Reviewing Turbomachine Sealing and Secondary Flows
Part A: Customer, Designer, and Research Issues

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Interaction between seal and engine flows is important to the implementation of new seal technology. This does not mean that gas path or power stream dynamics are unimportant, yet Brayton cycle machines, for example, are fairly mature. However, *turbomachine sealing represents your competitive edge*. Maintaining seal leakages and secondary flows within engine design specifications is the most efficient and cost effective way to enhance on the wing performance and minimize maintenance costs. Still, refurbished engine performance is 10 to 15 percent less than an out of the box engine depending on engine size and operations history and over time the engine becomes uneconomical. Changes in sealing, especially on the high-pressure-spool, dramatically change performance of the entire engine. This has been conclusively demonstrated in an YT-700 engine test where the CPD-seal, labyrinth seal was replaced by a dual brush seal. A direct comparison of SFC over a range in developed power showed a consistent reduction in SFC of over 1 percent.

With the exception of turbomachine seal-rotordynamics, the sealing research and development agenda of Ludwig (1978), the engine design requirements established by Campbell (1978) and the airline customer needs given by Smith (1978) remain as current objectives. It was the failures of the Space Shuttle Main Engine Turbomachinery that ushered in a new understanding of seal rotordynamics and sealing technology.

Part B: Rotordynamics Issues in Flow Systems with Small Clearances

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Today’s computational methods enable the determination of forces in complex systems, yet without field validation data/feedback there is a high risk of failure when the design envelope is challenged. The data of Childs, field data reported in NASA Conference Proceedings and Bently serve as sources of design information and the development of these computational codes. Over time all turbomachines degrade and instabilities often develop, requiring responsible, accurate, turbomachine diagnostics with proper decisions to prevent failures. For a smooth operating, reliable long lived machine, pay very close attention to sealing dynamics and diagnostic methods. Correcting the seals enabled the Space Shuttle Main Engine High Pressure Fuel Turbopump (SSME HPFTP) to operate successfully.

Cited are Armstrong’s drum rotor self excited oscillations model, where the classic “fix” is to add a split/severed damper ring or cylindrical damper drum and the Benckert-Wachter work that engendered swirl brake concepts.

Tam et al. (numerical) and Bently/Muszynska (analytical) models corroborate and implicate that destabilizing factors are related though increases in fluid average circumferential velocity. The stability threshold can be controlled by (a) external swirl and swirl-brakes and (b) increases in radial fluid film stiffness (e.g., hydrostatic; ambient pressures) to enhance rotor stability.

Part C: Powerstream Component Support Issues

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Cavity sealing of a turbomachine pump, compressor or turbine is demanding with significant impact on component and engine performance. But there are several computational modeling tools (e.g., NASA developed INDSEAL, SCISEAL, ADPAC) to help guide the designer and experimenter. And in time, data will emerge to more rigorously validate these efforts from rig experiments to results from the field operations.

Gas turbine engine externals inhabit the space between the engine case and the nacelle cowling. Rocket engine externals occupy a similar space within the confines of the aft-fairing frame. Within that space, overflowing with pipes, wires, fire-extinguishing components are challenges and opportunities for dynamic components improvements. All must function efficiently with a high degree of reliability in order for the engine to run.

Within the open literature, a darth of statistically significant data exists for critical engine components (e.g., HPT-disk) as does data for the basic materials. The classic deterministic method assumes full and certain knowledge exists for the service conditions and the material strength. In the “hands” of an experienced and seasoned designer/engineer, these are adequate. Yet, variations with loading can have a significant impact on component reliability, but without validation data, they are just studies. These deficits in statistical data bases require immediate attention.

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