1.0 GAS TURBINE ENGINE STEADY-STATE BEHAVIOUR

1.1 Introduction

The behaviour of a gas turbine engine depends on the aerodynamic interaction between the engine's components. The most important interactions are the effects of nozzles (propelling nozzles or turbine nozzle guide vanes) on compressor operation. Compressors are basically unstable units because they attempt to create a pressure rise in the direction of mass flow, whereas in normal duct flow a pressure ratio across the duct would cause flow from high pressure to low pressure. If the compressor blades fail to achieve their task, the basic pressure ratio takes over and partial or full reverse flow occurs (compressor stall or surge). Aerodynamic design of a gas turbine concentrates on controlling the operation of the engines compressors to maintain stable behaviour, and therefore in reviewing gas turbine behaviour we will concentrate on compressor performance.

Figure 1.1 shows the typical combinations of compressors and nozzles which occur in a gas turbine engine. A high pressure compressor on a 2-shaft or 3-shaft engine, or a single compressor on a turbojet, is controlled by the nozzle guide vanes of the high pressure or single turbine. The fan of a by-pass ratio engine is controlled by the cold nozzle (on an unmixed engine) or by the final nozzle on a mixed flow engine.

The basic effect of a nozzle is most easily understood if we consider the simple arrangement of a compressor on a test rig. A throttle (simple nozzle) is used downstream of the compressor to control its operation. The compressor shaft is usually driven by an electric motor. At constant speed the pressure ratio of the compressor is increased by closing the throttle. This occurs because the compressor must increase the density of the gas to push it through the smaller flow area of the throttle. As the pressure ratio increases the loading on the compressor blades increases and eventually the flow breaks down causing a stall. See Figure 1.2.

1.2 Degrees of Freedom

Each rotating component in an aero-engine has, in the performance sense, two degrees of freedom. These are essentially the flow and the power (or torque since speed is then a dependent variable). For example, it can be seen from a compressor characteristic (Fig 1.3) that by choosing a pressure ratio and a flow, all other parameters for the compressor are determined, such as speed and efficiency.

1.2.1 Constraints

The constraints in an aero-engine which enable a stable solution to be found at each combination of environment and stabilised throttle setting are: