# FRICTION NOISE OF ROUGH SURFACES AND DISSIPATION OF VIBRATION

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## ABSTRACT

*The sound produced by the friction of two objects with rough surfaces has a wide spectrum and generally a relatively low level. In this study, the dependence of the sound pressure level (SPL) with the contact area is investigated. It is found that for some solids, the acoustical power is proportional to the contact area while for some other solids, the sound is almost constant. These two regimes are interpreted in terms of energy balance. The thermodynamical approach highlights that these two regimes may be explained by introducing a dissipation law of vibration by the contact. This law states that the vibrational power dissipated by the contact is proportional to the contact area.*

## 1 INTRODUCTION

Friction sound occurs in a wide variety of daily situations [1]. From insect sound to industrial mechanisms, friction noise is so common that we may recognize them generally without difficulty. Among them, the sound produced by the friction of two solids with rough surfaces is of particular interest.

When rubbing two rough surfaces, the sound produced has a wide spectrum and a relatively low level. The mechanism responsible of the sound production stems from the interface itself [2]. Surfaces are not flat but made of numerous asperities whose size is of order of micrometer. During the sliding, asperities of the top surface hit asperities of the antagonist surface and all these micro-impacts generate a vibration into the solids which, in turn, produces the sound.

The empirical laws of roughness noise have been investigated in several papers [3]. In particular, it has been found that the Sound Pressure Level is a log law of the sliding speed and the surface roughness.

This paper outlines the dependence of roughness noise with the contact area. It is observed that the sound is usually not proportional to the contact area but is related to it by a more complicated law.

## 2 OBSERVATION OF TWO REGIMES

Let us start by a simple observation. When rubbing sugar lumps on a table surface, a sound is produced which may be attributed to a roughness noise. The sugar lumps play the role of sound sources while the table in vibration plays the role of a resonator which radiates the sound. It can be checked with a sonometer or more simply by hearing the noise, that *the larger the number of lumps the stronger the sound*. Results of this experiment are shown in Figure 1, left. The noise level increases with a slope near $9$ dB per decade.

But if the experiment is done on a drum membrane, the results are quite different. It may be observed that the sound pressure level remains almost constant as the number of sugar lumps varies (Figure 1, right).

Two regimes exist for roughness noise, a first regime where the constancy law applies and a second one where the additivity law applies [4].

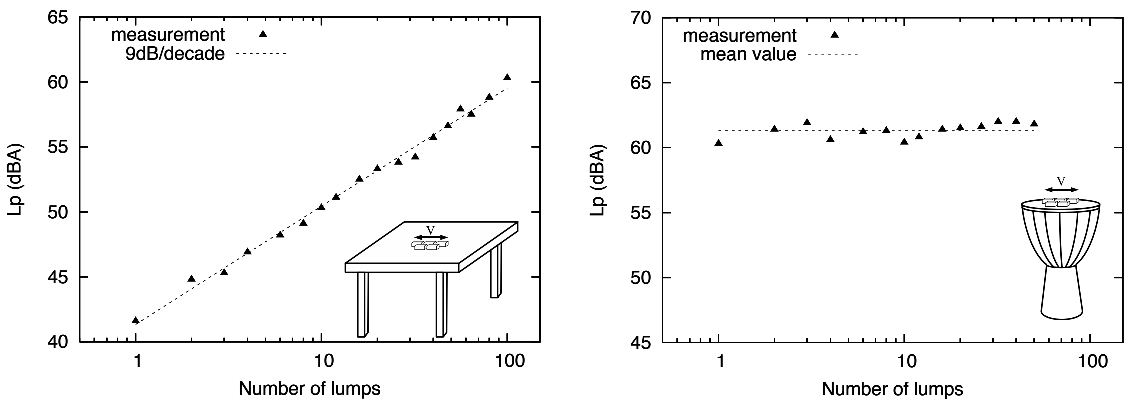


Figure 1: Evolution of SPL versus number of sugar lumps on a wood table (left) and on a drum membrane (right).

