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SIMULATION OF CRYOGENIC TURBOPUMP ANNULAR SEALS

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In reference (1) San Andres employs the NBS software package MIPROPS to account for density's dependence on pressure in the simulation of liquid annular seals. His example on a LH_2 seal showed a significant change in the mass coefficient compared to a constant density model. San Andres Yang and Childs (2,3) extended this analysis by including the pressure and temperature dependence of density, specific heat, viscosity, volumetric expansion and thermal conductivity in a coupled solution of the energy, momentum and continuity equations. Their example showed very significant changes in stiffness and inertia for a high speed (38,000 rpm), large L/D ratio (0.5) LOX seal, as compared to their constant temperature results.

The current research rederived the San Andres-Yang-Childs (SYC) analysis and extended it to include not only the Moody friction model of SYC but also the Hir's friction model. The derivation begins with obtaining the local differential equations of continuity, momentum and energy conservation in the seal. These equations are averaged across the film thickness to obtain the resulting "bulk flow" differential equations. Shear stress and convective heat loss through the stator (seal) and rotor are related to the Moody and Hir's friction factor model. The Holman analogy is employed to relate heat conduction in or out of the fluid film's boundary layer to the friction induced shear stress.

The steady state problem (d/dt=0) was solved using a shooting algorithm for the two-point boundary value problem. This require a simultaneous integration of the two momentum equations and the continuity and energy equation. The results for temperature increase through the seal shows excellent agreement with the SYC model results as shown in figure 1. The SYC papers also describes an approximate solution algorithm which assumes constant properties and friction factors along the length of a concentric, straight seal. This model was deciphered and programmed and shows excellent agreement with the published SYC approximate solution results, a comparison of which is shown in figure 1.

The linearization coefficient expressions were derived to solve the first order (perturbation) problem for the dynamic coefficients. This linearization procedure was performed for both the Hir's and Moody models and revealed two errors in the SYC linearization coefficients for the viscosity and density in the circumferential momentum equations, and a missing convective heat flux term in the energy equation. The results showed that the Hir's model linearization coefficients were quite different from their Moody counterparts, while maintaining a similar form as regards to programming.

The non-dimensional equations employed in the preceding analysis were used to derive similarity conditions and expressions to infer LOX seal characteristics from those of a similar water seal. The branch is currently developing this tester and required sizing information along with equations which relate characteristics of the two seals. The similarity analysis was confirmed by running the TAMUSEAL code for a LOX seal and for its "similar" water seal. The results of these two runs showed nearly perfect agreement with those predicted by the similarity equations. This numerical check was performed for both a Hir's and a Moody model type seal. The same study identified non-dimensional dynamic coefficients which remain invariant for seals that are mutually similar, i.e., obey the same conditions of similarity.

The detailed analysis and results of this work may be found in the 430 page report, "Thermal and Similarity Studies for Cryogenic Liquid Annular Seals" issued by the Summer Faculty Fellow to the Mechanical Systems Controls Branch.Future work includes programming the first order solution to the thermohydrodynamic problem to obtain the resulting dynamic coefficients, including seal housing flexibility and extending the bulk flow model to include impeller forces.

The Fellow also planned an installation of an impact damper on the TTB-ATD-HPOTP. The proposed location of the impact damper is shown in figure 2. This device will consist of 12-20 specially designed, cylindrical impactors contained in a ring type fixture. This type of damper has been successfully employed in LN_2 at Texas A&M.Testing of the impact damper may begin as early as Summer '94 if approved by the TTB Review Panel.

REFERENCES

1. San Andres, L.A., "Analysis of Variable Fluid Properties, Turbulent Annual Seals," ASME Journal of Tribology, Vol. 113, October, 1991, pp. 694-702.

2. San Andres, L.A., "Thermal Effects in Cryogenic Liquid Annular Seals - Part II: Numerical Solution and Results," ASME/STLE Joint Tribology Conference, Paper No. 92-Trib-5, pp. 1-8.

3. Yang, Z., San Andres, L., and Childs, D., "Thermal Effects in Cryogenic Liquid Annular Seals - Part I: Theory and Approximate Solution," ASME/STLE Joint Tribology Conference, Paper No. 92-Trib-4, pp. 1-10.

