Health Monitoring for Axial-Piston Variable Displacement Pump

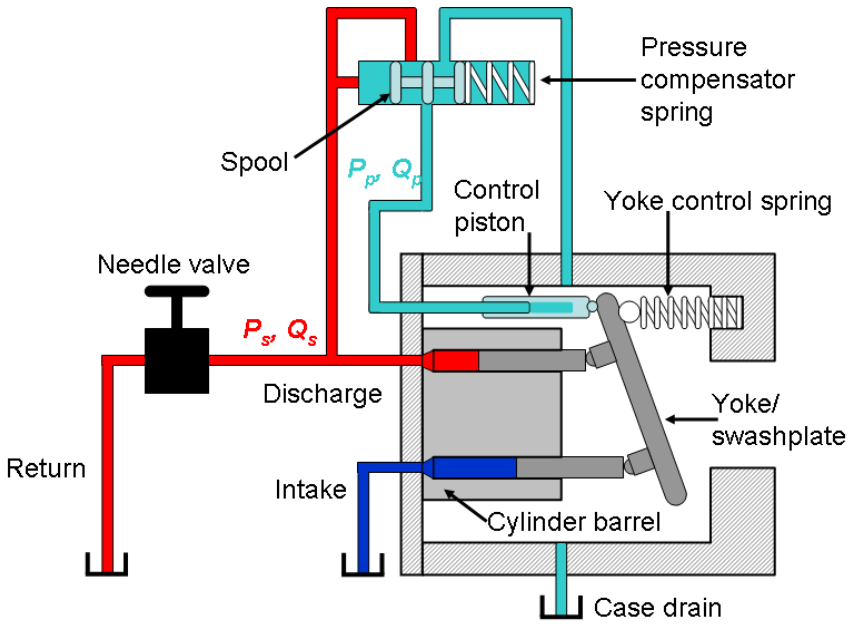
Pushing the Boundaries of Machinery Prognostics

Motivation

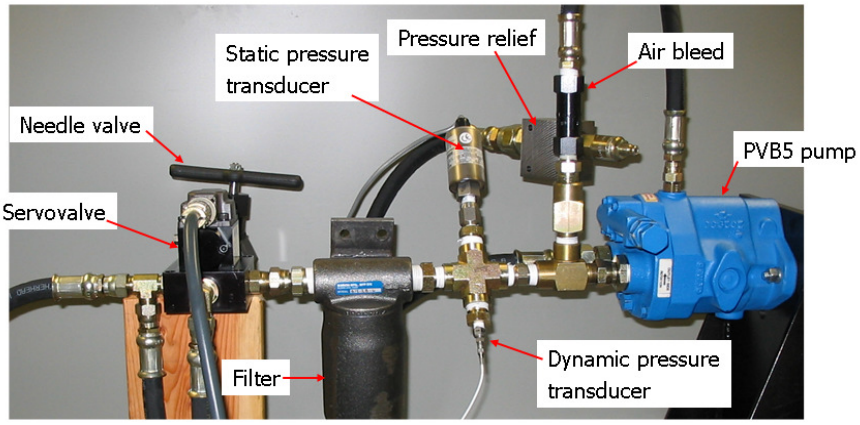
In recent years, significant research has been directed towards condition monitoring, diagnostics, and prognostics for the major gas turbine engine turbomachinery components, and also towards general engine health. These components are expensive to maintain, and their failure frequently has immediate safety implications. However, the degradation, faults, and failures of turbine engine accessories lead to the majority of events that compromise mission success and availability. Much less research has been focused on these faults in the electrical, hydraulic, and pneumatic accessory components. Sentient is addressing this gap with research into fault identification on many accessory applications, including several promising fault estimation algorithms for diagnosing axial-piston variable displacement pumps (VDP) similar to the pump shown.

Solution

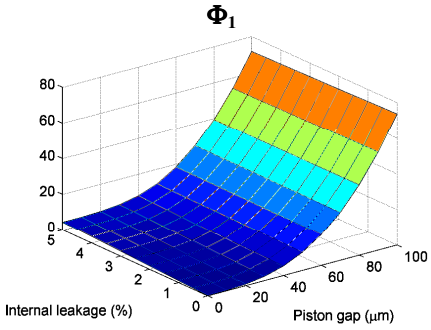
Sentient approaches diagnostic problems with the attitude that if you know the physics behind common failures, then you can create the best diagnostics to detect them. This certainly holds true for axial-piston variable displacement pumps. Sentient created a physics-based dynamic model of the VDP including common fault modes. The model is coupled with a Hybrid Model/Feature-Based Fault Detection algorithm that uses the model to identify features in transient and/or steady-state response to discriminate healthy and faulted operation. This approach provides a low overhead technique that can determine type and severity of faults by calculating features and using a table lookup to ease demand on computational and memory resources.

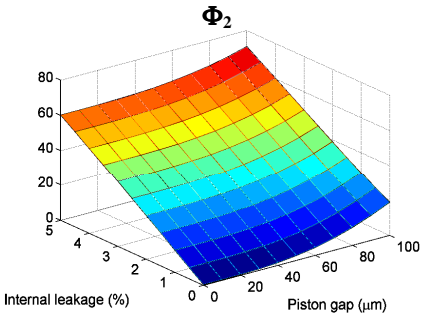


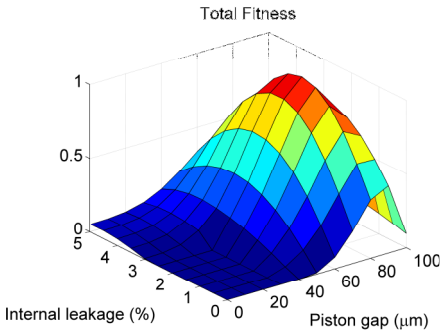
In faulted operation, there can be piston leakage through the annular gap between the piston and cylinder barrel walls, external leakage through the valve plate and cylinder barrel interface at the discharge chamber, or internal leakage along the valve plate and cylinder barrel interface between two adjacent piston chambers.



Experimental verification of physics-based models is key. Sentient has unique experimental facilities with full data acquisition capability to test hydraulic components in realistic operational regimes for validation of the model diagnostics. The Hybrid Model/Feature-Based Fault Detection algorithm uses the model to identify features in transient and/or steady-state response that can discriminate healthy and faulted operation. Some examples are that time-domain trends in mean and standard deviation can differentiate between external leakage and other leakages, and frequency-domain features can differentiate between piston leakage and internal leakage. The figure on the left below shows how feature Φ_1 depends more on piston leakage, whereas the figure in the middle shows that feature Φ_2 depends more on internal leakage. A fitness function derived from features can discriminate the presence and severity of each fault type. Shown below on the far right, Total Fitness is the probability of a faulted condition.







A key advantage of Sentient's diagnostic method is the ability to use existing sensed parameters for diagnosis (i.e. no additional PHM sensors needed). Other benefits include high sensitivity coupled with low false alarm rates, the ability to isolate multiple types of faults, and a good balance between computational requirements and performance.

Contact Sentient Corporation for more information on our hydraulic health monitoring technology and a discussion about how this technology can improve your maintenance capability:

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