

INFLUENCE OF SLIDING SPEED ON ROUGHNESS NOISE

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This article presents an experiment and numerical simulation on friction noise. The noise emitted by a solid rubbing on a rough surface, also called roughness noise, results from a complex interaction between microscopic asperities of both surfaces. It is characterized by a wide band spectrum, a low noise levels and a weak mechanical interaction. The level is controlled by several external parameters such as surface roughness, normal load and sliding speed. The purpose of our study is to understand the evolution of roughness noise versus sliding speed. To achieve this goal, an experimental approach and numerical simulation have been used and the obtained results highlight the law between sound level and sliding velocity. The main conclusion of the study is that noise level versus sliding speed follows a power law with an exponent about 3/4.

Keywords: roughness noise, sliding speed, vibratory level

1. Introduction

In the field of friction noise, the noise due to mechanical instabilities was largely studied in literature. But the role of roughness on friction noise has not received a so great attention, and its phenomenology is not yet fully explained. In literature, some experimental studies have proposed a relationship between the sound pressure level and the sliding speed [5-7].

The study in this paper was realized in the case of flat-flat contact at a constant sliding speed and surface roughness. The dependence of vibration level L_V (dB) with the sliding speed showed that L_V is a logarithmic function. The objective is to clarify if the vibration level is an increasing function of the sliding speed according to the empiric following law:

$$L_V(\text{dB}) \propto 20 \log_{10} V^n \quad (1)$$

where the slope n varies between 0.6 and 1.1 [4-8].

This paper provides an experiment and numerical simulations to verify the relationship between the vibration level and the sliding velocity.

2. Experimental Setup

The experiment consists in rubbing two samples with rough surfaces and in recording the vibration of plate. Rubbing test were carried out for dry contact, under light load and with a varying sliding speed.

2.1 Principle of the experiment

Rigid slider is pulled by a small synchronous motor with a constant velocity V on a resonator (Figure 1). The base of the slider and the track on the resonator are rough. W denotes the weight of the slider.

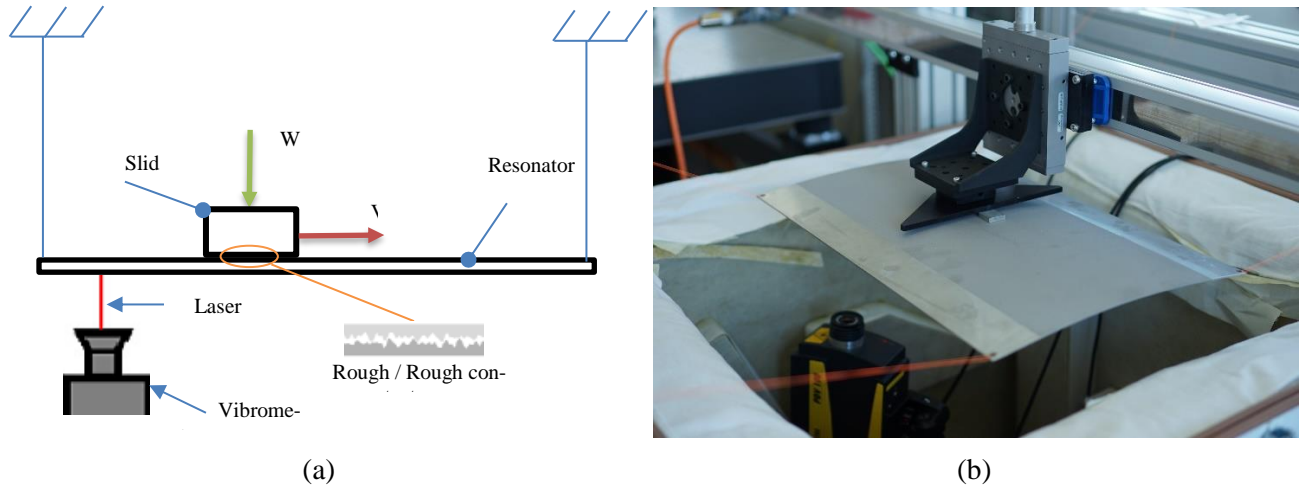


Figure 1: (a): Principle of the experiment, (b): Experimental setup

Table 1 shows the characteristics of the resonator and the slider.

