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THE LONGITUDINALLY OSCILLATING RIBBON AS A SENSOR FOR MASS CHANGES IN CONTROLLED ATMOSPHERES

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ABSTRACT

If a ribbon of metal , plastics or fiber web is clamped at both ends and excited to perform longitudinal oscillations as an autonomous oscillator, the frequency changes in a reproducible manner with applied mass . This effect can be utilized to determine masses of condensed or adsorbed layers and precipitated particles. The measured values are indifferent to the density of the surrounding atmosphere.

INTRODUCTION

In former papers it could be shown, that the natural frequency of transversally vibrating thin ribbons depends on the mass of applied layers or particles. This enables continous sensitive mass determination. Ribbons as mass detectors are in so far advantageous, as the object can be preserved as a document and also later on analysed. [1] Fig. 1 shows the relations which are essential in this method. A disadvantage consists in the fact, that the density of the ambient gas influences the frequency of oscillation and therefore causes errors , if it changes without being noticed. This gave reason to consider the longitudinally oscillating ribbon as a device for mass determination.

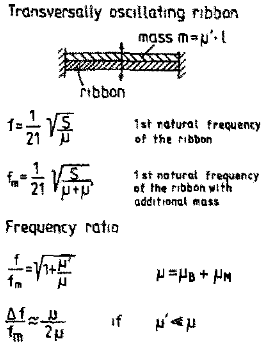

Fig.1

MEASURING RESULTS WITH THE TRANSVERSALLY VIBRATING RIBBON

Fig. 2 shows the frequency- mass relationship of a fiber band which was kept under constant tensile force and excited to perform transversal oscillations as an autonomous oscillator by electrostatic forces.
Provided , that the force is in phase with the velocity of oscillation, external and internal damping of the ribbon do not affect the frequency .
A sensitivity of 0,5 Hz /mg was obtained. [2]

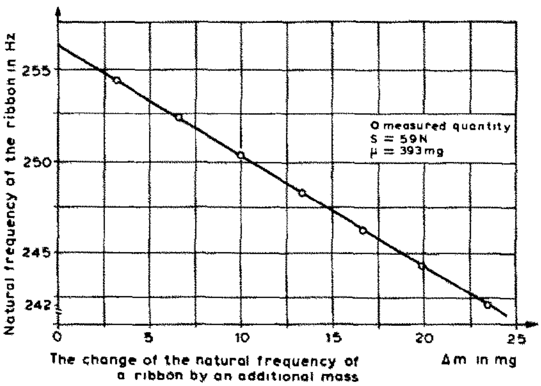

Fig.2 Transversally vibrating Filter Band

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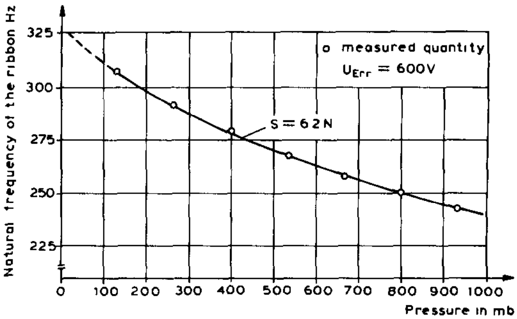
In **fig. 3** the dependance of frequency on pressure of the ambient air is presented. In measuring dust concentration, this influence can be canceled by taking frequency readings with and without precipitated particles and forming the ratio. If however, the atmosphere is a parameter in an experiment, as in sorption measurement or thermogravimetry, changes in gas density constitute a source of error



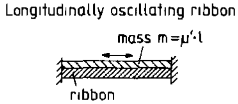
The influence of cooscillating air volume on the natural frequency of the ribbon

fig.3 Influence Of Ambient Air

DETERMINATION OF MASSES WITH THE LONGITUDINALLY OSSCILLATING RIBBON

The surface of a ribbon, oscillating in the longitudinal mode is coupled to the ambient gas only by shear forces, which do not induce frequency shifts.

Fig. 4 shows the relations involved. Experiments have been carried out with metal ribbons of various thickness. [2] The ribbons were excited at one end by a piezoelectric actuator and the oscillation at the other end was detected. by a piecoelectric receiver. Compared with the transversally vibrating ribbon, the longitudinally oscillating one has a by far higher natural frequency. The sensitivity depends on the mass of the unloaded band. With a metal ribbon of 0,1 mm thickness, a width of 10 mm and a length of 150 mm, a sensitivity of 20 Hz/mg was obtained as it is shown in **fig. 5**.
While tensile forces cause a decrease in frequency because of strain predominating over transversal contraction, Youngs modulus has a direct bearing on frequency.
In the course of development of a dust concentration meter, the experimental arrangement for this measuring technique was improved [3]. As **fig.6** shows, the ribbon is stretched between two clamping jaws, each connected to a pair of piezoelectric rings which are polarized in an opposite sense and work in push-pull action. One of the transducers excites the ribbon to longitudinal oscillations, while the other detects the forces which are produced by the ensuing standing waves.



