Static and Dynamic Characterization of Hydrostatic Bearings with Micro Gap Sizes

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INSTRUCTIONS
Hydrostatic bearings with gap sizes between 20 and 50 µm are state of the art in precision machine applications. Smaller gap sizes would improve the stiffness, the damping and the power consumption. This paper presents an experimental and a theoretical analysis of hydrostatic bearings with micro gap sizes of 5 µm in comparison to standard hydrostatic bearings.

DESIGN OF THE TEST BENCH
The company KERN developed a test bench for the experiments. Within this test bench a static load up to 6 kN per pocket and a dynamic load of 150 N peak to peak with a frequency of 1500 Hz can be applied. An attached PC records the supply pressure, the pocket pressure, the gap size and the applied load. The forces are applied parallel. A preloaded package of disc springs delivers the static load. A piezo actuator with a stiff coupling applies the dynamic load, see figure 1. This parallel force design allows high static forces and a wide frequency range of the dynamic force.

The manufacturing tolerances in hydrostatic bearing with micro gap sizes are very small and therefore hard to manufacture. There is a big risk of non parallel bearing surfaces resulting in a non parallel gap. For this reason a self align concept has been chosen with three pockets in an isosceles triangle. The pockets surfaces are lapped to a flatness of less than 1 µm over the whole surface. Because of the small face of the bearing, the gap of one pocket is parallel within 1 µm. The bearing face is guided by a leaf spring. This guidance has a low influence to the measured dynamic behavior of the hydrostatic gap.

The design of the test bench is modular, so the bearing pocket module can be changed as well as the compensating devices. Therefore it is possible to experiment with infinite stiffness devices, capillary restrictor and diaphragm valves.

FIGURE 1. Hydrostatic test bench

CAPABILITIES OF THE TEST BENCH
Before the characterization the capability of the test bench has to be evaluated. The force frame and the measurement frame are not fully decoupled. To measure the correct stiffness, the stiffness of the combined frame is mapped and compensated.

For the evaluation of the dynamic capabilities of the test set up, the bearing face is turned down into contact situation. In this position the transfer function from the piezo force with an amplitude of 200 N to the displacement sensor is measured, see figure 2. The bode plot shows a horizontal line up to a frequency of 1250 Hz. At higher frequencies, system resonances of the test bench are distorting the measurement. The measurements in this area are not useful for the dynamic characterization. The phase shows a delay characteristic.
STATIC ANALYSIS
For the static analysis different static loads are applied to the hydrostatic gap. The displacements are measured. The following compensating devices are analyzed:

- Capillary restrictors with operating points at 5 µm and 20 µm
- Infinite stiffness device with a operating points at 5 µm and 15 µm

For all these devices the theoretical predictions fit well with the measured data, see the example in figure 3.

DYNAMIC ANALYSIS
For the dynamic analysis a static preload and an additional dynamic load are applied to the hydrostatic gap. The resulting displacement is measured. The transfer function is calculated by the time series. The theoretical predictions are done by a dynamic simulink model of the hydraulic and mechanical system. The modelling follows the approaches of Winterschladen [1] and Pollmann [2]. Figure 3 shows the dynamic stiffness of a hydrostatic gap at its operating point of 20 µm. The red line is the theoretical prediction and the blue line represents the measured data. The prediction works well at low frequencies near the static stiffness. Also the squeeze damping at 100 to 1000 Hz is well predicted. The damping and the resonance between 10 to 100 Hz are not well predicted.

CONCLUSION
This paper presents the design and the capabilities of a test bench for the characterization of hydrostatic bearing with micro gap sizes. It shows also dynamic and the static characterization of hydrostatic gaps in comparison to the theoretical prediction. The static prediction works well for standard and for micro gaps. The dynamic stiffness prediction has to be improved, especially for the application to micro gap sizes.

REFERENCES