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# Multi-straw Compliant Full Film Bearing Supports

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The introduction of compliance in hydrostatic bearings allows them to track a varying curvature of the counter surface, and thereby increases their potential performance, design freedom, and range of applications. The embodiment of this compliance in which decoupled tubular elements are used, allows for the support stiffness to be specifically designed for a specific load case, taking the desired deformation of the support into account. This work introduces an analytical design model that can be used to determine support performance. A circular hydrostatic bearing pad is used as case study.

**Keywords:** compliant bearing supports, pressure profile matching, meta-materials, full film lubrication.

## 1. Introduction

A compliant full film bearing support allows for a wider operational range of the bearing design. This is especially useful when designing for non-flat counter surface. The side-effect of such a design choice however is that the film pressure starts to influence the deformation of the support itself. This effect, called compliant-hydrostatic pre-loading, can be minimized by matching the stiffness profile of the support to the pressure profile of the bearing [1]. This work presents a meta-material-based design for such a support, apply named a multi-straw support, because of its construction out of multiple tubes.

## 2. Methods

The pressure distribution of a circular hydrostatic pad in terms of the geometry and recess pressure as a function of the radial coordinate r can be expressed as

$$P = P_r \frac{\ln(\frac{R}{r})}{\ln(\frac{R}{R_r})}$$

where $R$ is the bearing radius, $R_r$ the recess radius, and $P_r$ the recess pressure. By knowing the bearing pressure profile, a support stiffness can be designed for a specified desired support deformation. Here this support stiffness is realized using a meta-material consisting out of decoupled compliant compression tubular elements. These elements are defined by their radial i and angular j indexes. This means that the local stiffness of the tube element $K_{el}^{i,j}$ can be defined by the load case as:

$$K_{el}^{i,j} = \frac{\int_{\theta_1}^{\theta_2}\int_{r_1}^{r_2} Pr\, dr d\theta}{\delta(r,\theta)}$$

Where $\delta(r,\theta)$ is the desired local compression and $\theta_1$, $\theta_2, r_1$ and $r_2$ define a discrete region of the bearing surface. It has been shown before that this discrete approach can be used to approximate a continuous case with a relatively low number of elements [1]. Secondly, because of the tubular elements used, this stiffness can be directly defined by the geometry as:

$$K_{el}^{i,j} = \frac{\frac{1}{4}E\pi(D_{ex}^{i,j} - D_{in}^{i,j})^2}{L_0}$$

With $E$ being the Young's Modulus of the tube, $D_{ex}^{i,j}$ the external diameter of the tubular element, $D_{in}^{i,j}$ its inner diameter and $L_0$ its length. The length is directly limited by the element buckling load, which can be improved by adding planar stiffeners. This set of relatively simple equations allow for an analytical design model for this type of support.

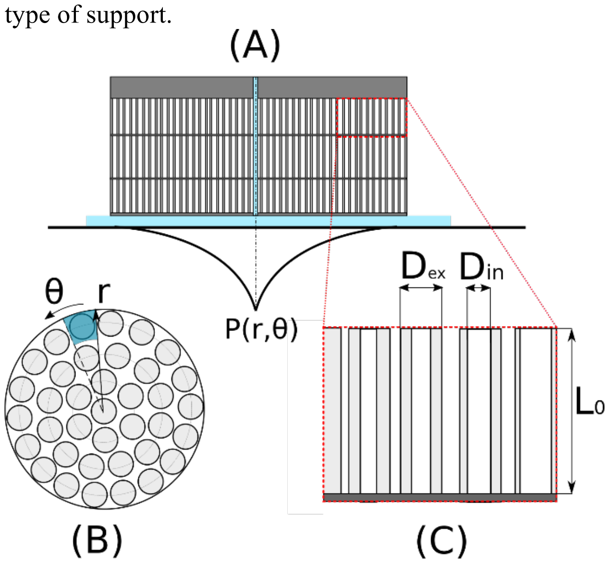


*Figure 1: (A) Circular pad multi-straw bearing support with planar stiffeners. (B) Bearing surface view with the location of the discrete elements. (C) Support design variables.*

## 3. Discussion

The use of decoupled elements in combination with the straight-forward realization of the desired stiffness allows for further improvement of compliant supports. The work will be expanded to determine the required discretization and stiffness performance of these support types. Finally, the model will be validated through numerical models and experiments.

## 4. References

[1] Nijssen, J.P.A., van Ostayen, R.A.J., Compliant Hydrostatic Bearings Utilizing Functionally Graded Materials, Journal of Tribology, 142(11), 2020.