

Results indicate that in most cases squeeze film damping and thermal transient effects are important in the analysis of transient seal response. For step increases in film thickness, the response is usually a decay as the rotor asymptotically approaches the initial steady-state conditions. Alternately for step decreases (of sufficient magnitude) in film thickness, the seal either “pops” open (in a monotonic fashion) or fails (collapses or pops open) due to the onset of oscillatory instabilities. Under certain conditions the response to small step decreases in film thickness appears to be stable and the rotor approaches the steady state asymptotically or in an oscillatory (but stable) manner.

It is not possible at this time to present a general stability map, but we can tentatively conclude that seals should be designed such that they are balanced (in the steady state) in a region of large positive stiffness. Even a small amount of coning would appear to assure stability for even large disturbances. Further it appears that the magnitude of the response parameter (a measure of thermal inertia) is important when considering response times and overshoot (in cases where the rotor tends to asymptotically return to steady-state conditions).

Two limitations to this model should be noted. First the assumption of one dimensional (axial) heat transfer in the seal plates for the transient model results in responses which never return precisely to the associated steady-state values. This is because transient heat flux variations (from the steady state) will always be felt at all later times and hence there will always be some temperature deviation (again from the steady state) throughout the leakage path. However for the test cases presented estimated values for the skin depth are sufficiently small so as to support the above assumption. An exact thermal analysis requires modeling the seal plates with finite dimensions, thus restricting the applicability of each computer code execution to a specific seal design rather than to a broad range of rotor/stator (axial) thicknesses. The second limitation is the discrete boiling and laminar flow assumptions, which are valid only for small film thicknesses where the leakage is low. As the seal gap increases, thermal convection becomes important and laminar two phase flow may appear over a portion of the seal face (Yasuna and Hughes, 1990). As the seal begins to pop open, the flow eventually becomes turbulent and adiabatic (Beatty and Hughes, 1986). A transient analysis including two phase turbulent fluid modeling is necessary to examine the full range of dynamic seal response.

DISCUSSION

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The authors have moved the analysis of two phase seal behavior an important step forward. Their dynamic analysis has the potential to explain face seal puffing. I would hope they would extend their analysis to consider two current applications in more detail. First, many flat faced seals operate with some degree of contact for most operating conditions but may, if their geometric balance ratio is low, pop open or puff at certain temperatures in the two phase regime. By including contact load support and contact friction heating, the authors' model should predict such behavior. While there exist static models that predict this point of instability, it would be very helpful using the dynamic model to see if the static predictions are correct and to better understand this behavior. Second,

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for radially tapered seals that operate under noncontacting conditions, the authors showed no instability or cyclic response. Could the authors investigate a wide range of conditions to see if this is always true, or is the stability condition both operation condition and design specific? This question has important implications for the application of such radially tapered seals in two phase applications.

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I'm pleased to see the authors' progress toward fuller modeling of “popping-open” phenomena in face seals. The complexity of this has been well demonstrated by tests and analysis at my company and others, and I appreciate that the authors are making no rash claims that this paper now gives the complete answers.

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