INTRODUCTION

The unsteady aerodynamics of wings and control surfaces has been studied ever since aeroelastic effects began to be felt in flight. With the widespread adoption of active control technology such study has assumed greater importance. Applications of active control technology such as ride quality improvement, gust load alleviation and flutter suppression are common in all but the smallest transport aircraft, while relaxed static stability, maneuver demand systems and buffet control are a must for the advanced fighter types. Thus active control technology is used over a wide range of speeds from subsonic to high supersonic and for a wide range of configurations from the conventional to the advanced fighter type, to augment and improve the performance and handling qualities of aircraft.

While electronics is central to the operation of an active control system, such a system ultimately acts through the aerodynamic lifting and control surfaces. Thus it is that while on one hand, the study of the unsteady aerodynamics of large aspect ratio wings that are prone to aeroelastic effects at high subsonic speed has now become a classical subject (Bisplinghoff [1955]), on the other hand, the study of the unsteady aerodynamics of all wing planform shapes including complex configurations consisting of a combination of low and moderate aspect ratio wings together with associated control surfaces over speeds ranging from low subsonic to high supersonic has also assumed great importance.

As in the case of the study of the steady aerodynamics of wings and control surfaces, both theoretical and experimental approaches have been pursued for the study of unsteady aerodynamics also. The earliest, classical, theoretical treatments of the subject were restricted mainly to the small amplitude motion of aerofoils in ideal flow (Wagner [1925], Kussner [1940], Theodorsen [1940], von Karman and Sears [1938]). With the availability of powerful digital computers and the development of advanced numerical techniques it is now possible to study numerically a wide variety of planforms and speed ranges with arbitrary motions. The ideal situation where one would be able to solve the Navier Stokes equations for any situation is, however, not likely to be realized in the near future. In fact, in most cases where a preliminary idea of the unsteady behaviour is required, it may be necessary to use methods based upon drastic simplifying assumptions, for example that of inviscid incompressible flow.

Wind tunnel experiments on the unsteady behaviour of wings and control surfaces have all the complications of the corresponding steady case. In addition, they have more since the data are by nature time varying and hence need more powerful methods of recording and interpretation. Also, since in most cases only small-amplitude motions are studied, the amplitudes of the unsteady data are small and generally contaminated with extraneous noise which the experimentalist has to take every care to reduce to a minimum. Even so, experimental results yield valuable physical insight and they serve to establish the validity - or, conversely, demarcate the limitations - of theoretical models based upon simplifying assumptions.

While most aircraft today are meant to fly at speeds where comressibility is important, they all have to pass through the low speed, incompressible, regime at least during two crucial phases of flight, namely takeoff and landing. Again, while low speed flows are generally simpler to study both theoretically and experimentally, the insight they may provide into a particular situation can be valuable. The study of unsteady aerodynamics at low speeds is therefore still important.

The aim of the present work is to investigate the unsteady behaviour of wing planforms at low speeds. The work consists of two parts, one theoretical and the other experimental. In the theoretical part, the vortex lattice method (Hedman [1966]) and the panel method (Hess [1972]) have been used to predict the aerodynamic behaviour of a wide range of planforms in general unsteady motion in ideal flow with the assumption that the flow is always fully attached. The panel method can handle thick wings, which the vortex lattice method cannot. In determining overall forces and moments, however, thickness, so long as it is moderate (as it is in the case of most practical aircraft wings) has a minor role and one of the aims of the study is to see how much the results produced by the vortex lattice method deviate from those produced by the theoretically more exact panel method.

In the experimental part, an attempt has been made to measure the longitudinal stability derivatives L_θ , M_θ , $L_{\dot\theta}$ and $M_{\dot\theta}$ for a wide range of wing planform shapes at small incidence. The results obtained experimentally are compared with those predicted using the vortex lattice method with the aim of determining how useful the method is in predicting the unsteady behaviour of wing planform shapes.

This thesis consists of six chapters. Chapter I is a brief review of the relevant portions of the literature on unsteady aerodynamics. The current status of the vortex lattice and panel methods, especially with regard to their application to unsteady aerodynamics, is reviewed. The aims, methods, instruments, and analysis techniques for conducting experiments in unsteady aerodynamics have also been reviewed here.

Chapter II is a detailed description of the application of the vortex lattice method to the prediction of the unsteady behaviour of wings of a wide range of planforms, from the rectangular to the slender delta in attached flow. Two different methods for modelling unsteady aerodynamics have been used, the explicit time-dependent and the simple harmonic oscillatory. While the former has been used with the vortex lattice method by a number of workers (Levin [1984], Konstadinopoulos [1985], Hancock and Lam [1987]), the latter model, namely simple harmonic oscillatory, does not appear to have been used with the vortex lattice method in three dimensions.

Chapter III is a detailed description of the application of the panel method to the prediction of the unsteady behaviour of wings. As in Chapter II, two different methods have been used for modelling the unsteady aerodynamics, namely the explicit time-dependent and the simple harmonic oscillatory. The aim here is to see how the results predicted by the panel method for thick wings compare with those predicted by the vortex lattice method for the same planform but without the thickness effect.

Chapter IV is a description of the experimental setup used to perform the experiments referred to earlier. The tunnel, the model mounting system, the sting balance, the models, the actuating mechanism for oscillating the models, the data aquisition system and the calibration procedure are all described in this chapter. The experiments had to be designed subject to certain narrow restrictions imposed by the working conditions; how these were circumvented is also described here.

Chapter V is a description of the results obtained from the experiments, the data reduction techniques used, and the corrections applied to the measured data. The comparison of the experimental results with the predictions of vortex lattice theory is shown here.

Chapter VI gives the concluding remarks on the suitabiliy of the vortex lattice method as a tool for studying the unsteady aerodynamics of wing planforms. It also suggests some ways of improving upon the present experimental technique, keeping in view the constraints imposed by extraneous factors.