Table 1: Characteristics of the slider and the resonator

Resonator			Slider		
ζ	Size (mm)	Ra (μm)	Size (m)	V (mm/s)	Ra (μm)
0.1%	450x300x2	5	20x20x5	1 - 1000	5

The resonator and the slider are made of stainless steel with Young's modulus $E = 210 \text{ GPa}$, Poisson's ratio $\nu = 0.3$ and mass density $\rho = 7800 \text{ kg/m}^3$.

The RMS value of the vibration velocity is measured within the frequency band [10 Hz-10 kHz] by a laser vibrometer with three velocity measuring ranges for maximum resolution up to $0.02 \mu\text{m/s}$.

2.2 Protocol

Rubbing tests were carried out for samples having same surface roughness obtained by the same machining process. Before tests, samples are carefully degreased with heptane, acetone and isopropanol. Each friction test is repeated three times. The test is run in ambient atmosphere (relative humidity varied from 73 to 76% and room temperature from 21 to 23 °C). The slider (top solid) is moving in the x-direction at constant speed V in the range $1 \leq V \leq 1000 \text{ mm/s}$ during friction test.

2.3 Experimental results

From vibrometer measurements, we can calculate the vibration level L_V . This physical quantity is obtained from the following relationship:

$$L_v = 20 \log_{10} \frac{V_{RMS}}{V_0} \quad (2)$$

Where $V_0 = 10^{-9}$ m/s and V_{RMS} is the root mean square vibration speed.

The measurements show that L_V is linear increasing functions of the logarithm of V (Figure 2).

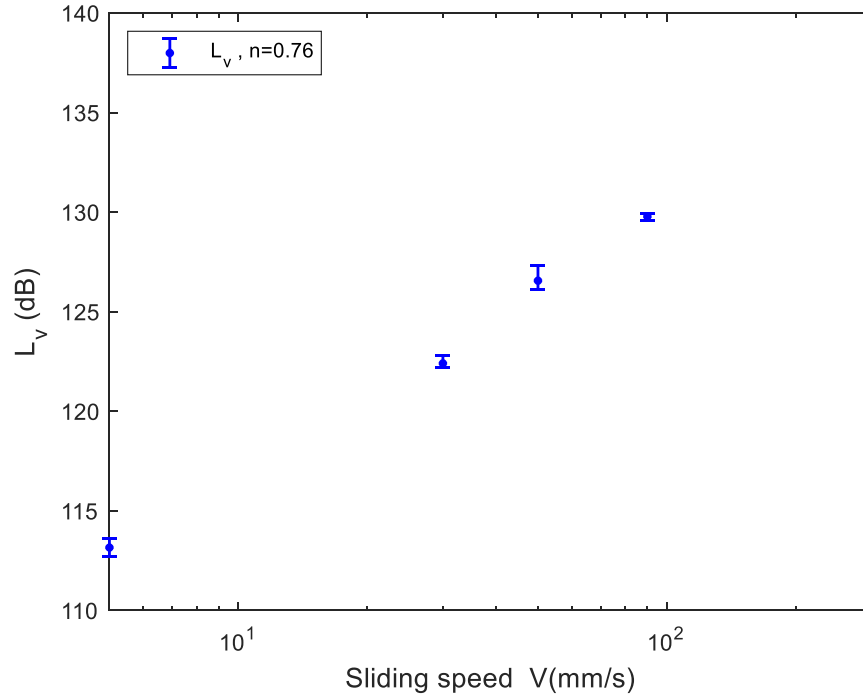


Figure 2: Evolution of vibration level L_V versus sliding speed V

The simulation results show that the vibration level L_V is a linear increasing function of the logarithm of the V (Figure 2) and the slope is $n = 0.76$. This result is in agreement with the observations of Stoimenov and al [8] ($0.7 \leq n \leq 0.85$), Nakai and yokoi [5] ($0.6 \leq n \leq 1.1$), Abdelounis and al [7] ($0.51 \leq n \leq 0.78$) for flat-flat contact.

3. Numerical simulation of roughness noise

3.1 Principle

The numerical approach used in this study is based on truncated modal decomposition of the vibration and central difference integration scheme and the penalty algorithm for contact [11].

The simulation is based on a 3D model implemented in the software program ra3D. The top solid moves horizontally with a constant velocity V while the bottom solid is fixed at both ends. The solids have nominally flat surfaces.

