

Preload and alignment mechanism for large scale aerostatic bearing

Jesper Riihola¹, Onni Leutonen¹, Mikael Miettinen¹, Raine Viitala¹

¹Aalto University

jesper.riihola@aalto.fi

Abstract

Deflection compensated nip rolls are used in the paper industry to press and calender paper. Currently, hydrostatic oil bearings are used to load the roll shell internally to counterbalance the external load and reduce roll from deflection. Recent studies aim to replace hydrostatic oil bearings with aerostatic bearings. An experimental deflection compensated roll with aerostatic bearings has been developed in previous work. The present work further develops the preload mechanism for the bearings to provide better alignment with the guide surface. The existing loading element consists of an air bladder that keep the bearings pressed against the inner surface of the roll. A new bearing design and loading mechanism was developed. The friction and load capacity of the bearing system was measured. The results show an improved performance of the modified preload system at an industrially feasible load.

Gas bearing, paper industry, deflection compensated nip roll

1. Introduction

The pulp and paper industry is a significant part of the overall energy consumption in Finland [1]. Of the industrial energy consumption, it represents more than half and of the total energy consumption about 25 percent [1]. This is not only limited to Finland as other countries also spend a major part of their energy consumption on the pulp and paper industry. Sweden spends almost 50 percent of their yearly industrial energy consumption on the pulp and paper industry [2]. In Germany the pulp and paper industry is in the top five of the highest energy consumers of the total industrial energy consumption [3].

Calendering is one of the manufacturing steps in paper production. In calendering, the paper web is run through a nip, two rolls pressed against each other. This pressing ensures that the paper web has a consistent thickness across the length and improves the surface finish. The lower roll is equipped with deflection-compensation components. The deflection compensation is commonly achieved with hydrostatic bearings which press against the inside of the hollow nip roll.

Currently, the bearings use oil in the lubrication between the loading shoe and the nip roll. By lowering the viscosity of the oil from 100 to 68 cSt a decrease in the waste energy of around 70 kW was made [4]. If a lubricant with an even lower viscosity were used the savings in waste energy could be even greater. The replacement of hydrostatic bearings with porous aerostatic bearings in deflection compensated rolls has been proposed [5,6].

Aerostatic bearings utilize externally supplied pressurised gas which is fed through a restrictor that distributes the pressure. The distributed pressure creates a thin air film between the bearing and counter surface that is usually between 5 µm to 20 µm [7].

This study aims to further develop the aerostatic loading element developed by Harding [5] by replacing the preload bladder mechanism with a pneumatic cylinders, increasing the surface area of the two bearings, and removing the loading chamber in the middle of the bearings. The setup is validated by

measuring the loading force and friction between the bearing and a hollow roll.

2. Methods

2.1. Bearing unit and preload mechanism

Bearings consisted of aluminium bodies with integrated air supply channels. The graphite restrictors for both bearings were machined from a single piece of electrical discharge machining electrode graphite to avoid variation in the permeability between the two restrictors. The machined porous graphite restrictors were bonded to the bearing bodies with an epoxy adhesive. After the adhesive had cured, the remaining of the graphite was machined to match the inner radius of the nip roll. The bearings were then ground against the inner surface of the roll lined with abrasive film in steps of decreasing particles size of 100 µm, 30 µm, 15 µm, and 9 µm. A finished bearing is presented in Figure 1.



Figure 1. A bearing finished with abrasive film installed in the measurement setup.

The preload mechanism utilised two 200 mm pneumatic cylinders, one for each bearing, to simultaneously load the bearings against the inside of the hollow roll on the opposite sides. The measurement setup is presented in Figure 2. Each of the pneumatic cylinders were mounted to the measurement

setup with a flexure system. The flexures enable the vertical and horizontal loads to be measured separately.

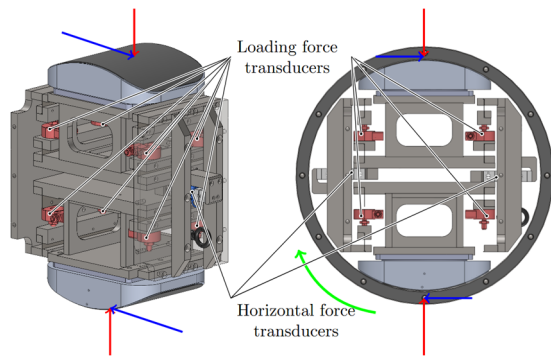


Figure 2. The measurement setup developed by Harding [5]. Figure modified from [5]. The red arrows represent the vertical loading reaction force and the blue arrows the horizontal reaction force. The green arrow indicates the roll rotation.

