Loading device for a paper machine roll

Introduction

The behavior of a paper machine rotor under dynamic loads caused by the paper track has significant impact to the paper quality as well as the efficiency and reliability of the process. Especially vibration of the rotor causes many troubles in paper manufacturing process, and the constantly increasing quality requirements of paper leads to higher quality requirements of critical rotor components as well. In this context, the bearings of the rotor are the most critical component, since they sustain the vibration coming from the rotor. The vibration of the rotor effects to eg. homogeneous thickness, surface quality and fine structure of the paper been processed. Also for the sake of cost-effect construction and manufacturability of the rotor, understanding this behaviour is important.

Paper industry is still a remarkable field in Finland, as the total production in 2016 was over ten million tonnes, from which 9,6 million tonnes went to export. Paper consumption globally has steadily risen, and in 2017 the consumption was 407 million tonnes. /1/

The objective of this research project is to measure vibration qualities on the rotor under constrained load caused by the paper track. A point loading device is built for this purpose. It will be studied, how the transform of the loading case and the damping effect of the paper track is affecting the amplitude of the rotor on different rotational speeds. Also the feasibility of the point loading device is computationally validated if it corresponds to real-world continuous force -loading case.

Current research is done without the constrained load of the paper track. The paper track load is a significant factor in real-world paper machines, and the past experiments related to rotor vibration could be replicated with the load present.

Viitala has showed in his doctoral dissertation the effect of bearing geometry on subcritical rotor vibration. During the machining of bearing rings clamping causes differences in in inner ring thickness. This excites vibrations on subcritical speeds. Measurements have been made without rotor loading. /2/

Kiviluoma et.al. have developed a method for in situ runout measurement of large cylindrical rotors. The method enables measuring thermal bending or so-called polygon effect in running rolls. /3/
Juhanko et.al. have pointed out that rotor wall thickness variation can cause dynamic geometry change. This change can be misinterpreted as either unbalance or half-critical vibration. /4/

Kurvinen et.al. have studied in which use cases complex and computational heavy bearing models should be used instead of simple models on order to get results accurate enough. /5/

The fundamental theory behind this phenomena is harmonic excitation of damped system. The loading belt can be seen as a viscous damper.

Fourier transformation is used to shift from time domain to frequency domain in order to find periodic phenomena.

Methods

The testing setup consists of a paper machine rotor, supported by two roller bearings attached to the rotor from both ends. The custom made split bearing housings stand on rigid steel jacks, which are fastened to guiding rails on the machine foundation. The rotor is driven from the other end with an electric motor. The bearing type used on the setup is SKF 23124 CCK/W33 two row roller bearings.

