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ON A VISCOUS DAMPER FOR A TWO-COMPONENT DYNAMOMETER

by

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SUMMARY

In the Laboratory of 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.

ZUSAMMENFASSUNG

Zwecks experimenteller Bestimmung der Schnitt- und Vorschubkräfte bei Dreharbeiten, wurde im Laboratorium für Fertigungstechnik der Technischen Hochschule Eindhoven ein Kraftmessgerät entwickelt.
Taktisch grundet sich die Messung auf die elastische Dehnung eines dünnwandigen Messrohres, die mittels Dehnungmessstreifen gemessen werden kann.
Die erste Eigenfrequenz des Kraftmessers liegt annäherend bei 1,5 kHz. Die reduzierte Ausslagweite q bei Resonanz beträgt 38. Mittels eines visköze Schwingungsdämpfers konnte der q-Wert zwecksgemäss bis auf 3 herabgesetzt werden.
Daher eignet sich der betreffende Kraftmesser für dynamische Messungen im Frequenzbereich bis 3 kHz.

RÉSUMÉ

Au Laboratoire de la Technologie Mécanique à l'Université Technique d'Eindhoven un dynamomètre pour mesurer des forces de cisaillement

et d'avance pendant des opérations de tournage est développé. Dans le fait le dynamomètre fonctionne avec un tube à paroi mince. La déformation élastique du tube à la suite des forces susdites est mesurée à l'aide des jauges de contrainte. La première fréquence naturelle du dynamomètre est approximativement 1,5 kHz d'une qualité q de 38. Pour réduire cette valeur q jusqu' à 3, un amortisseur a été ajouté. De cette manière le dynamomètre susdit est plus adapté aux mesures dynamiques jusqu' à 3 kHz.

INTRODUCTION.

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

The house 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 ÷ 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.

We choose a viscous damper in order to flatten the response curve of the dynamometer, because this type of damper could be conveniently integrated in the existing structure of the dynamometer. Furthermore, a viscous damper can be active in more than one direction.
The damper consists of two concentric cylinders (see Fig. 2).
Due to the construction of the dynamometer, the dimensions of the damper are limited. The average diameter of the cylindrical gap is 82 mm, the length of the gap is 22 mm. Now, the only variables of the damper are the thickness of the film and the oil viscosity.
In order to optimalize the damper with respect to these variables, we will use a method described by PETERS, VANHERCK and DU MONG {1}.
For the time being, we consider the damper base to be infinite stiff (see Fig. 3).

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

$$s_{11} = 20.05 \times 10^{-9} \text{ m/N},$$
$$s_{12} = 8.22 \times 10^{-9} \text{ m/N},$$
$$s_{22} = 4.46 \times 10^{-9} \text{ m/N}.$$

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

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

We find $C_{opt} = 0.102 \times 10^6$ Ns/m. This is a high damping constant. We have to make the thickness of the oilfilm as small as possible and still we will need an oil of high viscosity.
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 oilfilm must be at least 50 μm. Furthermore, it must be ensured that the damper rings are concentric when the dynamometer is typically loaded.
We chose e = 60 μm and found with Eq. (2) and the C_{opt}-value for the oil viscosity $\eta = 14$ Ns/m^2. This is a very high viscosity; it corresponds with 15700 centistokes. For the first experiments we used a silicon oil wit a viscosity of about 12500 centistokes at 20°C.

Sealing the damper without introducing a significant spring constant was attained by mounting thin protuding concentric flanges on the damper rings (see Fig. 4).
The flanges were sealed with a ring of RTV silicone rubber sealant.

RESULTS.

During our experiments, we observed that the earshaped flanges were not as stiff as anticipated.
Due to the great damping constant, the system of both earshaped 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 centistokes, 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 fase should be sufficiently stiffened and its final compliance be fed into the equation for C_{opt} (Eq.1).

REFERENCES:

{1} PETERS, J., VANHERCK, P. and DU MONG, W: Technical Note on Damping of Machine Tools. CRIF, December 1967 - Mc 23.

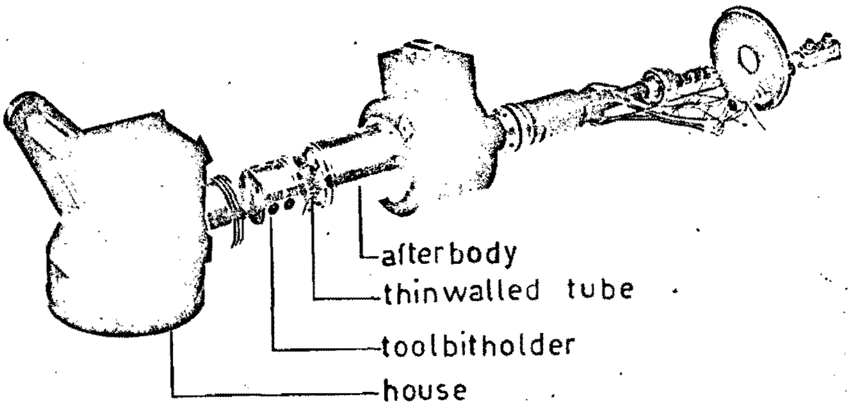

Fig. 1. Photograph of the dynamometer.

