Pump Users
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Technical Paper

(max. 8-10 pages including abstract)

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Experimental and Theoretical Investigations concerning the Operation Limit of Three-Spindle Screw Pumps

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Summary

The displacement and for the first time elastic bending of a hydrodynamic supported idle screw of a 3-spindle screw pump is measured by a set of inductive sensors with a resolution of less than a micro meter. The measurements lead to the conclusion that the idle spindle cannot be modeled as a rigid body, and that elastic bending has to taken into account. From our experimental results and efficient and accurate hydrodynamic models an operation limit program was obtained.

Introduction

Screw pumps are kinematic pulsation free positive displacement pumps. The hydrodynamic supported sidewise idle spindles are driven by engagement of the center drive spindle (**Figure 1**). In unpropitious operation points of low rotating speed, low viscosity and high pressure difference contact between the idle spindle and the casing may occur. It is state of the art to experience this operation limit experimentally. The aim of the present research is to improve the physical understanding of the problem and finally to predict the operation limit on truly physical grounds.

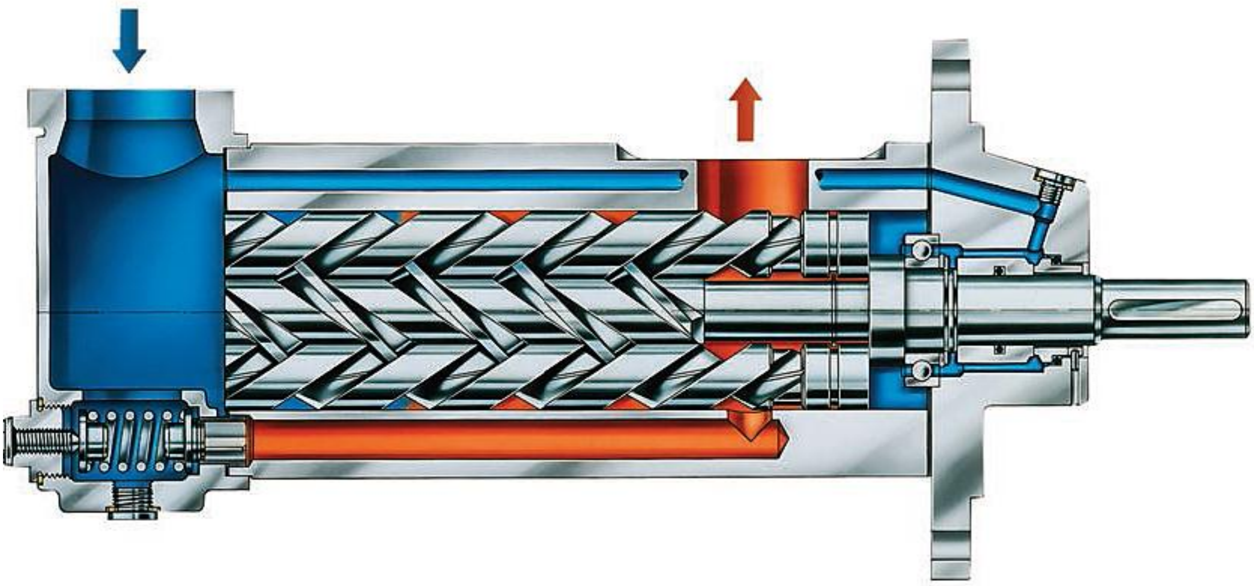

Figure 1: 3-spindle screw pump /8/

The paper is structured in a hydrodynamic modeling part, experimental setup and results and in the end the presentation of the new operation limit program.

Hydrodynamic Modelling

Fluid structure interaction calculations were done for understanding the bending behaviour of the idle screw, but in center of development, sales and pump users interest is a fast and accurate fully scalable physical model, predicting the operation limit as exact as possible.

Due to that, at first an efficient pressure load model had to be modelled. The surface of drive and idle spindle were separated in 48 different subsections each (**Figure 2**). The simulation includes only one screw pitch, so most subsections are either in contact with the suction or the discharge side. In those cases the pressure has not to be calculated but is still known.

