures. The computational efficiency of STSEM is shown through the Timoshenko beam problem. Results show that STSEM lessens the CPU time for computation. The effect of uncertainty is quantified considering static, free vibration and dynamic analysis. Aerospace structures are subject to transient loading which consists of high-frequency content and noise from undesired vibration. The use of periodic structures helps to control or reduce the undesired vibration. In this thesis, the effect of material uncertainty on the stop band characteristics of periodic bar and beam structures is also investigated. Periodicity is common in aerospace structures (e.g., fuselage structure). The basic building blocks of any structure are bar, beam and plate structures which also influence the design of the whole structure. The periodic analysis of these structures is essential to investigate the dispersion characteristics. The periodic analysis is carried out for 1-D bar and beam considering uncertainty in the material properties. A TSEM based transfer matrix formulation and wave finite element method is proposed to carry out the analysis. The analysis shows a considerable saving of CPU time and also quantifies the individual effects of random parameters on the stop bands of a periodic bar and Timoshenko beam. Parametric analysis is performed and insight is given for design aspects regarding the stop bands in the frequency range of interest.