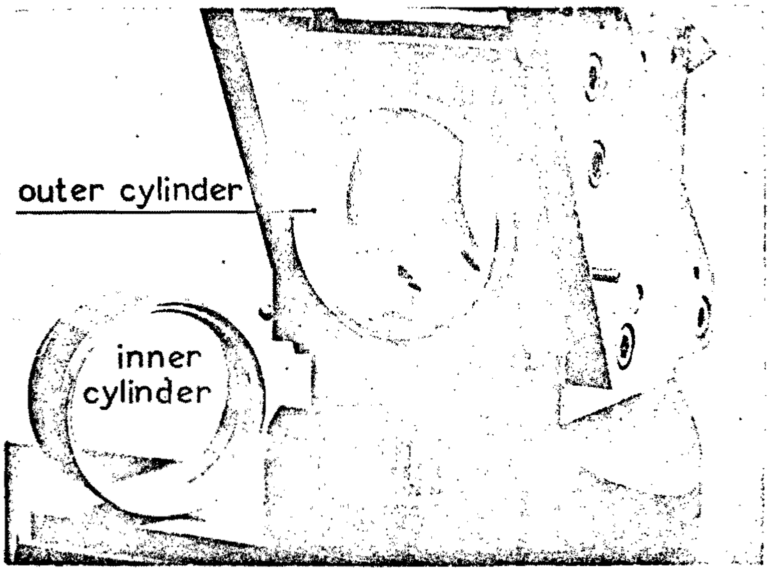

Fig. 2. Photograph of the damper.

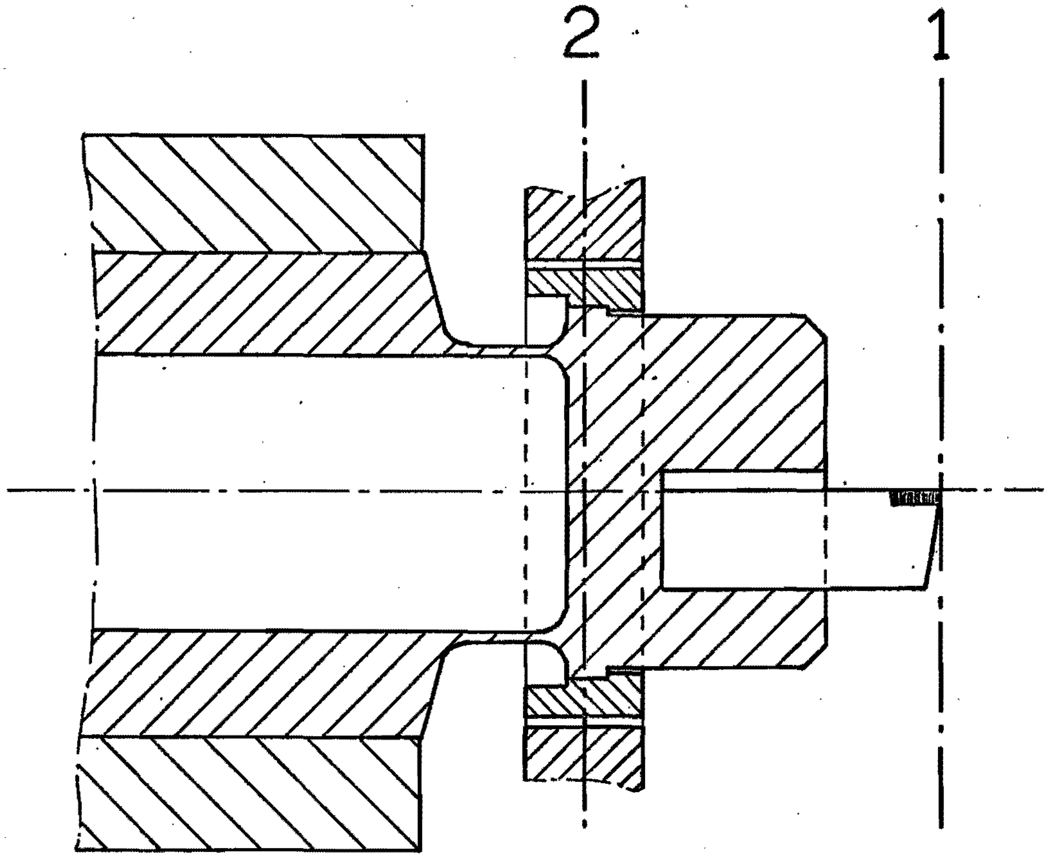

Fig. 3. Diagram of dynamometer and damper.

