LECTURE 3

AERODYNAMIC CONTROLS

1 INTRODUCTION

This lecture is concerned with the control characteristics of deflected aerodynamic surfaces on guided weapons. As I said in the first lecture of the course, the controls are the essence of a guided weapon, because however clever the guidance equipment and autopilot may be in compensating for erratic characteristics in the static aerodynamics, they cannot function if the demanded manoeuvres cannot be realised by generating the appropriate control forces.
It was pointed out in the first lecture that there are several ways of providing these control forces, and another lecturer is dealing with methods such as spoilers, jet reaction controls and thrust vector control.

In the case of aircraft, most deflected surface controls are in the form of hinged panels at the trailing edge of a wing, stabiliser or vertical fin. On some high speed fighter aircraft a complete stabiliser is hinged, and can provide both elevator and aileron control. This is the exception, however. In the case of guided weapons the use of all-moving surfaces is the rule, not the exception, since the requirement for trimmed incidence and lateral acceleration are more demanding than for aircraft.

The next four sections will deal with controls at the tail and at the front of a weapon body, moving wing controls and controls placed within the wing planform. In general, cruciform configurations will be studied.

2 TAIL CONTROLS

The most common layout for aircraft and guided weapons is a combination of a body with a fixed wing placed close to the centre of gravity and another set of surfaces at the rear. On a guided weapon these rear surfaces not only act as stabilisers but may also act as all-moving controls for motion in pitch, yaw and roll. I put it in this way to emphasise that even though another method of control is chosen - say thrust vector control - the rear surfaces are still required to achieve the appropriate stability, unless a completely autostabilised system is chosen.

The control force developed on a horizontal pair of tail controlled panels in isolation can be estimated by putting the two panels together and treating them as an isolated wing, the "nett wing". At the rear of the body however this control force is modified by the following interference effects:

a. Control-body interference due to the body incidence, in the same way as for fixed wing-body interference. This is represented by factors K_W and K_B to the normal force on the nett tail, where K_W is the mean "body up-wash" over the tail span, and K_B represents the carry-over lift on the body.

b. Control-body interference due to control deflection. This is represented by factors k_W and k_B to the normal force on the nett tail arising from control deflection.

c. The downwash field from parts of the body upstream of the control.

d. The downwash field from the wing upstream of the control.

e. The reduced kinetic pressure in the wake from the wing.

The normal force on the nett tail is calculated in exactly the same way as for wings, so that the particular problems of tail controls are concerned with the values of the factors K_W, K_B, k_W, and k_B, of the downwash due to streamwise vortices and of the reduced kinetic pressure.

The body-tail interference factors commonly used may be obtained from slender-body theory, as described in References 1 and 2. By definition, therefore, they are independent of Mach number and strictly applicable to planforms such as delta wings of low aspect ratio rather than to rectangular planforms. Corresponding factors for non-slender shapes have been computed using linearised supersonic theory. These factors must be used intelligently and if there is any likelihood of the tail surfaces stalling, suitable plausible assumptions must be made about the manner of applying the factors, though strictly speaking the factors are not valid under these conditions. For example K_W represents the increase in incidence of the tail surface due to the upwash around the inclined body. It has the theoretical value 2 at the root section and decreases towards the tip. Thus the local incidence at the tail root may be twice the body incidence, even if the tail is undeflected, and this may bring the tail beyond its stalling incidence. Thus K_W should be applied to the incidence of the nett tail, not to the normal force, and a knowledge of the characteristics of the nett tail in a real viscous flow will indicate whether a loss of effectiveness is likely to occur. At a roll angle other than zero the interference factor K_φ also has to be included in the calculation of the panel loads.

The calculation of the downwash at tail surfaces is difficult, and the various attempts to do this have met with mixed success. A later lecturer will deal in detail with this problem, along with the wing-body and body-tail interference mentioned above, so I will not deal with it in detail here. However some general remarks will be in order since it is impossible to treat control problems without considering the effect of downwash.

Behind a monoplane wing alone at incidence and at zero roll angle the trailing vortices lie at an angle below the plane of the wing, the downward velocity