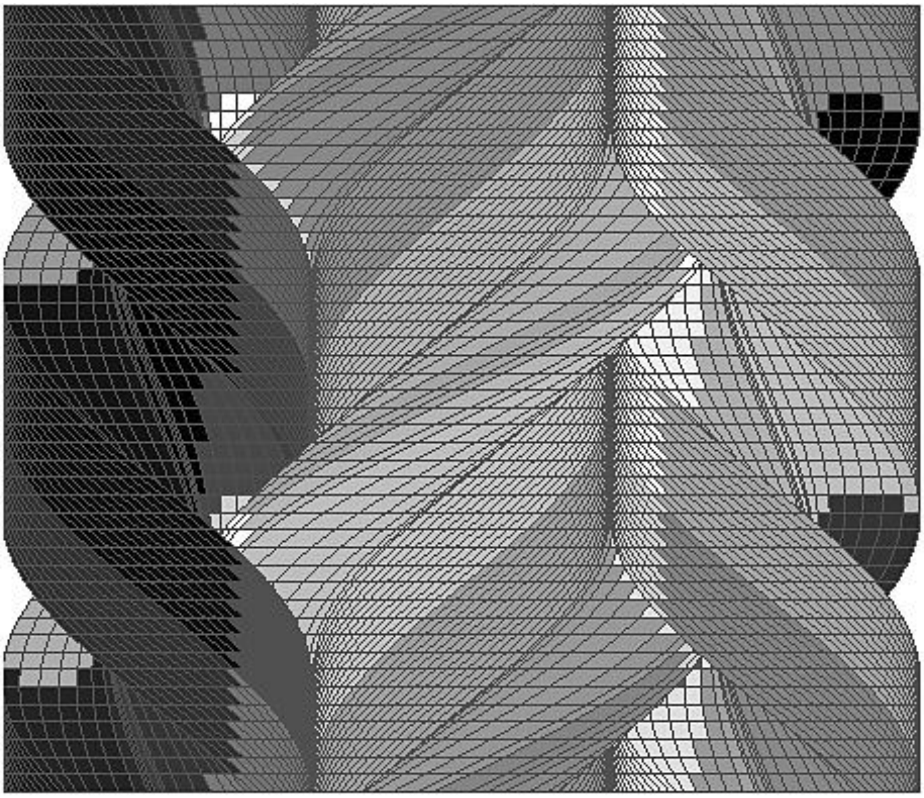

Figure 2: Surface subsections

Only the rhombic flat projection of the area gap at the exterior diameter of the idle screw was calculated by the Reynolds lubrication equation (**Figure 3**).

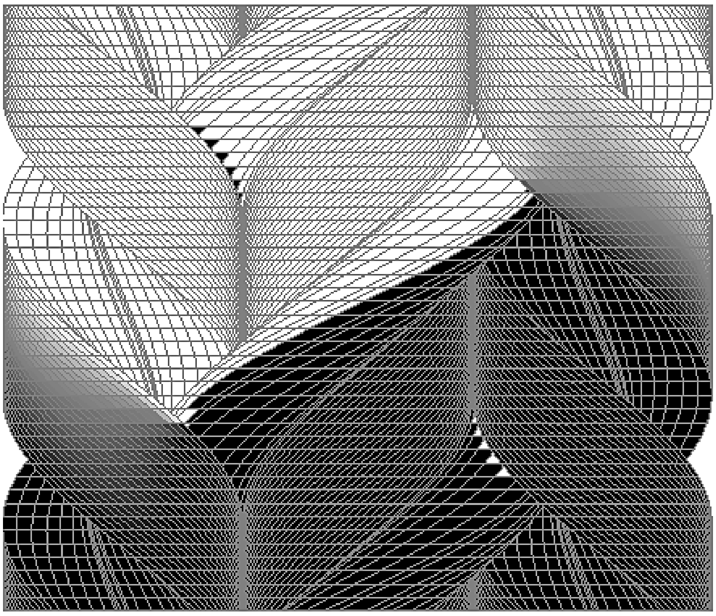

Figure 3: Load pressure distribution

Because of the similarity of every pressure step, it is not necessary to calculate all pressure steps in one model. The axial moment and the resulting forces are identic by calculating all differential pressure on one step /5/. Indeed energy conservation and axial load conservation over the cross-sectional area of the 3-spindlebore hole are fulfilled and the radial idle spindle load is validated to a high standard three-pitch CFD-solution.