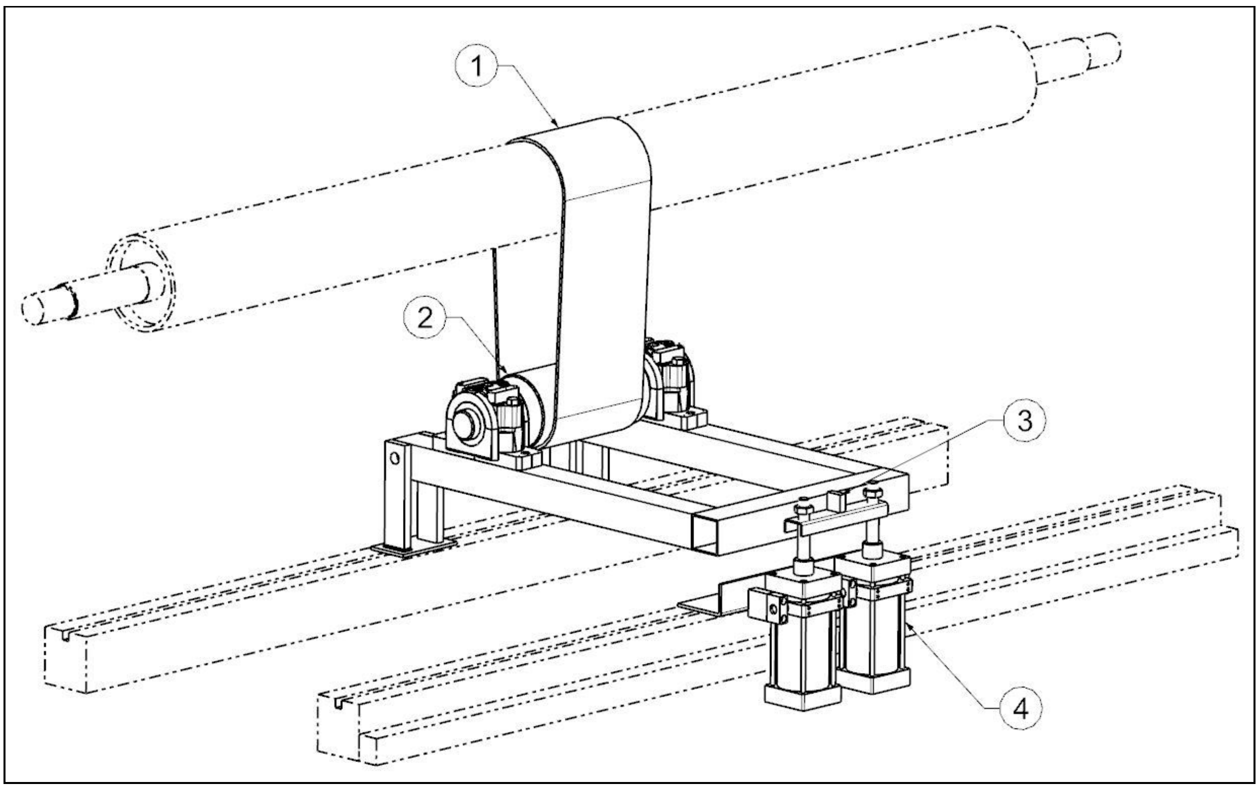
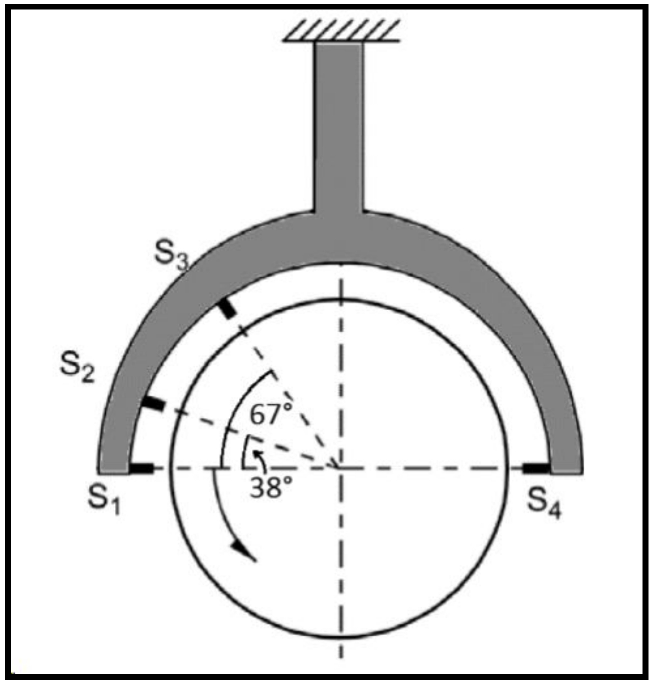


Figure X Loading device

On the testing setup there is a measurement instrument frame that can be lowered on top of the rotor to measure any deformations caused by spinning of the rotor structure. The measurement arrangement is a so called four-point method, in which four laser sensors divided around the spinning rotor to measure distance of each to the rotor surface.



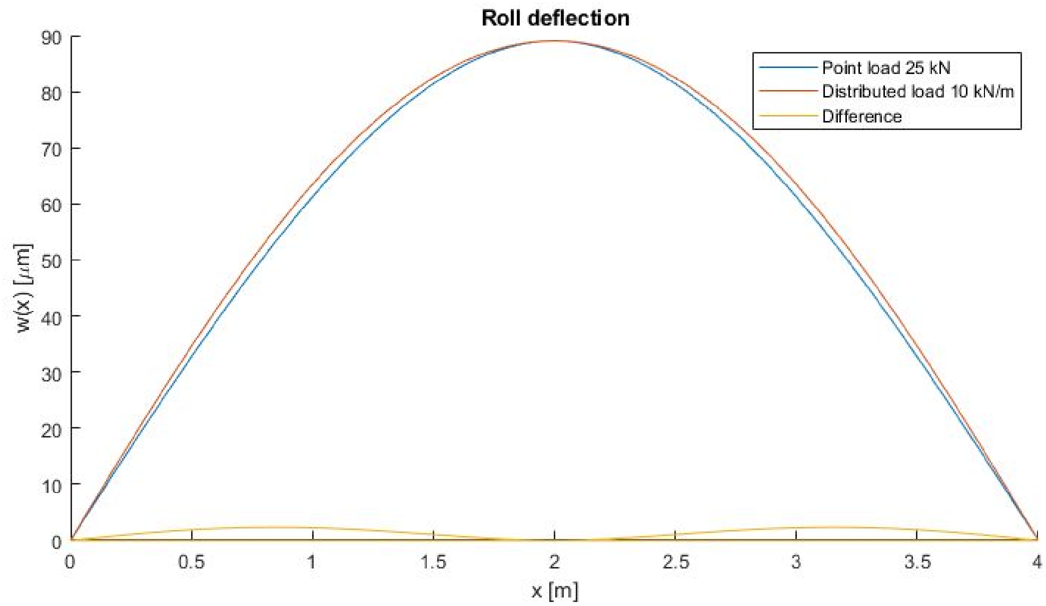
Four-point measurement (Viitala)

Four-point method combines common two-point method with newer three-point method used to measure roundness. Two point method can only be used for examining diameter variation, since it does not differ the surface waviness from center point variation. Three point method conversely separates the center point movement from the surface parameters, and thus can be used to examine those parameters. The sensors are placed as S1, S2 and S3 are on figure X. Mathematically deriving the surface parameters from individual sensor data is relatively complicated, and is not presented in this paper.

