Name:

ID #:

Department of Mechanical Engineering
ME EN 7960 - Precision Machine Design

Problem Set 1 - Homogenous Transformation Matrices

Assigned: Wednesday, September 6, 2006

Due: Wednesday, September 13, 2006, 4 pm in 2110 MEB

Problem 1

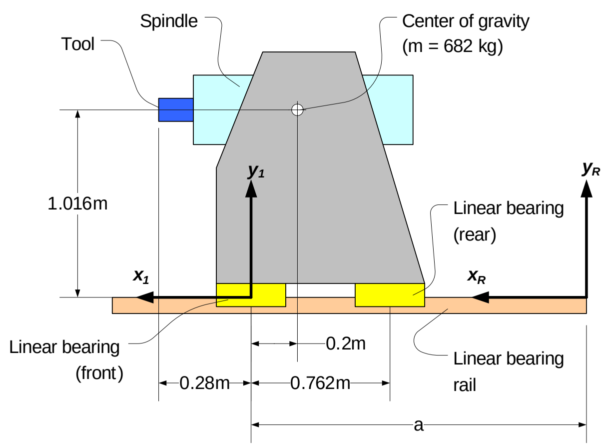

Figure 1 Linear axis

The linear axis shown in Figure 1 consists of two linear bearing trucks, a spindle with a mass *m* of 682 kg, and a carriage which can be treated as being weightless. The linear bearings can be treated as linear springs with a vertical stiffness of 350 E6 N/m.

a) Derive the homogenous transformation matrices required to determine the error that can expected at the tool tip (0.28m, 1.016m)? Determine the error at the tool tip as a result of gravity.

b) If the axis was calibrated after assembly to eliminate the effects of gravity but is now subject to a 0.5 g acceleration in the positive x-direction, what is the resulting error at the tool tip?

Problem 2

Figure 3 shows an assembly of two linear axes that are stacked up and perpendicular to each other, thereby providing the ability to position the work piece holder in the x-y plane of a machine tool. The y-axis is mounted on top of the x-axis. The offsets shown in Figure 3 show the starting positions of both axes.

a) For the 5 rail grades available, determine the maximum error (measured at the center of the work piece holder) as a result of geometric errors of the linear rails. Assume that the rails are straight (not bowed), but non-parallel. For the rail orientation for each axis refer to Figure 4.

Geometric details:

- The A axis coordinate system at the starting point is located at (550 mm, 150 mm, 450 mm) with respect to X_R, Y_R, Z_R.
- The B axis coordinate system at the starting point is located at (0 mm, 100 mm, -250 mm) with respect to X_A, Y_A, Z_A.
- The location of the work piece is (200 mm, 115 mm, 325 mm) with respect to X_B, Y_B, Z_B.

Problem 3

Assume that you are operating on a limited budget that allows you to only buy one pair of precision grade rails while the second pair would have to be a normal grade (regardless of length).

a) On which axis would you mount the precision grade and on which axis the normal grade?

b) What would be the difference in errors if you had the setup reversed? Determine the numerical value.

Problem 4

If the rails are not straight as in Problem 2 but bowed as shown in Figure 2, how would you have to modify the approach used in Problem 2 to arrive at a reasonable estimate in terms of error motions?