On the other hand the journal bearing effect reaction force has to be calculated. Its also calculated on the rhombic sealing area on the exterior diameter of the idle spindle (**Figure 4**).

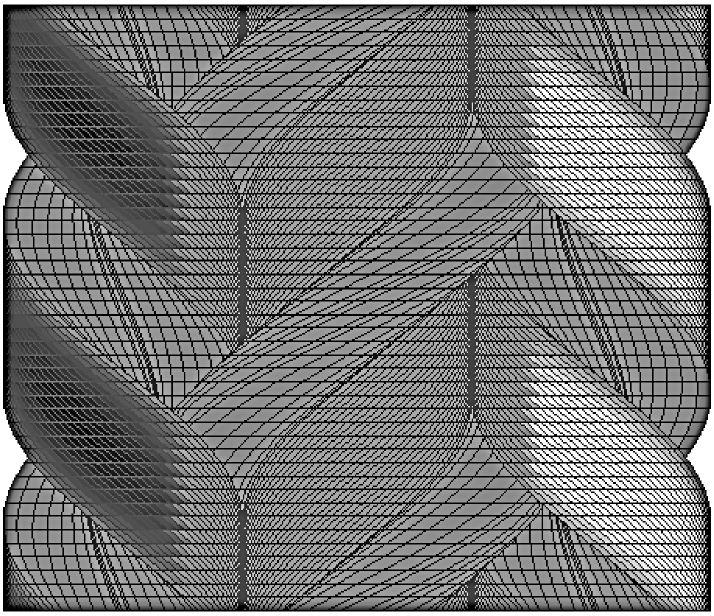

Figure 4: Journal bearing pressure distribution

Experimental setup

Former experimental studies by the authors leaded to the conclusion that the movement of the idle screw can't be understood as a rigid body movement /3/. Bending aspects have to be taken into account. Therefore a set of four inductive distance sensors was placed along the idle spindle axis. The axial distance of the sensors is equal to the pitch of the idle screw. The sensor head is embedded in a magnetic inert sealing elastomer plug, which is shaped to the casing contour. The sensor and the plug are hold in position by a brass screw (**Figure 5**).

