

1. Midterm - Solutions

Note Title

9/25/2006

Problem 1

What is backlash and why is it important to eliminate it?

a) backlash is the lack of immediate engagement inside motion elements that causes delays upon reversal of direction. This delay makes accurate servo control difficult and may cause unexpected motion of machine components.

b) Features of compressive preloading:

This is typically achieved with a double nut that contains an undersized spacer which forces the two nuts to be closer together than determined by the thread. As a result, both nuts are always in contact with the thread of the shaft on both sides.

The two nuts are arranged in a front-to-front setup which reduces the nut's ability to resist a moment.

This setup is thermally stable for the case that the nut is at a higher temperature than the shaft.

c) Additional advantage:

- Increased stiffness

Disadvantage

- Increased friction
- Increased heat generation
- Reduced load capacity

Problem 2

$$k_N = 200 \frac{\text{N}}{\mu\text{m}}$$

$$k_B = 95 \frac{\text{N}}{\mu\text{m}}$$

$$d_{tr} = 14.5 \text{ mm}$$

$$k_{axial} = 50 \frac{\text{N}}{\mu\text{m}}$$

$$\frac{1}{k_{axial}} = \frac{1}{k_N} + \frac{1}{k_B} + \frac{1}{k_S} \quad \text{where } k_S = \frac{A \cdot E}{l_b}$$

$$\frac{l_b}{A \cdot E} = \frac{1}{k_{axial}} - \frac{1}{k_N} - \frac{1}{k_B} \quad \rightarrow l_b = A \cdot E \left(\frac{1}{k_{axial}} - \frac{1}{k_N} - \frac{1}{k_B} \right)$$

$$\rightarrow l_b = \frac{\pi d_{tr}^2}{4} \cdot E \left(\frac{1}{k_{axial}} - \frac{1}{k_N} - \frac{1}{k_B} \right)$$

$$= \frac{\pi \cdot (0.0145 \text{ m})^2}{4} \cdot 207 \cdot 10^9 \frac{\text{N}}{\text{m}^2} \left(\frac{1}{50 \cdot 10^6 \frac{\text{N}}{\text{m}}} - \frac{1}{200 \cdot 10^6 \frac{\text{N}}{\text{m}}} - \frac{1}{95 \cdot 10^6 \frac{\text{N}}{\text{m}}} \right)$$

$$= \underline{\underline{0.153 \text{ m}}}$$

Problem 3

rotary encoders

- easy to install on the back of the motor
- inexpensive
- accuracy is limited by
 - axial compliance of ballscrew assembly
 - torsional compliance of the ballscrew assembly
 - thermal expansion of the shaft and nut
 - accuracy of the shaft
 - cost not affected by lengths of travel
 - unlimited travel
 - easy to shield and seal

linear encoders

- needs room to install
- not affected by any of the above errors
- typically limited travel
- seals increase friction
- requires precise alignment between read head and encoder strip

Problem 4

a) possible ball screw support configurations

① fixed-free, fixed-supported, fixed-fixed

b) discuss differences in terms of cost and performance

cost: fixed-free is the least expensive method because it uses only one bearing block (instead of two). This requires less machining and is faster to assemble. fixed-supported is more expensive because it uses two bearing blocks, which also requires more machining (assembly surface). The assembly is fairly simple.

fixed-fixed is the most expensive method because it uses two bearing blocks and requires great care during assembly.

performance:

- 1) stiffness: fixed-free and fixed-supported achieve comparable axial stiffness. Fixed-fixed is considerably stiffer.
- 2) rotational speed: fixed-free has the lowest allowable speed, followed by fixed-supported. Fixed-fixed allows the highest speed.

3) buckling: fixed-free allows the lowest axial load due to buckling, followed by fixed-supported. Fixed-fixed will buckle at much higher loads.