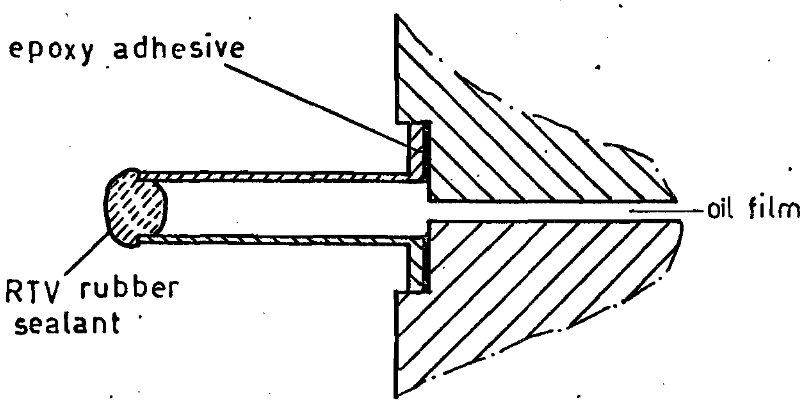

Fig. 4. Sealing of the damper.

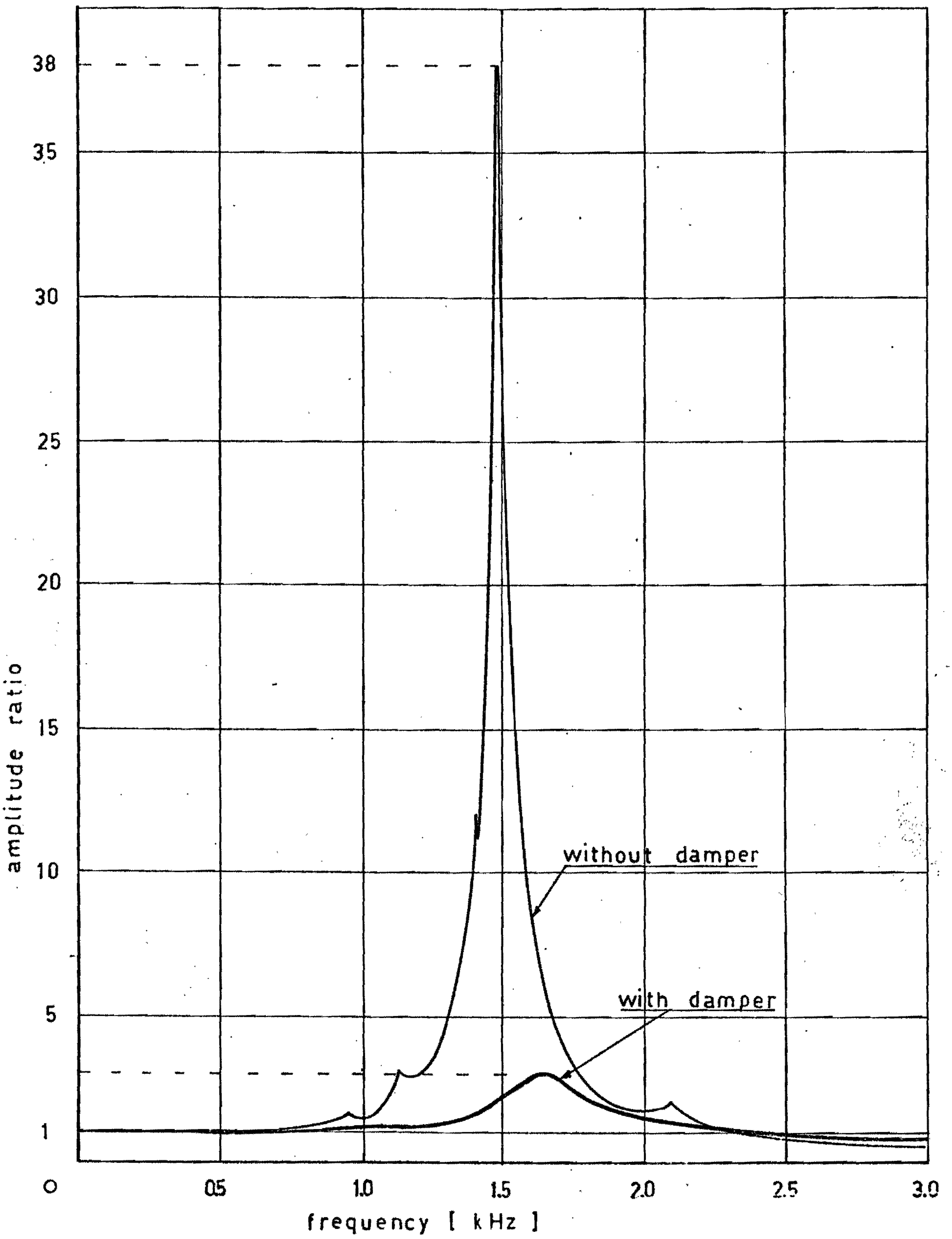

Fig. 5. Response of the dynamometer in cutting force direction.