B-2-1.4 Automatic lead accuracy measuring system of NSK

In response to the demand for high precision in production technology, NSK is the first in the world that developed and uses "Lead Accuracy Measuring System (LAMS)." Lead accuracy is measured by the system that employs a laser interferometer measuring instrument and a personal computer.

Fig. 1.4 shows the lead accuracy measuring system. The inspection date of the ball screw is shown in Fig. 1.5. The laser interferometer measures either ball nut travel accuracy or lead accuracy of the ball thread. The data which are input into a computer are processed into four characteristics readings regarding lead accuracy. (See Page B41.)

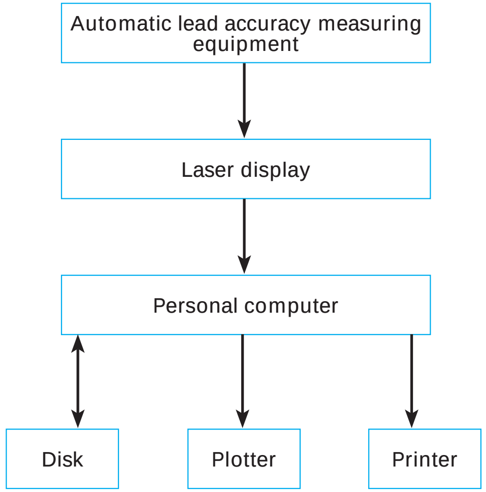

Fig. 1.4 Lead accuracy measuring system

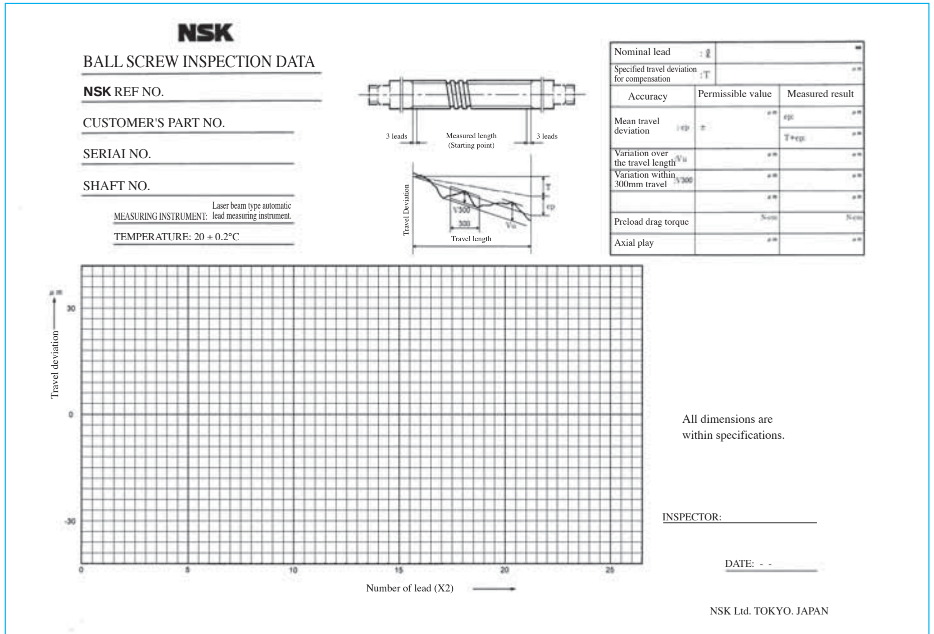

Fig. 1.5 Ball screw Inspection data

B-2-2 Static Load Limitation

Ball screw, based on its function, will generally receive axial load only. Ball screw shaft in general is long, so it is necessary to consider 3 items below:

- Buckling load of the screw shaft
- Yielding of the screw shaft by tensional or compressive stress
- Permanent deformation at the ball contact points

B-2-2.1 Buckling Load

It is necessary to calculate whether the ball screw shaft is safe against buckling.