## 3 EXPERIMENT

In order to reproduce the above observation, the following experiment has been realized. A thin stainless steel is fixed at its corners on rigid supports. The surface of the plate is prepared by grinding in order to provide a Gaussian random roughness. On the plate, called the resonator, are pulled several identical solids, called the sliders. The slider surface is prepared in same condition as the plate. During the movement, a vibration is generated into the plate. The vibrational level is recorded by several accelerometers. The experiment consists in measuring the RMS-vibrational level versus the number of sliders. Results are shown in Figure 2.

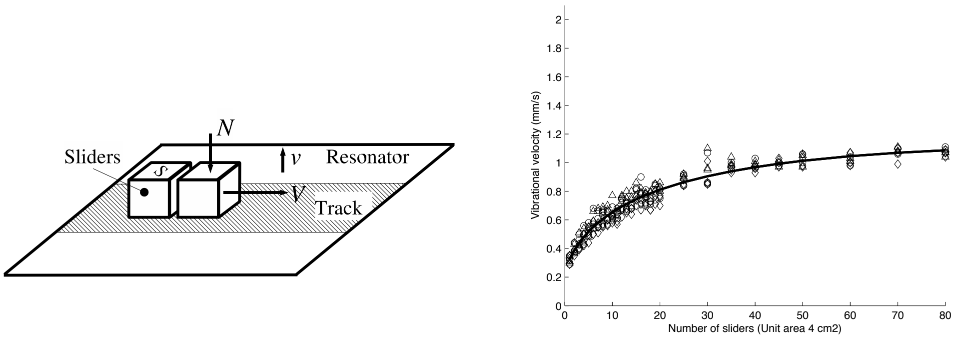


Figure 2: Left, principle of the experiment. Right, evolution of vibrational level versus number of sliders.

## 4 COMMENTS

The above experiment clearly shows that the slope of sound (vibrational level) versus contact area (number of sliders) is not constant. We observe for small area a strong slope (near 10dB/decade) which is associated to the linear regime of the wood table. But for large contact area, the slope decreases and becomes almost zero as in the case of a drum membrane. So, not only both regimes may be reproduced on the same system but also all intermediate regimes.

The following interpretation may be proposed [5].

The resonator is assimilated to a thermodynamical system which contains vibrational energy $E = WA$ where $A$ is the plate area and $W$ the energy density assumed to be uniform (diffuse field). The energy level results from an energy balance. The sliders are sources which supply energy to the resonator. The power being supplied is proportional to the contact area $S$ (number of sliders),

$$P_{\text{inj}} = pS \tag{1}$$

The vibrational energy stored in the resonator is dissipated by two processes. The first process is the natural damping of the plate without contact. If the reverberation time is measured, then the damping loss factor $\eta\omega$ is inversely proportional to it. The dissipation law is,

$$P_{\text{diss}} = \eta\omega WA \tag{2}$$

But a second cause is responsible of dissipation, the contact itself. In practice for a reverberant structure, a contact for instance by bolts or rivets may generate more dissipation than natural damping. So, we introduce the following law,

$$P_{\text{fric}} = cWS \tag{3}$$

where $c$ is an ad-hoc constant. The dissipation by friction is therefore assumed to be proportional to the contact area $S$.

By the energy balance $P_{\text{inj}} = P_{\text{diss}} + P_{\text{fric}}$, the energy density is readily obtained,

$$W = \frac{pS}{\eta\omega A + cS} \tag{4}$$

In the asymptotic case $cS << \eta\omega A$ (small contact area), the vibrational level is $W = pS/\eta\omega A$. It is found to be proportional to the contact area as in the wood table experiment. This is the regime where natural damping dominates. But in the limit case $cS >> \eta\omega A$, the energy density is constant $W = p/c$ as observed on a drum membrane. This is the regime where the damping induced by contact dominates.

## 5 CONCLUDING REMARKS

In conclusion, it has been shown that the sound pressure level is generally not proportional to the contact area. The saturation level is reached $p/c$ for large contact area. These results may easily be interpreted if we adopt the ansazt that the dissipation of vibrational energy in a contact is proportional to the contact area.

## ACKNOWLEDGMENTS

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