DRY FRICTION OF A SOLID BODY IN A ROTATING DRUM

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We analyze experimentally the dynamic behaviour of a solid body sliding within a rotating drum. Our prelimanary measurements indicate that the occuring dynamics can be divided into two regimes of different kinds of slip and/or stick oscillations. For the interpretation of our results a modified *Coulomb* friction law must be considered.

Introduction

Friction has an important influence on the flow behaviour of granular matter. For a quantitative understanding exact data on the slip- and stick friction properties are necessary. A convenient way of measuring higher order corrections to the *Coulomb* friction law is provided by observing a sliding particle in a rotating drum. A fascinating feature of this experimental setup is that small changes of the underlying friction law lead to qualitatively different dynamical behaviour of the particle.[1,2,3]

Experimental Setup

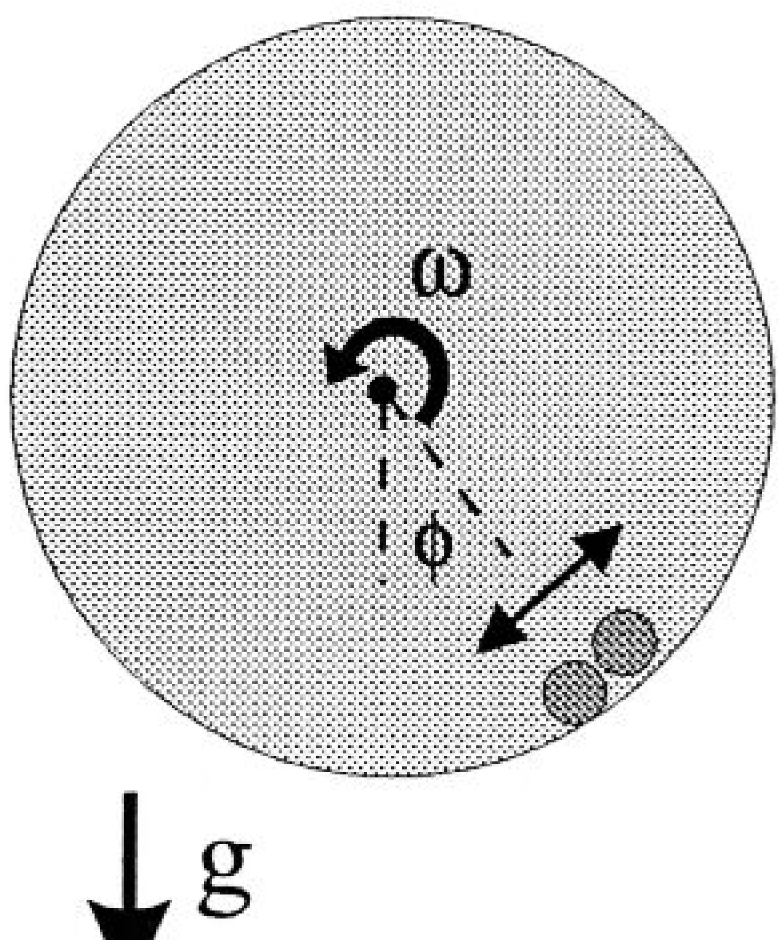

Figure 1: Experimental Setup

The sketch of the experimental setup is given above. A drum consisting of PLEXIGLAS with an inner diameter of 96mm is mechanically coupled to a gear which is driven by a motor. The measured excentricity of the rotating drum is smaller than 0.22 mm.

The sliding body consists of two spheres of 10 mm diameter glued together in order to suppress the rotational degree of freedom of a single sphere. An advantage of using a spherical body is the well defined curvature of the contact area. The body is guided by a U-shaped channel of approximately 1 mm depth. A camera which is connected to a computer samples the picture of the sliding body with a frequency of 25 Hz. During this period the picture is analyzed by a computer programm to give the angle ϕ of the body relative to the bottom of the drum. For one fixed frequency of the motor 2048 pictures are analyzed. A measurement thus takes about 85 seconds. A detailed part of such a time series is shown in Fig. 2.