Buckling load, i.e. permissible compressive load "P" to axial direction, is calculated as follows.

$$P = \alpha = \frac{N \bullet \pi^2 \bullet E \bullet I}{L^2} = m\,\frac{d_r^{\,4}}{L^2} \times 10^4 \quad \text{(N)} \cdots\cdots (\text{Ⅱ-2})$$

In this formula:

α : Safety factor (α = 0.5)

E : Elastic modulus (E = 2.06 x 10^5 MPa)

I : Moment of inertia

$$I = \frac{\pi}{64} d_r^{\,4} \quad (\text{mm}^4) \cdots\cdots (\text{Ⅱ-3})$$

d_r : Screw shaft root diameter (mm) [See the dimension table.]

L : Unsupported length (mm) [See Fig. 4.1 and 4.2 'Supporting conditions of screw shaft and nut' in Page B55.)

m, N : Factors determined by the supporting condition of the ball screw shaft

Table 2.1 Factors of bucking load

Supporting condition	m	N
Fixed - Fixed support	19.9	4
Fixed - Simple support	10.0	2
Fixed support - Free	1.2	0.25
Simple - Simple support	5.0	1

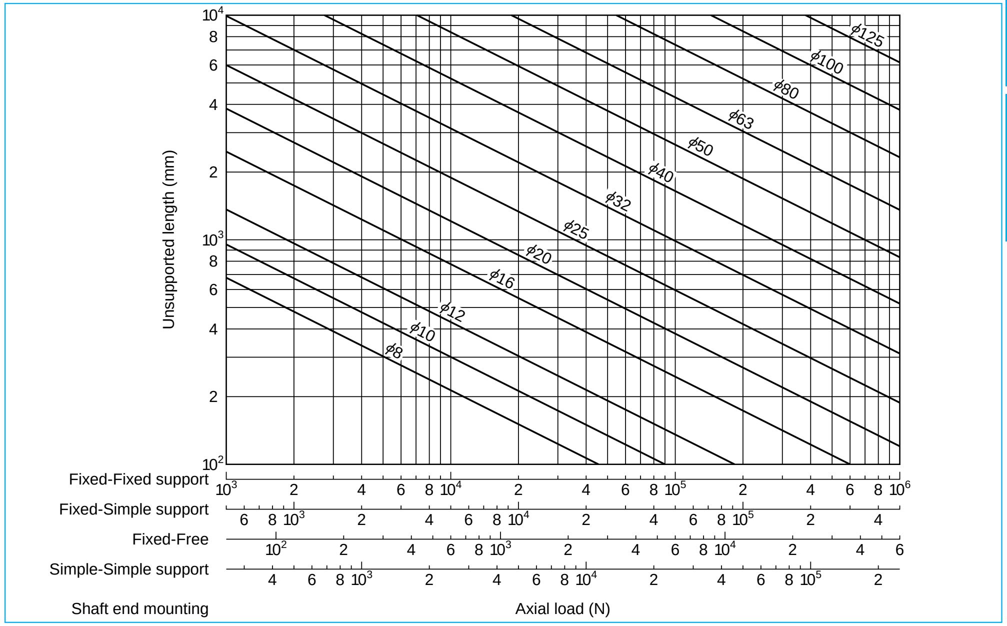

Fig. 2.1 Buckling load

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<<Calculation example of buckling load>>

Calculate buckling load under the conditions in Fig. 2.2.

<Use conditions>

Nut model: DFT4010-5

Supporting condition is Fixed - Fixed support (From the supporting condition (ii) in Fig. 4.1 'Supporting conditions of screw shaft and nut' in Page B55.)