The bending modes due to bearing and rotor structure irregularities have been measured without any external load so far. In original use case the wire fabric tension may be as high as 10 kN/m. (Tuoko, p. 4). This gives a 40 kN uniformly distributed load in our case.

Full width loading was not used. Analysis of beams shows, that if a uniformly distributed load q_0 over a beam (length L) is replaced with a 5/8 * q_0 * L point force at the middle of the beam the maximum deflection is equal. For practical reasons a 400 mm flat belt was chosen to be used to transmit the load on the test rotor. FEM analysis shows, that 25,5 kN load gives approximately equal maximum deflection as a 40 kN distributed load or a 25 kN point load.

The rotor deflection with distributed load and point load and their difference as a function of the axial place on the rotor is shown in **µ**m in figure 1.



Vibrations are measured from rotating rotor similar as in Viitala's research, to maintain possibility to compare results to rotating roll without load. Measuring setup is shown in figure X. With four laser distance sensor (Matsushita NAIS LM 300) and incremental rotary encoder (Heidenhain ROD 420) it's possible to collect vibration data from rotating roll. Trough filtering and data acquisition we collect data with PC and LabView software. Laser measurement signal is amplified to correspond 1 volt is 1 mm. Signal is also filtered by low-pass filter from 1940 Hz frequency. This prevents aliasing in vibration data.

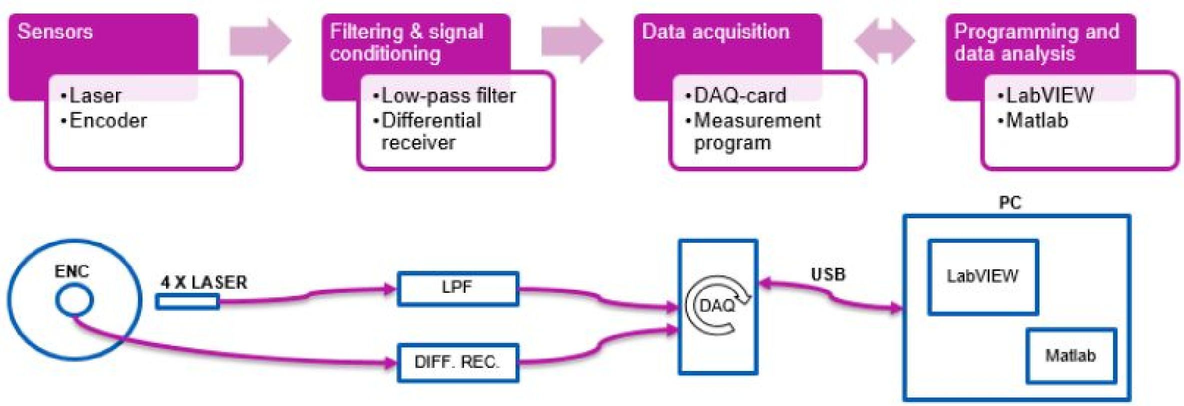


Figure X Vibrations measuring system (Viitala, p.37)

In our study we are examining how roll loading affects to vibrations, it's important control and measure loading force. Pneumatic cylinder produces force to tension belt. Cylinder is attached to arm which connects roll and cylinder. Shaft load cell is installed to cylinder arm connection pin. From arm geometric we can calculate belt tension force. Load [cell voltage] is measured with LabView. Cylinder pressure is controlled SMC electronic pressure controller which is connected to LabView also. We use LabView PID-controller to control pressure and therefore belt tension force. Pneumatic system is also equipped also with over pressure valve, because full pressure from test hall air grid (8 bar?) produces approximately 82 kN tension force to belt which damages belt.

Results

Discussion

References

/1/ https://www.forestindustries.fi/statistics/pulp-and-paper-industry/

/2/ Viitala, Raine. 2018. Effect of Assembled Bearing Inner Ring Geometry on Subcritical Rotor Vibration.

/3/ Kiviluoma, P., Porkka, E., Pirttiniemi, J.& Kuosmanen, P. 2010. ACCELEROMETER BASED IN SITU RUNOUT MEASUREMENT OF ROTORS.

/4/ Juhanko, J.; Porkka, E.; Widmaier, T.& Kuosmanen, P. 2010. EFFECT OF WALL THICKNESS VARIATION ON DYNAMIC GEOMETRY OF ROTATING CYLINDER.

/5/ Kurvinen, Emil; Sopanen, Jussi; Mikkola, Aki. 2015. Ball bearing model performance on various sized rotors with and without centrifugal and gyroscopic forces.