Experimental Results

Looking at Fig. 2 one can recognize the slip-stick-motion of the sliding body: At the rising edge of the sawtooth-like curve the body sticks to the rotating drum. At the falling edge of the curve the body slips "downhill." The velocity of the falling motion is different compared to that of the rising one. This measurement was performed at a driving frequency of 0.525 Hz. In order to have a helpful tool for identifying the stick motion of the particle the dotted lines in Fig. 2 indicate the slope corresponding to this velocity. It is apparent that most of the time the body does *not* stick to the rotating drum, we rather deal with a sliding motion of the particle.

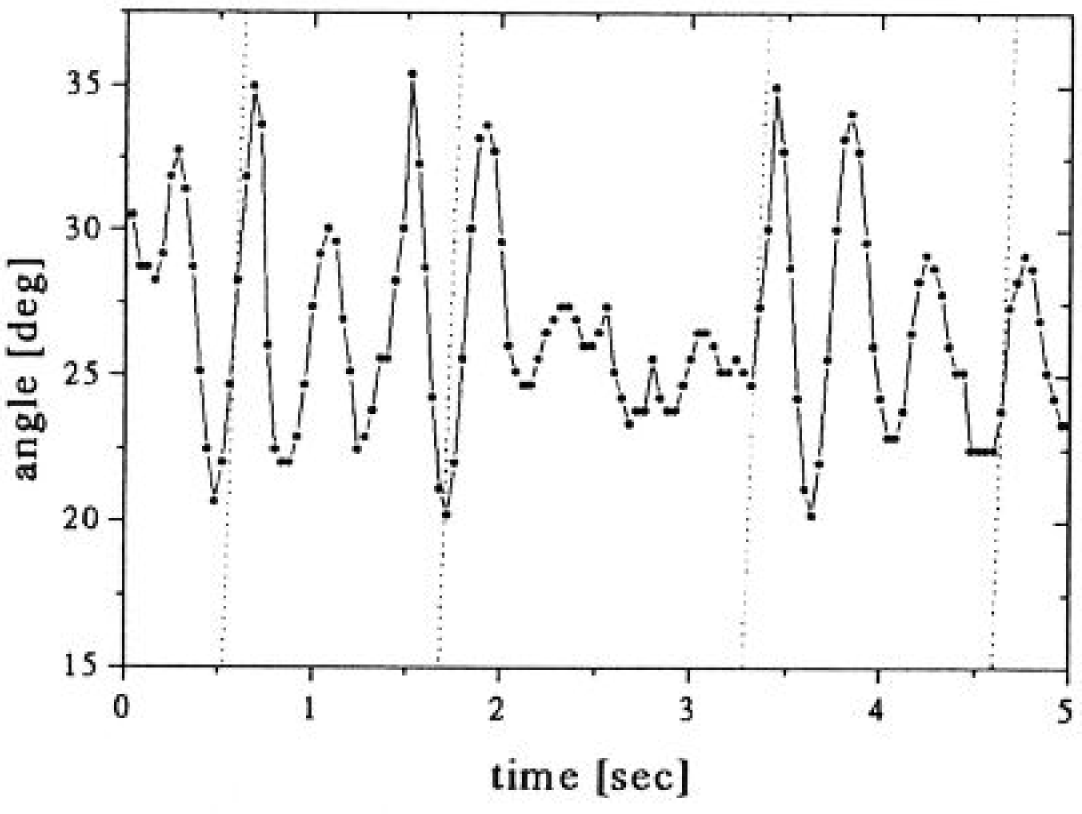

Figure 2: Detailed part of a time series of the angle of the sliding body

Figure 3 shows the corresponding power spectrum which mainly consists of integer multiples of the driving frequency. This locking phenomenon must be considered as an artifact of the experimental setup, which we attribute to the slight excentricity of the rotating drum. The driving frequency is marked by an arrow.