4. Yang, Z., San Andres, L.A., and Childs, D., "Importance of Heat Transfer from Fluid Film to Stator in Turbulent Flow Annular Seals," WEAR, Vol. 160, 1993, pp. 269-277.

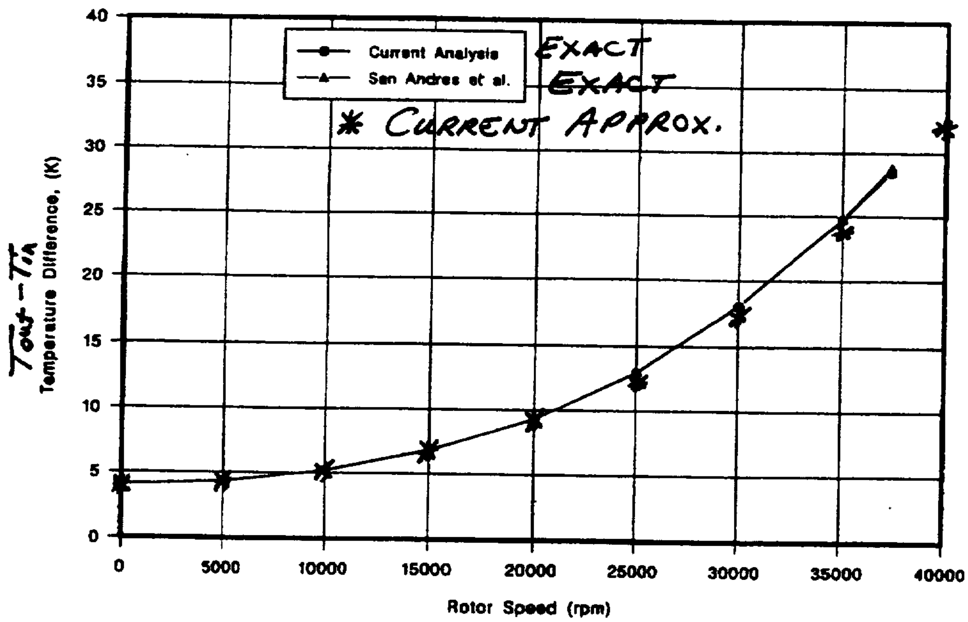
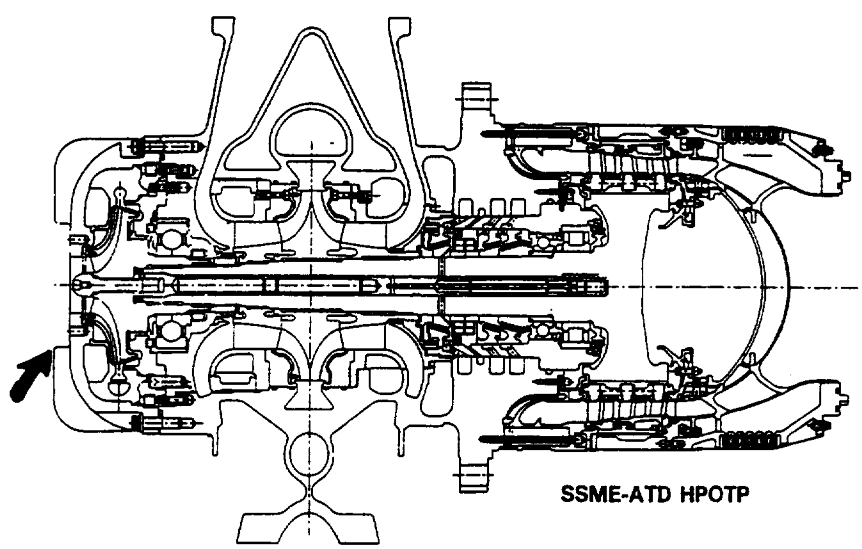


FIGURE 1 - COMPARISON BETWEEN THE EXACT AND APPROXIMATE TEMPERATURE RISES



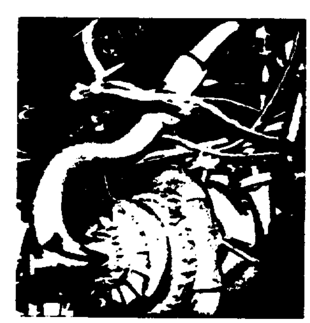


FIGURE 2 - PROPOSED LOCATION OF THE SSME-ATD-HPOTP IMPACT DAMPER