Probabilistic Lifing Analysis of Turbine Blades in presence of Manufacturing Uncertainty

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Abstract

The life of turbine blades is central to the integrity of the aircraft engine. Due to the inevitable influence of manufacturing uncertainty on these turbine blades, it becomes important to understand and model its effect on the life of these blades. The characterization, quantification and segregation of manufacturing uncertainty is a subject of research in itself which involves understanding and application of the available probabilistic data analysis techniques [Thakur, Keane and Nair (2009)]. Once data capturing these variations is available, it seems ideal to use it for generating 3-d model representations of the probable manufactured blade shapes. Meshes on these perturbed geometries may then be used for finite element analysis (FEA) and lifing calculations.

Generation of a new model in any CAD tool for each and every manufactured blade shape can prove to be a very costly affair. This leads to the need for exploring existing geometry manipulation techniques, such as Free Form Deformation (FFD) [Sederberg and Parry (1986)], which can aid in morphing the base/nominal geometry to different shapes as desired. However, the application of this technique in deforming turbine blade geometries to model manufacturing uncertainty remains relatively unexplored, especially when a limited number of measurements are available per blade to characterize these differences.

In the present work, FFD has been employed to deform the nominal turbine blade model in order to generate 3-d models of the probable manufactured blade shapes. The best possible match to the expected blade shape is obtained by using FFD in conjunction with optimization. Lifing estimations on these perturbed geometries are made using SCO3, a Rolls-Royce proprietary FEA tool. The results show that the presence of manufacturing uncertainty may result in a reduction of around 2% in mean life relative to the designed life with a maximum relative reduction of around 4% for turbine blades manufactured over a span of one year. These results may further be employed for robust design studies against manufacturing uncertainty resulting in not only a better mean life but also reduced variations in the expected life.

References

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Thakur, N. and A. J. Keane and P. B. Nair. Probabilistic Analysis of Manufacturing Uncertainty in Turbine Blades. *Proceedings of the ASME-IDETC/CIE 2009 Conference*, San Diego, California, USA, August-September 2009.