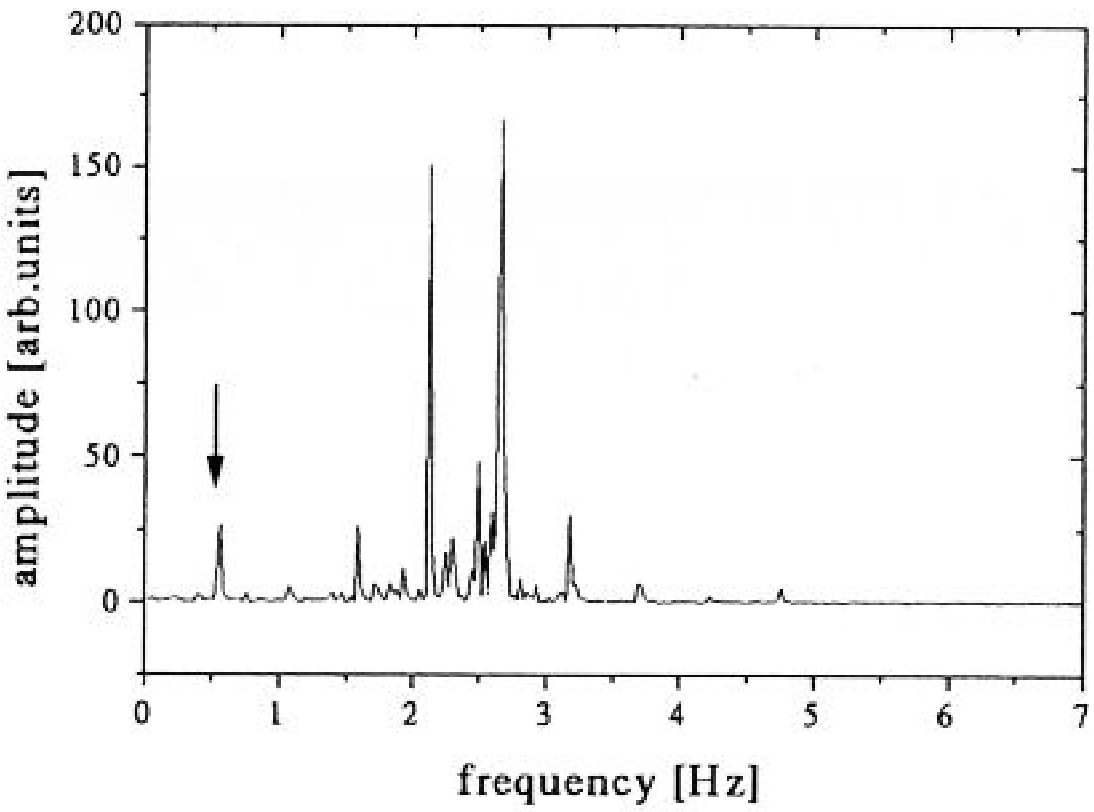

Figure 3: Typical power spectrum of the sliding body

In Fig. 4 the frequency of the dominant mode of the power spectrum versus the frequency of the motor is plotted.