Unsupported length L = 2000 mm

Screw shaft root diameter d_r = 34.4 mm (From the dimension table)

<Calculation>

Support condition is Fixed - Fixed support, From Table 2.1 in Page B48

N = 4

m =19.9

By Formula (Ⅱ-2) in Page B48

$$P = m\frac{d_r^4}{L^2} \cdot 10^4 = 19.9 \times \frac{34.4^4}{2000^2} \times 10^4 = 69667 \text{ (N)}$$

Therefore,

Permissible buckling load P = 69600 N

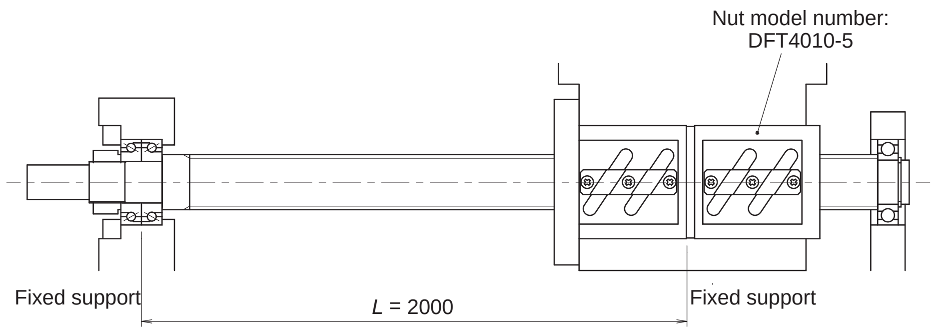

Fig. 2.2 Calculation example of buckling load

B-2-2.2 Yield by Tensional/Compressive stress

It is necessary to consider permissible load in regards to the yield stress.

Permissible load "P" by tensional or compressive stress to screw shaft is

$$P = \sigma \cdot A = 1.15 d_r^2 \times 10^2 \text{ (N)} \qquad (\text{Ⅱ-4})$$

In this formula:

σ : Allowable stress (= 147 MPa)

A : Cross section area of a screw shaft using root diameter (mm^2)

$$A = \frac{\pi}{4} \cdot d_r^2 \text{ (mm}^2\text{)} \qquad (\text{Ⅱ-5})$$

d_r : Screw shaft root diameter (mm)

<<Calculation example of yield load>>

Obtain load in respect to the allowable stress under the conditions in Fig. 2.2.

<Use conditions>

Nut model: DFT4010-5

Screw shaft root diameter d_r = 34.4 (mm)

(From the dimension table)

<Calculation>

By Formula Ⅱ-4

$P = 1.15 d_r^2 \times 10^2 = 1.15 \times 34.4^2 \times 10^2$

= 136086 (N)

Therefore,

Permissible load P = 136000 N

B-2-2.3 Permanent Deformation of the Ball Contact Point

Exposed to an excessively heavy load in axial direction, the balls are squashed, and the ball rolling surface is dented. The deformations on these points do not perfectly restore to original shape after the load is removed. They are permanently disfigured. It is necessary to determine the limitation of this disfigurement to containing it within a certain range.

(1) Basic static load rating C_{0a}

Basic static load rating C_{0a} is a load to axial direction that results in the combined permanent deformation equal to 0.01% of the ball diameter at the contact points of ball and ball grooves of the screw shaft and nut.

(2) Calculation of permissible load by C_{0a}

P_o (allowable axial direction load to limit the permanent deformation) is calculated using C_{0a}.

$$P_0 = \frac{C_{0a}}{f_s} \text{ (N)} \qquad (\text{Ⅱ-6})$$

In this formula, f_s: Static permissible load factor

Table 2.2 Static permissible load factor

At time of normal operation	1 – 2
With vibration impact	1.5 – 3

<<Calculation example of maximum allowable load>>

Obtain maximum allowable load to the ball groove section under conditions in Fig. 2.2

<Use conditions>

Nut model: DFT4010-5

Basic static load rating C_{0a} = 137000 (N)

(From the dimension table)

Static permissible load factor f_s = 2

(normal operation, no vibration impact)

<Calculation>

By Formula Ⅱ-6, maximum allowable load of the ball groove section

$$P_0 = \frac{C_{0a}}{f_s} = \frac{137000}{2} = 68500 \text{ (N)}$$