$f = \frac{1}{2l}\sqrt{\frac{E}{\varrho}}$ 1st natural frequency of the ribbon

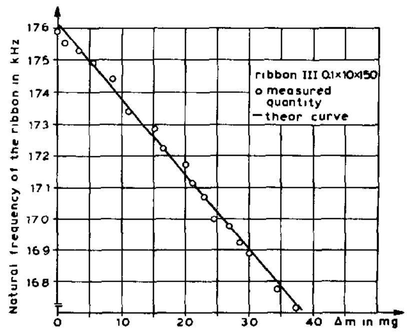
$f_m = \frac{1}{2l}\sqrt{\frac{m_B \cdot E}{(m+m_B)\varrho}}$ 1st natural frequency of the ribbon with additional mass

Frequency ratio

$\frac{f}{f_m} \sqrt{1+\frac{m}{m_B}}$

$\frac{\Delta f}{f_m} = \frac{m}{2m_B}$ if $m \ll m_B$

fig.4



The change of the natural frequency of a ribbon by an additional mass

fig.5 Longitudinaly oscillating Ribbon

The signal of the second transducer provides the information, whether the driving frequency is equal to the natural frequency of the ribbon . For this purpose, input voltage and output signal are compared with regard to phase with the aid of a discriminator , whose output voltage controls the frequency of the driving generator.
Desired value of the phase difference is 90°, it corresponds to a mode of oscillation with nodes in the points of fixation.
A band pass prevents the generation of higher harmonics, the amplitude is kept constant by feed back control.
Results of experiments with ribbons of metal, polycarbonate and glass fiber are presented in fig. 7 . The highest sensitivity , up to 35 Hz/mg, was attained with the glas fiber- ribbon, but thinner films of polycarbonate should enable even better results. Calibration was performed by affixing weighed zellophane stripes onto the sensor band.
From the partial differential equation for the longitudinally oscillating ribbon, the theoretical course of the sensitivity for the first and second harmonic was calculated and drawn in fig. 8.
If zellophane stripes of uniform mass are affixed one after another at various points of the ribbon, the measured sensitivity deviates from the calculated one only slightly in the points of maximum amplitude but strongly in the nodal points , where the values are negative.
This is due to the fact, that the resilience of the zellophane stripes has no considerable effect on frequency in the points of maximum amplitude, where the strain is minimal but a strong bearing on the frequeny in the nodes , which are distinguished by maximum strain.
If the ribbon consists of a pure metal, f.i. platinum, its temperature can be determined by measuring the electrical resistance. Variations of the modulus of elasticity with temperature can thereby be corrected. Mass determination by longitudinal oscillations can be combined with measurement of specific heat capacity with the aid of temperature fluctuations according to the method developed by Jacobs.[4]

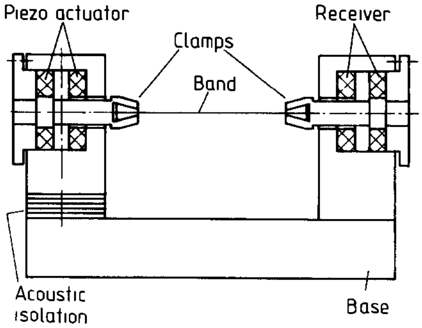


fig. 6 Experimental Set Up

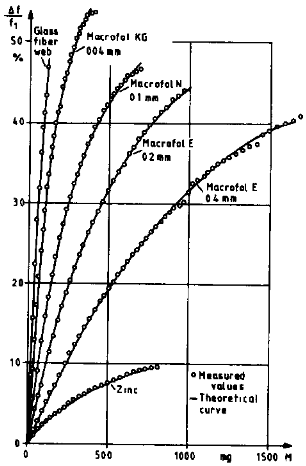


fig.7 Various Oscillating Ribbons

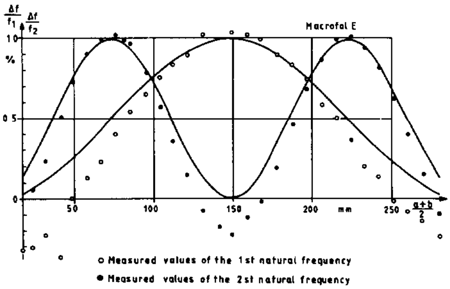


fig.8 Local Sensitivity

CONCLUSION :

Experiments have shown, that the longitudinally oscillating band is well suited as mass detector in controlled atmospheres.
Its natural frequency is sensitive to mass changes and indifferent to the density of ambient gases. Masses of continous layers and precipitated particles can be determined. In the region of maximum sensitivity, i.e. in the central part of the ribbon, the consistency of the affixed layers does not affect the frequency.

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