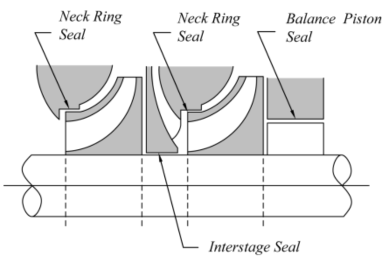
TEXAS A&M ENGINEERING
EXPERIMENT STATION

Turbomachinery Laboratory
Turbomachinery Research Consortium

Tests of a Plain Annular (Liquid) Seal in the Laminar, Transition, and Turbulent Regime with a Swirl Brake

Dara Childs

Annular seals dramatically influence the rotordynamics *of **all*** centrifugal pumps. The seals of interest are shown in figure 1. Leakage flow that goes down the front face of an impeller is restricted by the *neck rin*g (*or wearing*) seal. The main flow exits an impeller and then proceeds through a diffuser before entering the following impeller. Part of that flow leaks back along the pump shaft through the *interstage* seal and then proceeds radially outwards up the back face of the preceding impeller. For a styraight-through pump, leakage flow from the last impeller goes down the back face of the last impeller, out through the *balance piston* seal, and is then returned to the pump inlet. The balance-piston seal absorbs the full head rise of a straight-through pump. A similar situation holds for the last stage of the back-to-back pump with leakage flow going down the back side of the last impeller, then through a center seal to proceed radially outwards along the back side of the last impeller of the opposing-flow stages. The center seal absorbs about one half of the pump's head rise.



Wearing-ring. Interstage, and balance piston seals

Fig. 1 Centrifugal-pump annular seals

For pumps handling high viscosity fluids in the laminar regime, seal-reaction forces due to fluid rotation tend to behave more like forces from an uncavitated plain journal bearing than a Lomakin seal. Absent cavitation, they create unstable oil whirl in the centered position with precessional motion at a little less than 50% of running speed, which can lead eventually to oil whip with precessional motion at the rotor's 1^{st} damped natural frequency. This behavior has been reported for many vertical pumps. Loading the seals into an eccentric position can suppress oil whirl. However, seal wear out will regularly eliminate the stabilizing effect of eccentricity and put the machine back into whirl. Swirl brakes are not predicted to be effective for annular seals that are handling highly viscous flow *for new clearances*. *They are predicted to become effective as the clearances increase due to wear* [5]. **There are no data for annular seals in the laminar and transition flow regime with swirl brakes.** Also, there are no data available that measures the inlet (and exit) fluid preswirl for a seal with swirl brakes for these flow regimes.

This project entails the manufacture and tests a smooth annular seal to be operated with 3 clearances (new, 2X, 3X), using an ISO VG46 oil with running speeds to 8000 rpm and ΔPs to 20 bars. The seals will be tested from centered to an eccentricity ratio of ≅ 0.9. Tests will use 1 nominal pre-swirl ring aimed at getting a preswirl ratio ~0.7 for new clearances and 3600 rpm speeds. One empirically-designed swirl brake will be used for all tests. For the speed, ΔP, and clearance ranges specified, we expect the seal flow to be in the laminar, transition, and turbulent regime. Static test data will be obtained for leakage, preswirl, and static load-eccentricity results (from centered to an eccentricity of ~0.9 × Cr) plus rotordynamic coefficients. We don't have a code that predicts the flow field for a combined swirl brake and annular seal. However, the flow data will be useful in the future to anchor CFD predictions. The results will establish the

TEL. **979.845.7417 |** FAX **979.845.1835**
turbo@turbo-lab.tamu.edu
509 MEOB | 3254 TAMU | College Station, TX 77843-3254

range of effectiveness of swirl brakes in improving seal rotordynamic behavior over a previously unexamined flow regime (running speed, clearances, preswirl ratios, and ΔPs).