2.3. Measurement procedure

The setup was tested with loads ranging from 1000 N to 25 000 N with 1000 N increments by adjusting the pressure in the pneumatic cylinders. For the graphite restrictor a supply pressure of 0.8 MPa was used for all the measurements. For each measurement point the data was recorded for 10 s.

The coupling between horizontal and vertical loading force was measured on a stationary roll at each of the load steps. Then the roll was rotated at 756 rpm, and the measurements were repeated. The mean value of the measurement was then used for the given increment. For each measurement the preload force, for both the top and bottom bearing, as well as the horizontal force was measured.

3. Results and discussion

3.1. Static coupling between vertical preload and horizontal force on a stationary roll

The preload force caused some horizontal force which can be seen in the horizontal load measurements at each load increment in Figure 3. This coupling could be caused by the bearings not being in the vertical centre line of the roll which causes a horizontal component when the load is applied. Additionally, the roll was not perfectly round which could cause some alignment error in the bearings.

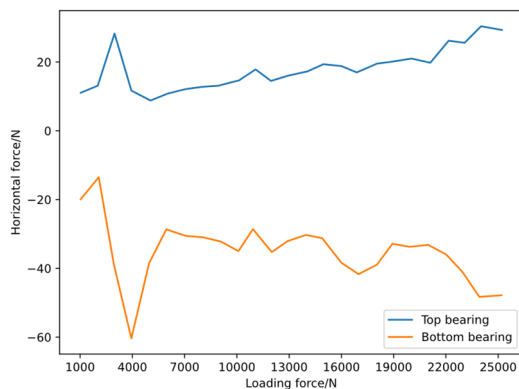


Figure 3. Coupling between the vertical preload force and the measured horizontal force for each force increment from 1 000 N to 25 000 N.

3.2. Horizontal force with rotating nip roll

The measurement result of the horizontal force with varying vertical loading force is presented in Figure 4. The horizontal

force was relatively steady up to a loading force of 15 000 N for the top bearing and 19 000 N for the bottom bearing was reached. Further increasing the load, the horizontal force increases for both bearings. Maximum load of 20 000 N was reached when the bearings made contact with the roll. This was presumably caused by the overloading of the bearings due to the imperfect opposing surface of the roll. The inside of the roll was not ground after previous destructive testing where the load on the bearing was increased until a bearing failure. This could have a negative impact on the load carrying capacity of the bearings as the gap between the bearing and the opposing roll surface is not consistent across the bearing surface.

The measured horizontal force indicates low level of friction. The negative horizontal load values are presumably caused by the coupling of the vertical load to the horizontal force measurement.

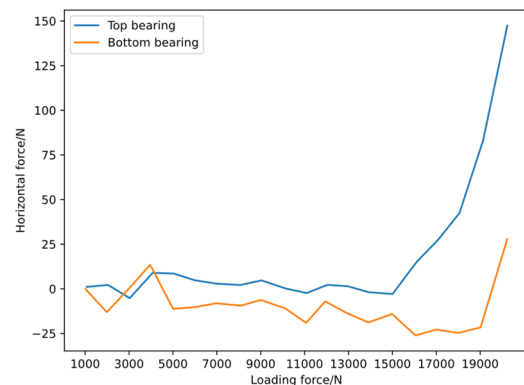


Figure 4. The horizontal force as a function of the loading force for both the top and bottom bearing.

4. Conclusions

The developed preload mechanism improved the maximum force by eliminating leakage. The loading mechanism was able to produce a larger loading force while maintaining alignment with the inner surface of the roll. The horizontal load measurement results indicate low level of friction. However, the coupling of applied vertical load to the horizontal load measurements suggest further research is required.

The premature failure of the bearings was likely caused by the damaged surface of the roll. By resurfacing the inside of the roll, the bearings could be able to withstand even greater loads without contact.

5. Acknowledgements

The research was funded by Business Finland (Better bearing, seal and vibration technology, grant number 1740/31/2025).

References

- [1] Enerdata 2024 Finland energy report. URL: <https://www.enerdata.net/estore/country-profiles/finland.html>.
- [2] C. Stenqvist, J. Nilsson, K. Ericsson. G. Modig 2011 Energy management in Swedish pulp and paper industry-the daily grind that matters
- [3] L. Vogel, M. Neumann, S. Linz 2023 Calculation and development of the new production index for energy-intensive industrial branches
- [4] Valmet 2019 Significant energy savings with oil viscosity upgrade
- [5] L. Harding 2025 Porous aerostatic bearings for paper machine roll deflection compensation, Master's thesis, Aalto University
- [6] J. Majuri 2023 Robust aerostatic bearing for large rotor, Master's thesis, Aalto University
- [7] Gao Q, Chen W, Lu L, Huo D, Cheng K 2019 Aerostatic bearings design and analysis with the application to precision engineering: State-of-the-art and future perspectives *Tribology International* 135 pp 1-17