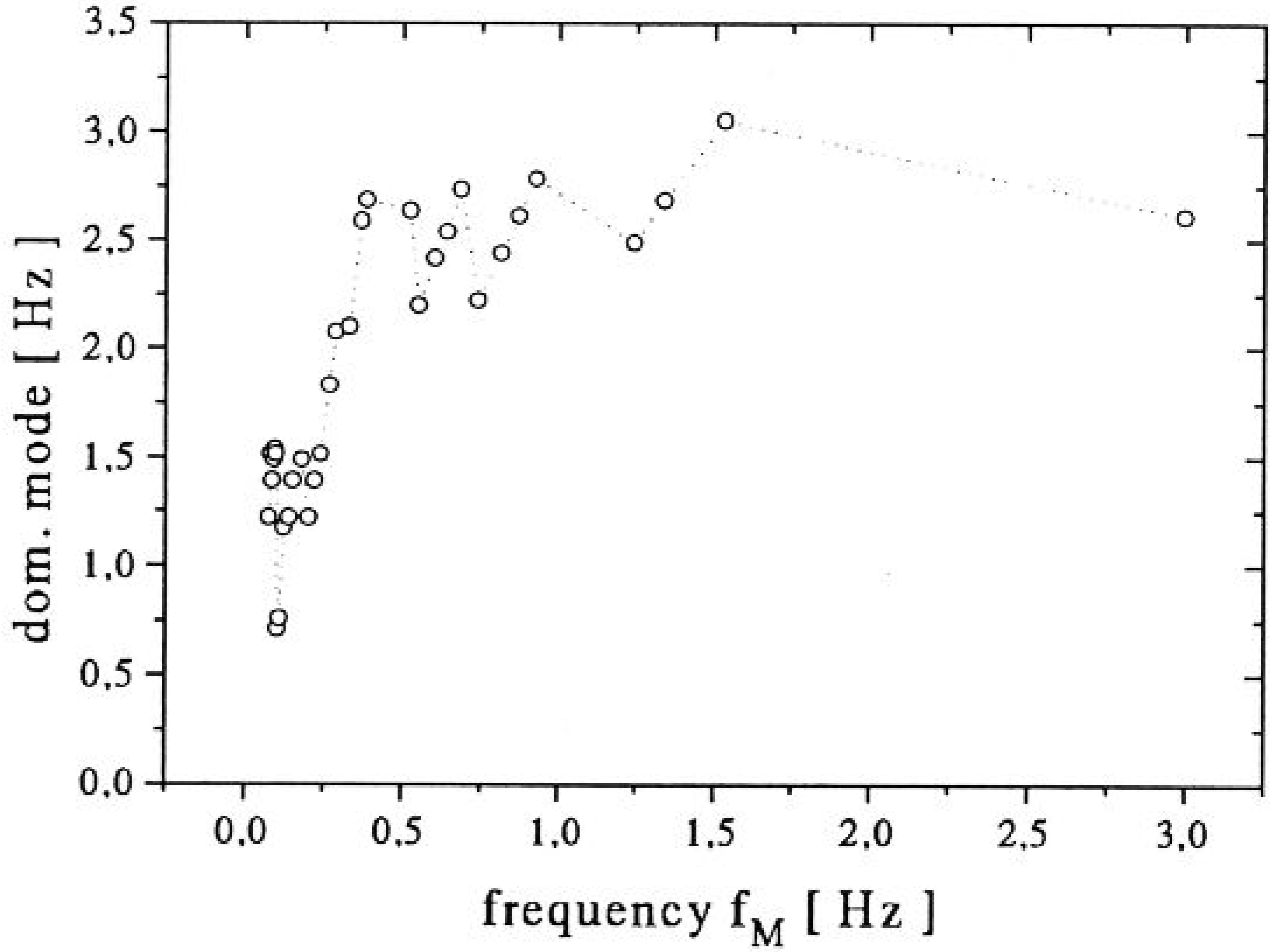

Figure 4: Dominant mode of the power spectra versus the motor frequency

For driving frequencies above 0.3 Hz the plot is reminescent of the resonance curve of a nonlinear oscillator with a characteristic frequency of about 2.5 Hz. Below 0.3 Hz this oscillator seems to have a smaller characteristic frequency of approximately 1.3 Hz. This change in the dynamical behaviour is presumably caused by the velocity dependence of the friction coefficient. This change can also be seen in Fig. 5 showing the frequency dependence of the mean location of the sliding body. It is obvious that the angle – and thus the friction coefficient – increases with increasing driving frequency. A detailed analysis is neceassary to explain the subtle features of this measurement.

