

Radial Piston Pumps: Performance and Efficiency

The modeling method for the performance of positive displacement pumps of hydraulic pumps is based on collecting operational data of the pump for its operational envelope and using equations with empirical fitting parameters and fit these equations to the data. This way values for the fitting parameters are obtained, with which the equations can be used as model for the operating performance of this specific pump. By implementing this modelling method no information about the contribution of each component present in the pump to the performance losses is obtained. A model which analyzes each component and estimates its contribution to the total power losses would be beneficial in the design of pumps. Therefore the answers to the following research questions are sought after in this work:

- What are the components critical to performance within hydraulic pumps?
- To what accuracy can a component-wise, analytical model for pump performance be created?
- How sensitive to certain parameters used in the equations is the model?
- What are the possibilities of implementing this model into pump design?

After the pump system was analyzed and the internal interactions found, the components which effect pump performance the most were identified. These include bearings, rollers, seals, springs, valves and leakage flow which is dependent on gap size, piston movement and viscosity of the hydraulic fluid. For these components analytical equations are presented which are incorporated in the model.

The accuracy of the model is tested by comparing its results to test data of an experimental camring driven radial piston pump. The model predicts leakage flow to an average difference of 3% relative to the data, but outliers up to 49% for high pressures and -35% for low pressures are observed. Input torque is predicted to an average difference of -19% relative to the data. This difference is mainly caused by the inaccuracy of the predictions below 30 bar operating condition, where outliers up to -61% are observed. These results are compared to an empiric modelling method and are found to be more accurate for leakage flow for the entire operational envelope, yet on average less accurate for input torque.

The sensitivity of the model to certain parameters is tested. The parameters investigated are the rolling resistance coefficient of rollers and bearings, bearing lubricant viscosity, hydraulic fluid temperature, piston-cylinder alignment and the corresponding forces resisting piston motion and the assumption of laminar leakage flow.

To show the possibilities of the model in pump design the rollers and appurtenant bearings present in the pump are replaced with hydrostatic bearings. The design is discussed and a hydrostatic bearing with an orifice restrictor is designed of which implementation will approximate the total efficiency of the pump with rollers. The Reynolds number of the flow necessary is found to be too high for capillary restrictors. To approximate the same total efficiency for each operating condition the average bearing flow is found to be 0.0016 L/s, which corresponds to an average fluid film height of 12 μm . The orifice restrictor diameter which allows this flow is found to equal 0.24 mm.

This work shows the possibilities of such a model, yet there is plenty room for improvement of the accuracy of the predictions made. Recommendations to this end are given in the conclusion and recommendations of the report.

Therefore, it is concluded that for a large size wind turbine, inclusion of hull flexibility is necessary when evaluating the dynamic properties of the tower and is certainly important for dynamic response analysis.

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