On a viscous damper for a two-component dynamometer

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On a Viscous Damper for a Two-Component Dynamometer

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SUMMARY. In the Laboratory for Production Engineering at the Eindhoven University of Technology, a dynamometer has been developed for measuring cutting and feed forces during turning operations.

Actually, the dynamometer works with a thin-walled tube. The elastic deformation of the tube due to the named forces is measured with the aid of strain-gauges.

The first natural frequency of the dynamometer is at approximately 1·5 kHz with a quality q of 38.

In order to decrease this q-value, a viscous damper was added. This lowered q to 3. Thus, the dynamometer mentioned is more suitable for dynamic measurements up to 3 kHz.

RESUME. Au laboratoire de technologie mécanique de l'Université d'Eindhoven on a développé un dynamomètre pour mesurer l'effort de coupe et d'avance lié aux opérations de tournage. Le dynamomètre est constitué par un tube à parois minces dont la déformation élastique est mesurée à l'aide de jauges extensométriques. La première fréquence naturelle du dynamomètre est approximativement de 1·5 kHz et son facteur de qualité est de 38. Pour réduire cette dernière valeur jusqu'à 3, on a ajouté un amortiseur. De cette façon, le dynamomètre peut fonctionner en mesure dynamique jusqu'a 3 kHz.

ZUSAMMENFASSUNG. Zur experimentellen Bestimmung der Schnitt- und Vorschubkräfte beim Drehen wurde im Laboratorium für Fertigungstechnik der Technischen Hochschule Eindhoven ein Kraftmeßgerät entwickelt. Die Messung beruht auf der elastischen Dehnung eines dünnwandigen Rohres, die mit Dehnungsmeßstreifen gemessen wird. Die erste Eigenfrequenz des Gerätes liegt bei 1·5 kHz. Bei Resonanz beträgt der Vergrößerungsfaktor 38; er kann durch Verwendung eines Schwingungsdämpfers auf 3 herabgesetzt werden. Daher eignet sich der Kraftmesser für dynamische Messungen bis 3 kHz.

INTRODUCTION

THE dynamometer consists of the toolbit-holder, a thin-walled tube with strain-gauges, and a stiff after body which can be clamped in a housing (see Fig. 1). The after body contains compensating strain-gauges and electrical terminals. The dynamometer can be cooled with water.

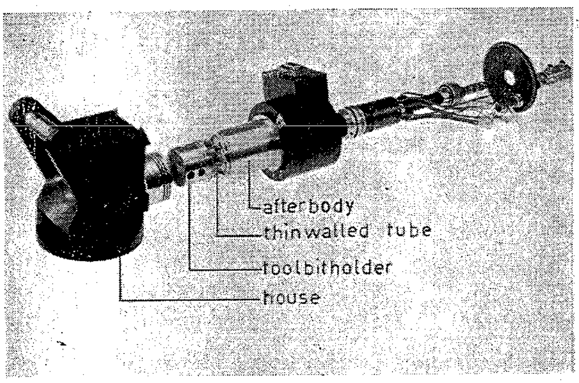

Fig. 1. *Photograph of dynamometer.*

The housing in which the body is clamped, has a calibration feature. It consists of two earshaped flanges connected by a grooved bar. In this groove, a lever can pivot. By placing calibration weights on one end of the lever, known forces act on the dynamometer through a self-centering thrust-rod near the other end of the lever.

SPECIFICATIONS OF THE DYNAMOMETER

Measuring range:	0 to 10000 N (both directions)
Sensitivity:	0·26 μstrain/N (both directions)
Hysteresis:	less than 1%
Mutual influence:	less than 1·5%
Linearity:	better than 1%.

DESIGN OF THE DAMPER

A viscous damper was chosen in order to flatten the response curve of the dynamometer, because this type of damper could be conveniently integrated within the existing structure of the dynamometer. Furthermore, a viscous damper can be active in more than one direction.

The damper consisted of two concentric cylinders (see Fig. 2). Due to the construction of the dynamometer, the dimensions of the damper were

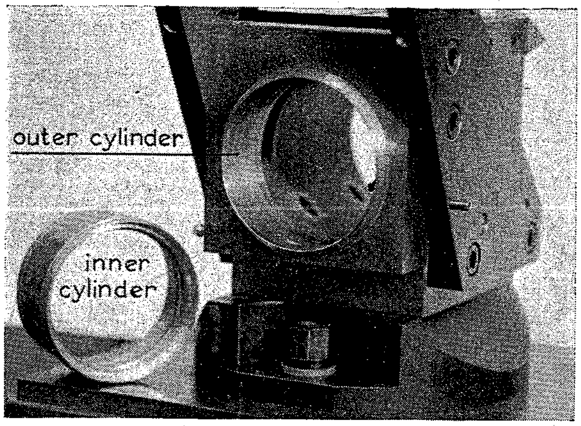

Fig. 2. Photograph of damper.

limited. The average diameter of the cylindrical gap was 82 mm, the length of the gap was 22 mm. The only variables of the damper were the thickness of the film and the oil viscosity.

In order to optimalize the damper with respect to these variables, a method described by Peters *et al.*[1] will be used. For the time being, the damper base is considered to be infinitely stiff (see Fig. 3).