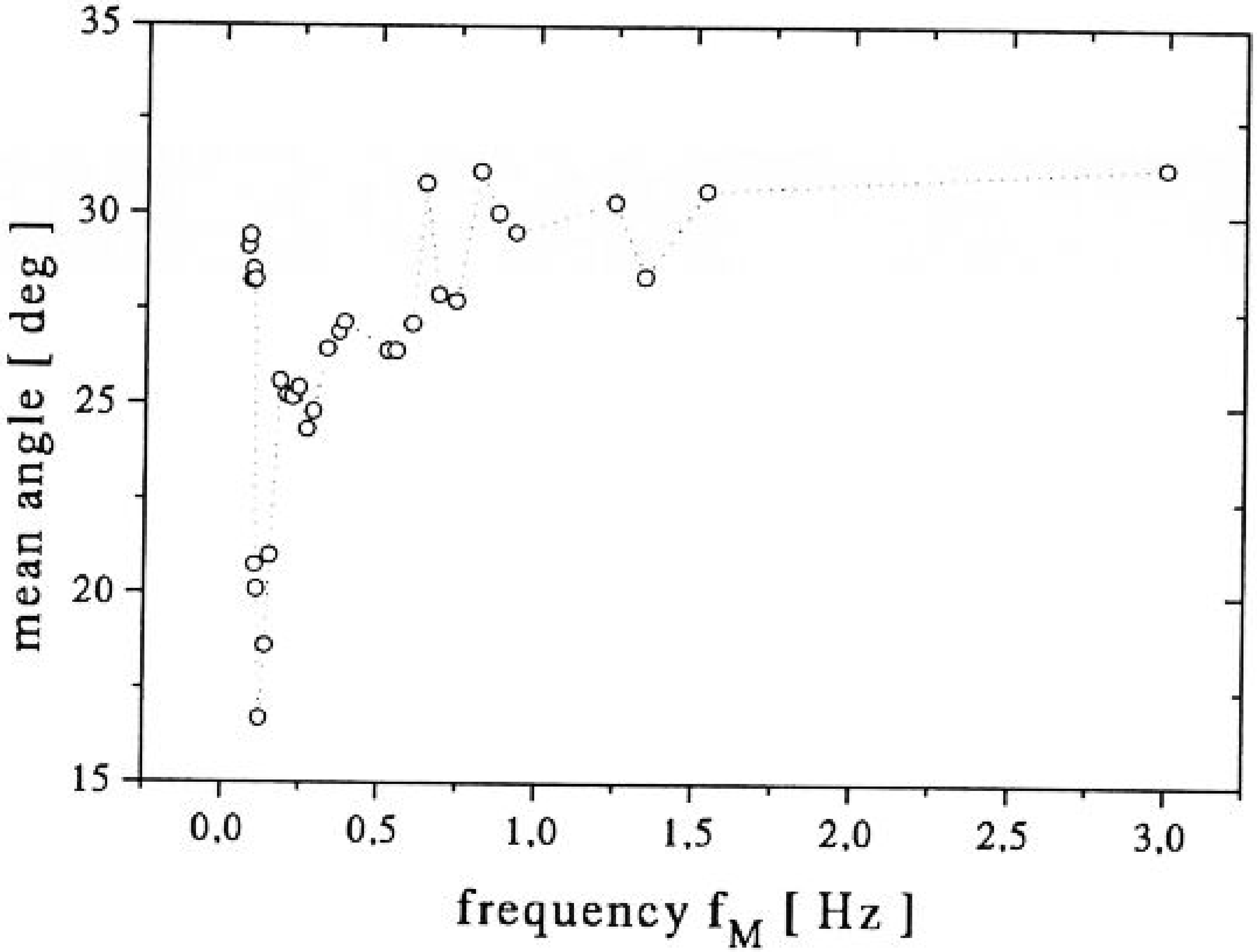

Figure 5: Mean value of the angle versus the motor frequency

Acknowledgement

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