Hayder sabah Al-Araji. Vibration Assessment of Aerodynamic Loads on Low Speed Aircraft Wings. University of Technology, Mechanical Engineering Department. Ph.D. Supervised by: Asst. Prof. Dr. Mauwafak Ali Tawfik &Asst. Prof. Dr. Mohammed Idrees Abu-Tabikh. 2012. pp 210.

Abstract

The aeroelastic responses, unsteady aerodynamic properties, and the flutter condition of a 3-D flexible aircraft wing were investigated by the development of a fluid-structure interaction (FSI) approach. The actual wing in this approach was represented by equivalent plate using suitable geometry, dynamic pressure and frequency scale factors.

Equivalent plate model (structure model) based on Rayleigh-Ritz method was combined with unsteady panel-discrete vortex method (aerodynamic model) to build a versatile, reliable, and relatively simple FSI model. This model could be used in the preliminary design stages of moderate to high aspect ratio and low swept wings of an aircraft at low subsonic speeds. The wing angle of attack, flap angle and air speed were considered as input variables in the present (FSI) model.

The suggested FSI algorithm was programmed starting from scratch and the problem solved by the main and accessory computer programs written in Matlab program. Time domain of generalized coordinates simulations were used to examine the dynamic aeroelastic instabilities of the system (e.g. the onset of flutter and limit cycle oscillation (LCO)).

The validity of the present theoretical method was tested through comparisons with the related published works and wind tunnel measurements. Flutter speed and flutter frequency were estimated for many Aluminum cantilever plates models of different aspect ratios and the results showed good agreement with the published works. The flutter speed and flutter frequency are within average absolute error of about 9% and 4.6 % respectively

The aeroelastic and aerodynamic behavior of different wind tunnel models (cantilever plates, oscillating wing, and flap wing) were investigated through three types of systematic experimental tests in a low speed wind tunnel. For the plates flutter experiments, it is found the theoretical values are under predicted in comparison with experiments. The flutter speed and flutter frequency are within average absolute error of about 13% and 16 % respectively.

After completion of validation test, the present (FSI) model was then utilized for the vibration assessment of a modern aircraft wing (Beechcraft 77 Skipper). Full dynamic response analyses were performed for this aircraft wing. The results include; aeroelastic responses before, during, and beyond flutter, flutter speed and flutter frequency, time history of lift coefficient, lift hysteresis loops, lift and pressure distribution along the wing. The flutter speed for the selected wing appears at 153 m/sec with the flutter frequency 15.5 Hz. The effect of forced vibration on aeroelastic and aerodynamic responses were also analyzed.

Finally, an adaptive neural controller to control the flutter in 3-D flexible wing was proposed in this thesis. The structure of the controller consists of two models namely modified Elman neural network (MENN) and feedforward multi-layer Perceptron (MLP). The MENN model was trained with off-line and on-line stages to guarantee that the outputs of the model accurately represent the heaving motion of the wing and this neural model acts as the identifier. The feedforward neural controller was trained off-line and adaptive weights were implemented on-line to find the generalized control action (function of addition lift force), which controls the heaving motion of the wing. A general back propagation algorithm was used to learn the feedforward neural controller and the neural identifier. Simulation results showed the effectiveness of the proposed control algorithm. This was

demonstrated by the minimized tracking error to zero approximation with very acceptable settling time of 0.6 sec.

Keywords: Fluid structure interaction, Flutter and Assumed mode method.