It was found for the respective compliances (displacement to force ratios):

$$s_{11} = 20{\cdot}05 \times 10^{-9} \text{ m/N},$$
$$s_{12} = 8{\cdot}22 \times 10^{-9} \text{ m/N},$$
$$s_{22} = 4{\cdot}46 \times 10^{-9} \text{ m/N}.$$

The angular velocity at natural frequency $\omega_n = 9 \times 10^3$ rad/s. Now, the optimal value of the damping constant C can be found with equation (1)

$$C_{\text{opt}} = \left| \frac{s_{11}}{\omega_n(s_{12}^2 - s_{11}s_{22})} \right| \tag{1}$$

and is $C_{\text{opt}} = 0{\cdot}102 \times 10^6$ Ns/m. This is a high damping constant. The thickness of the oil film has to be made as small as possible and still there is need for an oil of high viscosity.

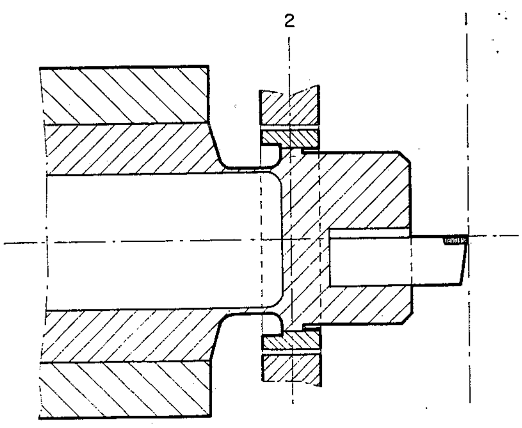

Fig. 3. Diagram of dynamometer and damper.

The damping constant for a pair of concentric cylinders can be computed as follows:

$$C = \frac{3\pi}{2}\eta\frac{D^4}{e^3}\left(\frac{L}{D} - \tanh\frac{L}{D}\right) \tag{2}$$

where

D = diameter of the oilring (m),
L = width of oilring (m),
e = thickness of the oilfilm (m),
η = oil viscosity (Ns/m^2).

Because of the displacement of the inner ring when the dynamometer is loaded, the thickness of the oil film must be at least 50 μm. Furthermore, it must be ensured that the damper rings are concentric when the dynamometer is typically loaded. The oil film thickness was selected as 60 μm and with equation (2) the C_{opt}-value for the oil viscosity is $\eta = 14 \text{ Ns/m}^2$. This is a very high viscosity; it corresponds to 15700 centi-stokes. For the initial experiments a silicon oil with a viscosity of about 12500 centi-stokes at 20°C was used.

Sealing the damper without introducing a significant spring constant was attained by mounting thin

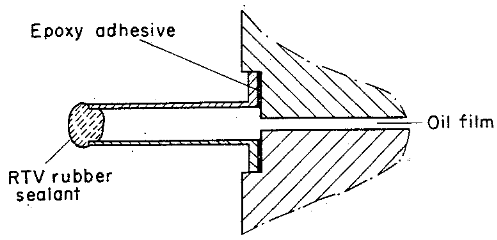

Fig. 4. Sealing of the damper.

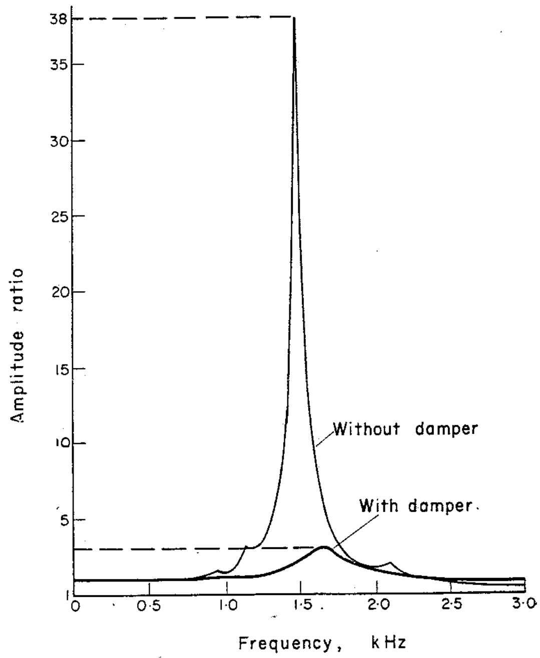

Fig. 5. Response of the dynamometer in cutting force direction.

protruding concentric flanges on the damper rings (see Fig. 4). The flanges were sealed with a ring of RTV silicone rubber sealant.

RESULTS

During the experiments, it was observed that the ear-shaped flanges were not as stiff as anticipated. Due to the great damping constant, the system of both ear-shaped flanges and connecting bar was closely coupled to the main vibrating system. This resulted in an upward shift of the original natural frequency and a q-value of about 10. By lowering the oil viscosity to 2000 centi-stokes, a q-value of 3 was attained. (see Fig. 5).

CONCLUSIONS

For purposes of dynamic measurements, a q-value of 3 at a resonance frequency of about 1·7 kHz is thought practicable. For still lower q-values, the damper base should be sufficiently stiffened and its final compliance be fed into the equation for C_{opt} [equation (1)].

REFERENCES

1. Peters, J., Vanherck, P. and Du Mong, W., Technical Note on Damping of Machine Tools. CRIF, December, Mc 23 (1967).