Figure 3 shows the rough surfaces generated numerically by using spectral method with Berstrom’s program [9]. This surface is characterized by their standard parameters Ra, Rq, Rsk, Rku and λ for respectively arithmetic roughness, quadratic roughness, Skewness, Kurtosis and correlation length. The number of nodes is 8400x600 ($N_x \times N_y$) and the step between tow nodes is 50 μm .

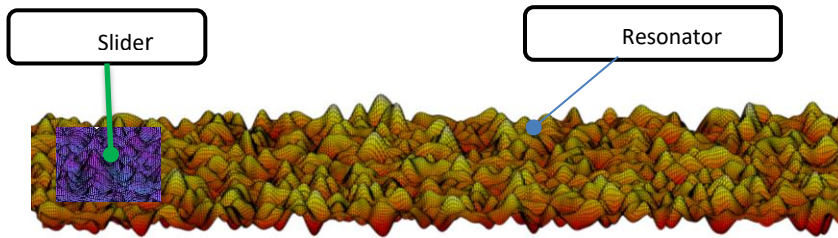


Figure 3: Rough surfaces generated numerically

3.2 Protocol

Rubbing tests were carried out for samples having same surface roughness and each friction test is repeated three times. The numerical simulations are performed with the following parameters (Table 3):

Table 3: Input and simulation parameters

Input parameters							Simulation parameters			
Material			Resonator		Slider					
E (GPa)	ρ (kg/m ³)	ν	ζ	Size (mm)	Size (mm)	Speed (mm/s)	Duration (s)	Time-step (s)	Sampling (Hz)	modes
210	7,800	0.3	0.1%	450x300x2	20x20x5	1 - 1000	0.4	1e-6	44100	200

3.3 Numerical results

Figure 6 shows that roughness noise is an increasing function of the logarithm of the sliding speed. Numerical results are in agreement with our experimental results.

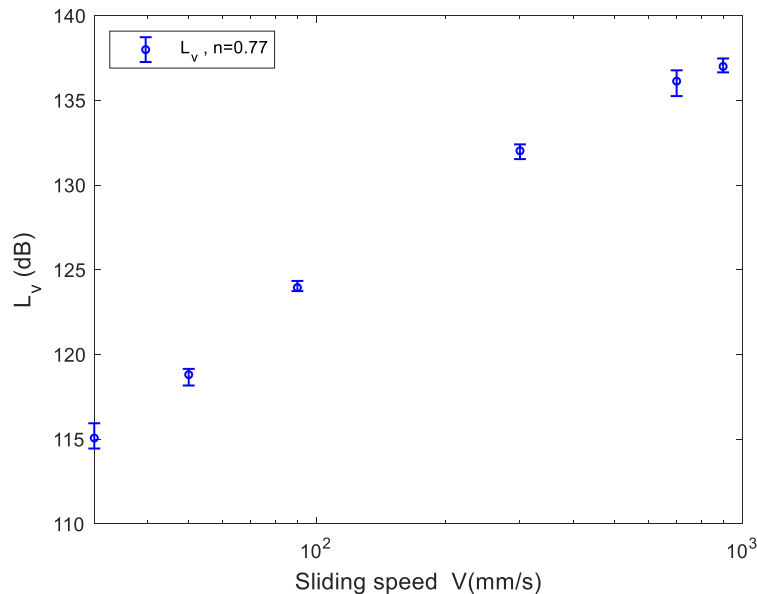


Figure 6: Evolution of vibration level L_v versus sliding speed V for surface roughness $R_a = 5 \mu\text{m}$

The simulation results also show that L_V is linear increasing functions of the logarithm of V (Figure 6) and the slope is $n = 0.77$. This result is in agreement with the numerical simulation of the dynamics of sliding rough surfaces with 2D model of Hung and al [18].

4. Discussion

The results of experiment and numerical simulation of roughness noise in the study are in agreement with previous studies. The magnitude of vibration level obtained by simulation is greater than the values found experimentally. This gap could be explained by:

- The numerical model of the resonator
- The value of the modal damping ratio
- The boundary conditions of the resonator

Another factor which affect strongly the vibration level and reduces sound level is dissipation in the roughness contact.

5. Conclusions

An experimental and numerical simulation investigation of friction noise between two rough and dry surfaces were carried out. The 3D model used for numerical simulation of roughness noise make realistic approach. The main conclusion of the study is that vibration level versus sliding speed follows a power law with an exponent about 3/4.

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