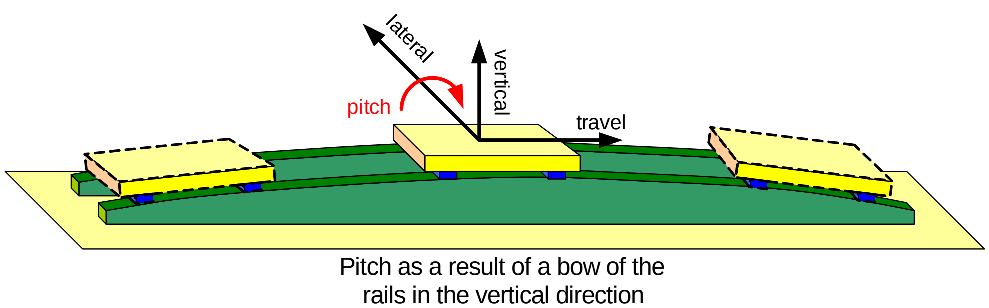

Figure 2 Non-straight bearing rails

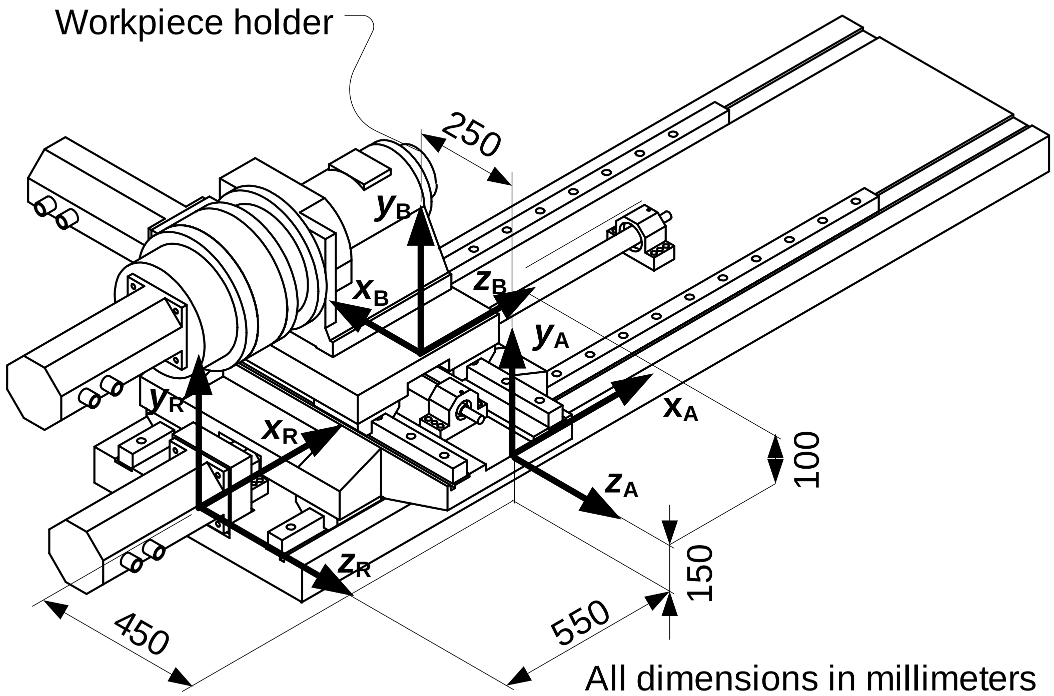

Figure 3 Stacked axes

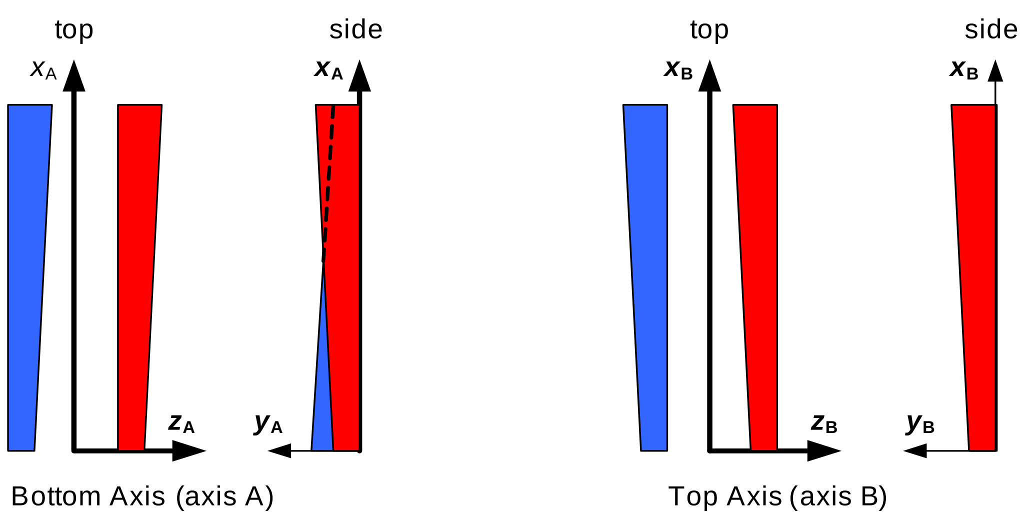

Figure 4 Arrangement of non-parallel rails

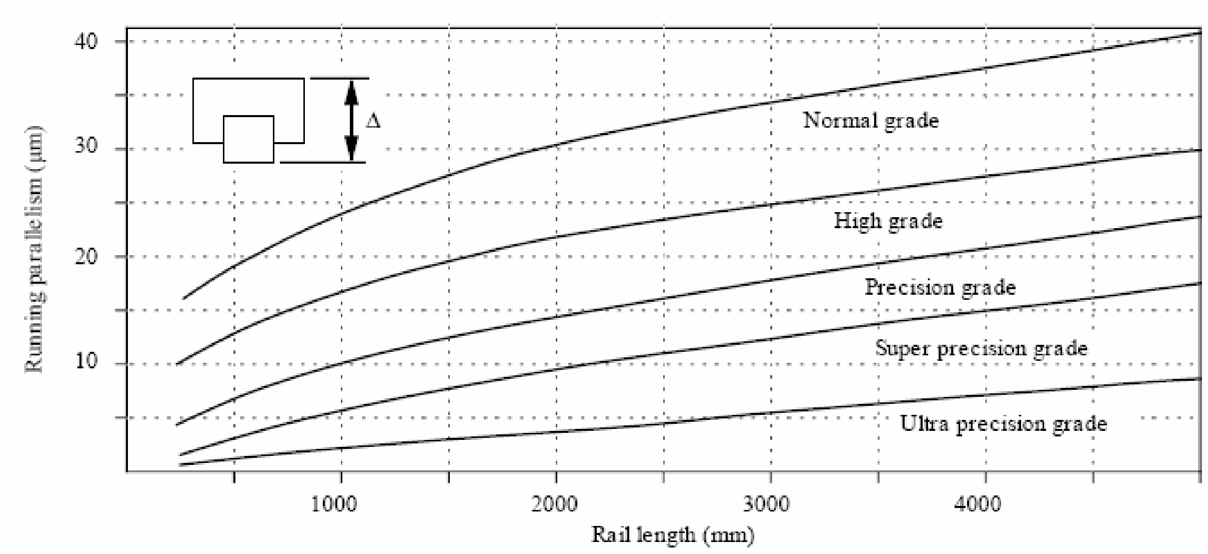

TABLE 1 Machine Data

Parameter	Value	Parameter	Value
axis A travel	1250 mm	axis B travel	350 mm
axis A rail spacing	350 mm	axis B rail spacing	250 mm
axis A bearing spacing	450 mm	axis B bearing spacing	300 mm