Name:

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THE UNIVERSITY OF UTAH

Department of Mechanical Engineering
ME EN 7960 - Precision Machine Design

Problem Set 3 - Linear Bearing Selection

Assigned: Friday, October 27, 2006

Due: Friday, November 10, 2006, 4 pm in MEB 2110

Problem 1

A common configuration for the design of linear axes is the use of rolling element linear guides which are available as off-the-shelf components in a number of different sizes from a number of different vendors.

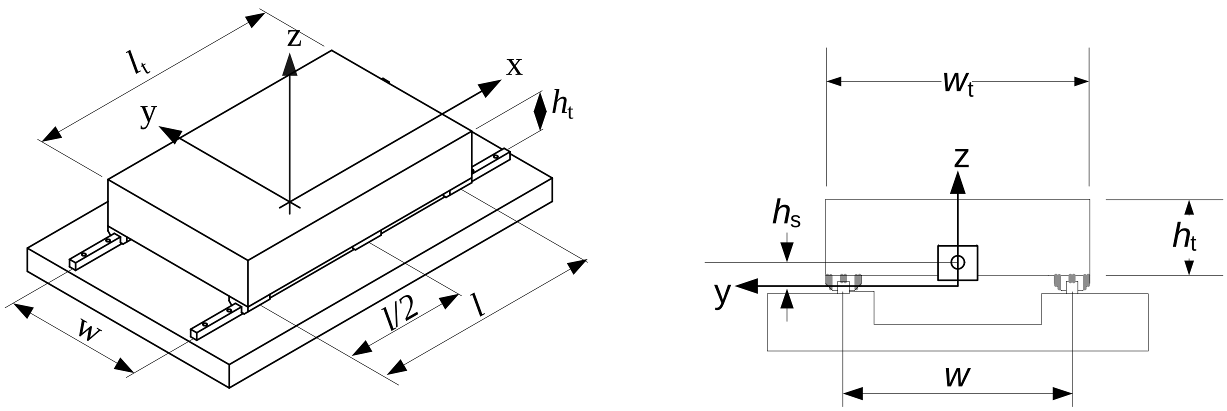

Figure 1 Linear axis consisting of 2 linear rails with 3 trucks each. The axis is driven by a ball screw.

a) Derive the stiffness matrix K (in analytical form) for the linear axis shown in Figure 1. Use the following assumptions:

- You may assume that the axis consists of 6 identical linear bearing trucks whose lateral stiffness k_h and vertical stiffness k_v can be modeled as linear springs.
- You may further assume that the table of this axis is significantly more rigid than the bearings, allowing you to model the table as a rigid body.
- Include a ballscrew with rigidity k_s that is mounted along the x-axis at point $S(0,0,h_s)$.

b) Derive the mass matrix for this linear axis (in analytical form) and determine the natural frequencies of the systems.

Problem 2

To assist in the otherwise tedious process of bearing selection, you are asked to develop an electronic tool (e.g. Microsoft Excel) that contains a number of standard bearing sizes (see Table 1) and calculates all relevant parameters. For the linear axis shown in Figure 1, the tool needs to have the following abilities:

- Use 6 identical linear bearings that are arranged as shown in Figure 1 whose lateral and vertical stiffness are modeled using linear springs.

- Allow a 3D load be applied to the axis at any point.
- Determine the displacement of any point of the axis in 3D.
- Determine the stiffness of any point of the axis.
- Determine the loads onto the bearings.
- Determine the bearing life.
- Estimate the natural frequencies of such a system.
- Provide a boolean check of the bearing life based on the following input parameters: Machining speed, required lifetime.

TABLE 1 THK SR Linear Bearings

Size	Radial Dynamic Load Rating C [kN]	Radial Static Load Rating C_0 [kN]	Vertical Stiffness [N/μm]	Horizontal Stiffness [N/μm]
15	5.39	11.1	360	263
20	7.16	14.4	455	350
25	11.7	22.5	581	416
30	17.2	32.5	679	441
35	23.8	44.1	827	555
45	55.3	101	1125	737
55	89.1	157	1369	847

TABLE 2 THK SR Basic Load Ratings in Various Directions

Model No.	Direction	Basic Dynamic Load Rating	Basic Static Load Rating
SR 15 - 70	Radial (= vertical down)	C	C_0
	Reverse Radial (= vertical up)		$C_{0,RR} = 0.5C_0$
	Lateral		$C_{0,L} = 0.43C_0$

TABLE 3 THK SR Equivalent Factor

Model No.	P_E	X	Y
SR 15 - 70	Equivalent load in radial direction	1	1.155

Problem 3

Using the tool in Problem 2, analyze the following proposed design for the THK SR 35:

a) Provide the compliance matrix (in numerical form).

b) What are the displacements at the point of load application?

c) What is the stiffness in x, y, and z at the point of the load application?

d) What is the maximum equivalent load on the bearings?

e) What is the lifetime of the bearing that has the largest equivalent load? Use an application factor of 1.5.

f) What are the first three resonance frequencies?

g) Provide a printout of your electronic tool that answers the above listed questions.

TABLE 4 Data

Parameter	Value	Parameter	Value
Table length l_t	500 mm	**Bearing spacing l**	450 mm
Table width w_t	300 mm	**Rail spacing w**	250 mm
Table height h_t	300 mm	**Ballscrew rigidity k_s**	280 N/µm
Table density	7850 kg/m^3	**Ballscrew mount in x**	0 mm
Point of applied load in x	200 mm	**Ballscrew mount in y**	0 mm
Point of applied load in y	100 mm	**Ballscrew mount in z**	-30 mm
Point of applied load in z	300 mm	**Applied load in x**	1000 N
Machining speed	0.5 m/min	**Applied load in y**	1000 N
Required life	40,000 hrs	**Applied load in z**	1000 N