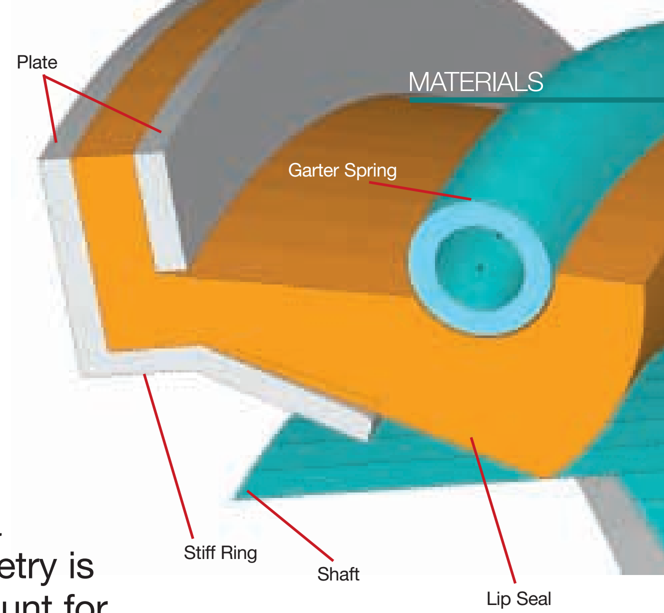
Predicting Wear in Radial Seals



Radial lip seal geometry simulation model

Finite element analysis is performed in a step-wise approach in which seal geometry is re-meshed with each load cycle to account for wear-off of material at the contact surface.

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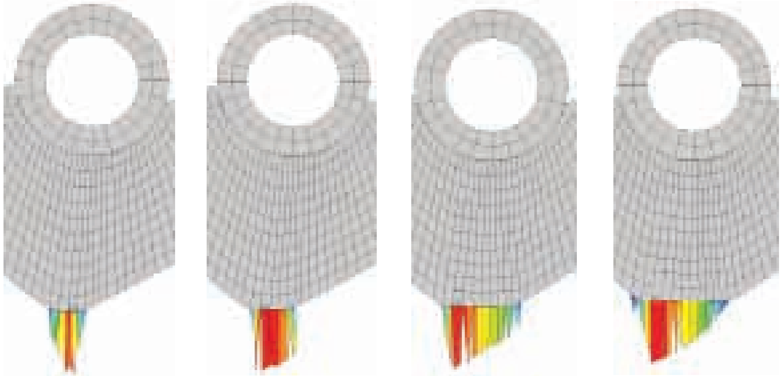
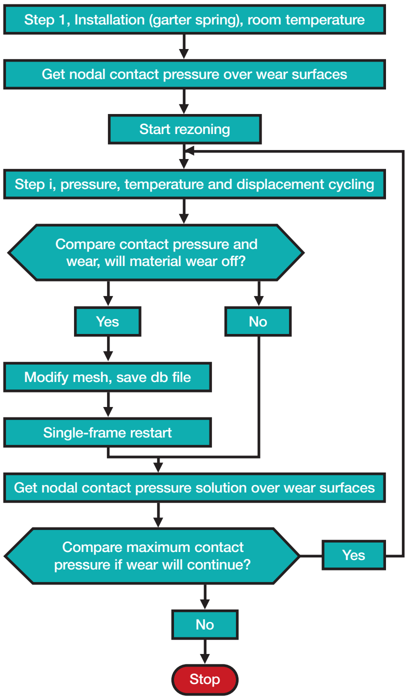
Radial shaft seals (including lip seals) made of elastomers or low-friction polytetrafluoroethylene (PTFE) materials are used in a wide range of products, including aircraft, vehicles and industrial equipment for sealing rotating shafts — primarily to keep out contaminants and keep in lubricating oil. A garter spring typically is used to create an adequate initial force between the shaft and the seal before high working pressure is built up. The seal contact pressure under the working pressure is a critical factor in seal performance and wear. This contact pressure is extremely difficult to measure because of the complexity of seal configuration, the size of contact area, and continuous changes in the contact profile due to material being worn off over the life of the seal.

At Emerson Climate Technology in Ohio, U.S.A., ANSYS Mechanical software is used extensively as a powerful tool to gain a more thorough understanding of seal deformation and contact pressure. To perform a realistic simulation and obtain accurate results, the analysis is performed in a step-wise approach in which the seal geometry is remeshed with each loading cycle to account for the effect of material wear at the contact surface. The simulation is performed using the single-frame restart feature and a non-standard re-meshing procedure for each solution cycle.

The PTFE material is temperature-dependent, time-dependent and pressure-sensitive. Restart preserves the stress and strain history for each cycle, moving nodes using solutions of the previous step and saving the modified geometry into a database file from step to step. Hence, the mesh of the wear zone is modified continuously as a function of contact pressure and sliding velocity.

The process accurately represents material removed from cycle to cycle as a smooth function of contact pressure, in which contact pressure gradually evolves with the progress of material worn off for the number of cycles. Results clearly indicate that both the distribution and contact pressure of the seal change continuously due to the loss of material. Since contact behavior strongly impacts lip seal performance, gaining this insight has been a key to optimizing seal design and improving product quality and reliability at Emerson Climate Technology. ■


Evolution of seal wear from cycle to cycle: The change in the interface at the bottom of the seal area (lower grey edge) illustrates a change in shape; contact pressure is plotted across this lower edge, where the red areas indicate regions of maximum pressures of 19, 9.5, 3.4 and 1.6 MPa, from left to right respectively.



Simulation flow chart for single-frame restart procedure used for FEA modeling of a continuously wearing seal geometry