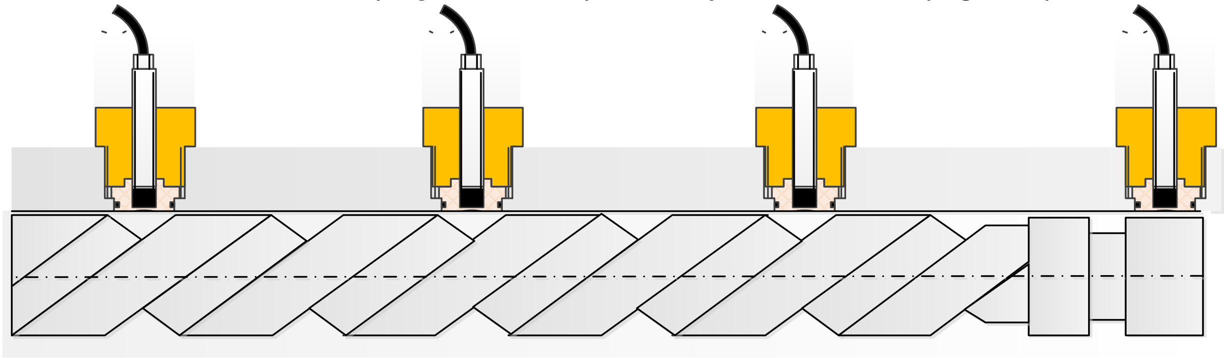

Figure 5: Axial sensor positions

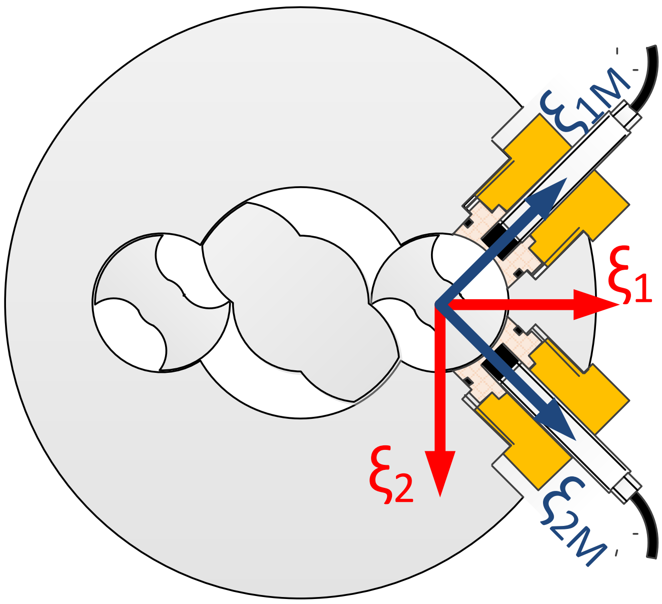

Figure 6: Coordinate systems, view from suction side

For horizontal and vertical displacement measurement the system is applied in two perpendicular measurement planes. (**Figure 6**). Due to the fact that an absolute changeless calibration of the center of the screw to the center of the housing is impossible, the origin of coordinates is defined by an initial point of operation, which has to be reproduced every measurement series. Experience shows that the measurement results are reproducible.

