Zero-Leak O-Rings by Using Adaptive Materials

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The goal of this research project is to design materials for O-rings so that the seal behaves in such a way as to counteract the leak producing processes that occur over time in use. The concepts and materials developed will also apply to other types of seals made of elastomeric materials.

Elastomeric materials are subjected to mechanical, thermal, chemical and other environmental effects in use, and molecular-level changes in material structure occur. Due to material property changes and permanent deformation the seal-counterface contact pressure decreases resulting in loss of sealing performance. The usual approach to material specification for dealing with aging effects in seals is to attempt to increase the stability of the material. More structurally stable materials are typically harder and stiffer. This results in loss of compliance of the seal material and decreasing ability to conform to gland shape. The end result is a loss of sealing performance.

A different approach to seal development is being pursued in this research. In contrast to designing materials based on initial material properties, O-ring material design is based on producing controlled, desired material behavior changes over time in use. The seal material is designed to have a response that counteracts leak producing processes. Since this is a natural material reaction to a changing sealing environment and no external processes are used to induce material behavior changes, the material is called passively adaptive.

The initial phase of the research resulted in a seal design concept and the demonstration of improved seal performance using two-dimensional physical and numerical experiments. This work is continuing and recent results are described in the poster. The results presented include:

- A problem statement defining the initial problem - minimizing compression set of statically loaded O-rings through material design
- An overview of the basic concept underlying the design of materials for use in improved seals – minimizing stored elastic energy that causes permanent material deformation.
- A summary of previous results indicating the effectiveness of the design rules developed.
- New experimental results showing that, indeed, stored elastic energy is correlated with permanent material deformation and so minimizing it is a rational basis for seal design.

- Current experimental and numerical results that show O-ring cross sections that have lower stored energy content and improved sealing performance in terms of increased retention of sealing pressure compared to typical, baseline O-ring designs.
- Experimental and numerical results comparing performance of typical one-material and composite structure O-rings for realistic seals, i.e, real O-rings rather than two-dimensional section models.
- New designs that preserve, and can increase, contact pressure, in contrast to the small losses in contact pressure in the previous modified designs.