STALL TRANSIENTS INCLUDING EFFECTS OF INLET DISTORTION AND INTAKE GEOMETRY

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PART I--INTRODUCTION

Compression-system instability, leading to surge, rotating-stall, or combinations of these phenomena, such as "classic surge", has been of concern to gas-turbine designers for at least 40 years. These instabilities come into play at low flow rates, and determine the safe "stall margin". In recent years, there has been special concern about the nonlinear transients which follow stall, how to predict and perhaps control them.

Early efforts [1] to analyze these phenomena were based on hopes for synthesis; that is, first to fully understand the unsteady aerodynamics of a cascade, then a stage, then a compressor, and then an engine. This detailed approach was not successful, because of the enormous complexity of the system in which a single blade row is embedded. A more fruitful approach has been the reverse, to proceed from the system toward smaller scale. This may be said to have begun with the work of Greitzer, Cumpsty, and Day [2-5]. An analysis of pure rotating stall by Moore [6] paralleled the surge analysis of Greitzer[2] , and showed the importance of an underlying, disturbance-free compressor characteristic.

Then, Moore and Greitzer [7] showed how to connect the surge and rotating-stall theories to permit the analysis of the general transients of interest, and Greitzer and Moore [8] exercized the theory enough to show that the theory was indeed capable of following a transient into either rotating stall or surge, as the system parameters dictate. It was at this point that Moore reviewed both the rotating-stall theory and the related combined-cycle theory in the VKI Lecture Series of 1984 [9].

The present lectures will begin by reviewing the original combined-cycle theory presented in 1984, with all its enabling approximations (PART II). Then the lectures will proceed to describe basic developments since then. First, the basic theory was amended to permit inlet flow distortion [10]; that permitted realistic transient calculations under the influence of throttle ramping, and enabled a corresponding, very approximate map of stall-mode boundaries to be described. An estimate of steady stall margin also emerged from that analyis. PART III will discuss those topics.

Next, in PART IV, certain advances will be discussed which improved the realism of the physical models used in the theory, especially those pertaining to the inlet flow, compressibility [11], and the "axisymmetric characteristic". Then, in PART V, attention will be turned to the new realism obtained by more ambitious computational efforts [12,13,14], especially that of McCaughan [12], to properly treat the shape of circumferential waves, and to correctly analyze potential flow in an ideal inlet. These results, for the first time, convincingly described post-stall performance, including recovery. Finally, in PART VI, the relation of the transient theory to modern nonlinear mechanics will be noted in the remarkable bifurcation analysis of McCaughan [15] , which showed systematically how modes are "chosen" by the equations, and which thereby provided mode boundaries correlating very well with experimental ones.

The lectures outlined above will follow an historical sequence; otherwise the purposes of the various advances cannot easily be made clear. The main track will be from [7 (or 9)] to [10] to [12] to [15]. These papers are readily available, so the chief effort in these lectures will be to call attention to the particular advances which seem important to the author.

A list of SYMBOLS and a list of REFERENCES will be provided at the end of these notes.

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