Experimental results

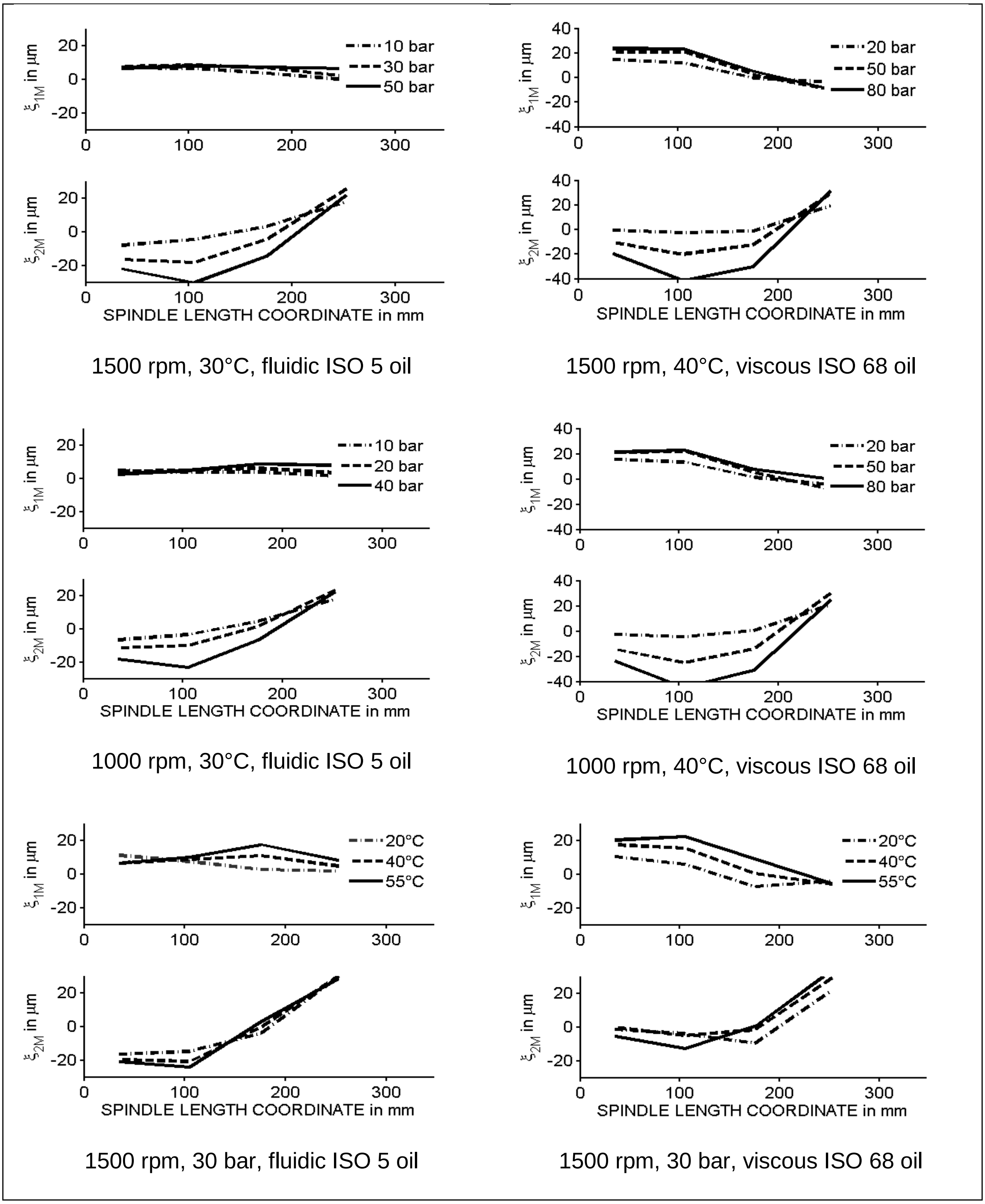

Figure 7: Idle spindle bending lines for various operation points

The displacement results are shown in **Figure 7**. The bending lines are constructed by four supporting points corresponding with the sensor positions. With increasing differential pressure the spindledislocates from the load-free center position. By increasing rotating speed and viscosity the idle spindle centers again. The idle spindle displaces to the upper sensor row under load and bends away from the lower sensor row towards the drive spindle. Bending is obvious, due to the fact, that the bending line is not linear, as it would be in case of rigid body displacement. The measurements were made for various rotating speeds, pressure differences, temperatures and with two different hydraulic fluids /6/.

Operation Limit Program

To get a forecast of pressure operation limit for a given viscosity and rotating speed the attainable jounal bearing reaction force for a minimal exeptable housing gap, defined bei the surface routhness of the spindle and the housing is calculated iterative, so that the force direction of the reaction gets the same as the later calculated pressure force. The radial pressure action force is calculated for 1 MPa differential pressure at first, and scaled to the pressure difference to get action and reaction force balanced. So in the end,we get the operation limit pressure.

An important assumption is coming from the experiment: Because of the weakness of the spindle it is not possible to get the pressure load beared over the whole length of the spindle. Inlet and outlet areas of the profile that have not closed chambers cannot be used as bearing systems. Even exterior jounal bearing flanges at the endings will have low effect on the bearing capacity. So the conservative assumption was made, that every pitch has to carry its own load. This whole process was optimized to a calculation time of about 20 seconds on a standard personal computer.

Conclusion

The paper shows measurements and approaches leading to an operation limit model predicting pressure operation limits that seem to fit quite well to the experimental experience. In the next step the operation limit of an existing pump will be measured for various critical operation points systematically and compared to the model calculating with measured clearance information of the same pump.

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Bibliographic details

/1/ Bevern, S., Thurner, J., Pelz, P., Holz, F.: Das dynamische Betriebsverhalten von Schraubenpumpen – ein neuer innovativer Berechnungsansatz, 8. VDI-Fachtagung Schraubenmaschinen, 2010

/2/ Bevern, S: Spaltströmungen und daraus resultierende Kräfte bei Spindelpumpen, TU Darmstadt, Bachelorarbeit, 2009

/3/ Rossow, P: Experimentelle Untersuchung der Verlagerung gleitgelagerter Schrauben-pumpen-Rotoren, TU Darmstadt, Bachelorarbeit, 2011

/4/ Spurk, J., Aksel, N.: Strömungslehre, Einführung in die Theorie der Strömungen, 7 Auf-lage, Springer-Verlag Berlin Heidelberg, 2007

/5/ Hamelberg, F: Läuferkräfte bei Schraubenpumpen, Dissertation Technische Hochschule Hannover, 1966

/6/ Stockert, S: Experimentelle Untersuchung der Biegelinie gleitgelagerter Schraubenpum-pen-Rotoren, TU Darmstadt, Bachelorarbeit, 2012

/7/ Thurner, J., Pelz, P., Holz, F.: Experimental and theoretical studies of the displacement and bending of a hydrodynamic supported idle spindle of a three-spindle screw pump, 8th International Fluid Power Conference, 2012

/8/ Leistritz Pumpen GmbH, L3M-F series

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