40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit
11 - 14 July 2004, Fort Lauderdale, Florida

AIAA 2004-3412

A Semi-Viscous Method for Compressor Performance Prediction

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The performance prediction of the modern axial compressor is a vital step in the design and analysis process. Not only are accurate flow and efficiency predictions necessary, but also reliable radial and axial work distributions predictions are needed to verify the design, and more importantly, uncover problems. Furthermore, an accurate and consistent predictive system can minimize the need for testing, resulting in substantial savings. While traditional S1S2 type systems are fast, they are limited in the transonic and subsonic regimes and not very reliable, often failing at or near the end walls. Multi-row CFD has come a long way, but also has its share of issues such as meshing, turbulence models, and mixing plane formulations. Furthermore, setup and turn around time for a multi-stage compressor make multi-row CFD less than efficient often requiring "expert" users. This paper presents a simple, physically sound, reliable, and efficient method for predicting axial compressor performance using a combination of single-row CFD and Streamline Curvature (Throughflow) codes. The method has been developed and tested on several industrial multi-stage compressors of varying sizes and loadings. In each case, the prediction was well within the measurement accuracy.

Nomenclature

P	=	pressure
V	=	flow velocity in a non-rotating frame of reference
W	=	flow velocity in a rotating frame of reference
η	=	adiabatic efficiency
π	=	total to total pressure ratio
ξ	=	loss coefficient

I. Introduction

PREDICTING the compressor performance is probably the most important step in the design process of a gas turbine engine. Traditionally, companies are reluctant to proceed with a truly clean sheet design. Extensive computations are conducted and compared to older, successful designs. Deviation from previous experience and previously successful designs are scrutinized, and only tweaks are allowed to proceed. Expensive tests are then conducted to verify and validate the new design. It is fair to say that manufacturing and mechanical robustness considerations have played a role in slowing down the evolution of the compressor. However, the aerodynamic uncertainty is still the driver behind the overall design philosophy.

It can be argued that the more devastating aerodynamic design mistakes would result in an axial mismatch. A poor estimate of the flow function entering a stage would, at the very least, lead to poor performance. Such an event will, almost always, necessitate a redesign. The consequences of such an event far exceed the cost of a redesign, or a missed deadline. They extend to the psyche of the organization as a whole and often contribute to an overall shying away from most innovations as they are quickly deemed "risky".

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