# DIRECT NUMERICAL SIMULATION OF FRICTION NOISE

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## ABSTRACT

*The friction of two solids with rough surfaces produces a typical sound generally called roughness noise [1]. This study focuses on the numerical simulation of what happens into the contact during the sliding. The mechanical equations of vibrating solids in contact are first set. They are solved by a modal approach. The contact is modeled at the scale of surface asperities which requires a very fine discretization. The results show that this approach is several times faster than the classical finite element method. Furthermore, it reproduces the empirical laws observed experimentally and provides the statistical properties of local events which are not accessible by experiment.*

## 1 INTRODUCTION

The sound produced by rubbing two rough surfaces under light contact pressure is called roughness noise [1]. Some examples of this noise are hand rubbing, stridulatory sound by insects or tyre/road contact noise [2]. The origin of this noise lies in the mechanical shocks between asperities of both surfaces [3]. The knowledge of what happens into the contact during the sliding is therefore the key for understanding the vibrational and acoustical behaviour of the system.

## 2 MODELLING

The simulation of is based on a 2D model which is made up of two nominally flat rough profiles in contact as shown in Figure 1. The top profile moves horizontally with a constant velocity $V$ while the bottom profile is fixed at both ends. The initial vertical gap i.e. the separation between the two reference lines of the profiles is $\delta$. During the movement asperities of the top profile can hit asperities of the bottom profile.

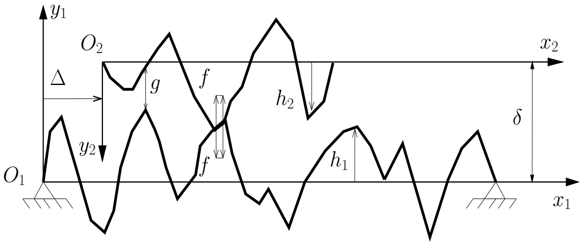


Figure 1. Sliding of two rough profiles. At time $t$, the horizontal offset is imposed $\Delta = Vt$

We make the following assumptions:

- The vertical deflection of the profiles follows the Euler-Bernoulli theory of beams (Small flexural vibration).

- The profiles are infinitely rigid in the horizontal direction and therefore the horizontal position of node is imposed (No longitudinal vibration).

- Profiles cannot penetrate each other (Signorini's condition).

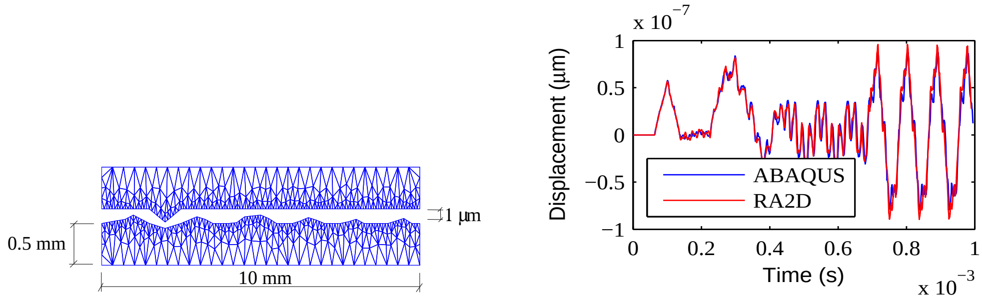
- The persistence of contact is ensured by a vertical gravity force.

## 3 VALIDATION

The proposed modelling is implemented in the software Ra2D and validated by a comparison with the finite element software ABAQUS Explicit. A toy model formed by two simple rough surfaces rubbed against each other is used. The top profile consists of only one peak whereas the bottom profile consists of six peaks as illustrated in Figure 2a. In Figure 2b shows a good agreement between the displacement of the summit of top asperity obtained by RA2D (red) and ABAQUS (blue). Furthermore, the CPU time with RA2D is 30s which is faster around 10 times than those with ABAQUS (280s).

## 4 RESULTS

A realistic sliding contact problem between two multi-asperity profiles is presented. The system is made of two solids, a parallelepipedic solid moving on a simply supported Euler beam. The numerical simulation are performed with the following parameters: time step $\tau = 0.1$ $\mu s$, duration of simulation $T = 1$ s, space step $\chi$=5 $\mu$m, number of nodes of lower profile: 90000.



(a)

(b)

Figure 2: Comparison between RA2D with ABAQUS.(a) Mesh in ABAQUS of the simple asperity problem. Displacement of the summit of top asperity obtained by RA2D (red) and ABAQUS (blue)

The shock between one node with the antagonist surface is determined mathematically from the time evolution of the contact force of this node. When the contact pressure is non-zero, the shock occurs. A shock may be caracterized by three properties the shock duration $\Delta t$, the maximal absolute value of contact force and the transferred energy $\Delta W$.

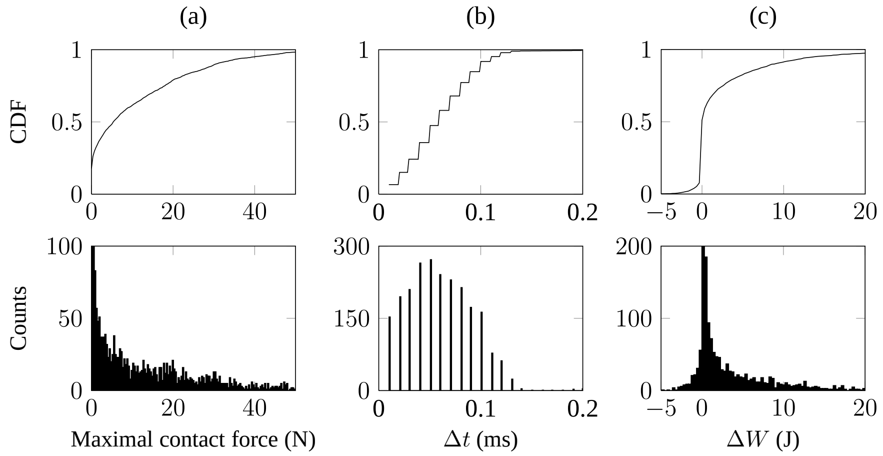


Figure 3: Cumulative distribution function (top) and histogram (bottom) of shock properties for $Ra$=5 $\mu m$, and $V$=70 cm/s. (a) Maximal contact force of shock, (b) Shock duration, (c) Transferred energy.

The macroscale vibration level $Lv$ of the resonator can be obtained as the space and time average of the vibrational velocity of nodes in the simulation. The vibration level is found to be a linear increasing function of the logarithm of both the surface roughness and sliding speed in good agreement with experimental results from the literature.

Finally, the CPU time is 9930 s (2.8 hours) per simulation. This is to be compared with several days of CPU time using the finite element method.

## 5 CONCLUSION

The comparison with the finite element method allows to validate the proposal modelling and enhance its rapidity. The realistic problem allows the full consideration of the statistical properties of asperity-scale shocks. The shock durations are of order of 1e-4 s. The histogram of the transferred energy per shock is asymmetric. When the transferred energy is positive, shocks act as the vibration and noise sources. On the contrary, the negative value of transferred energy dissipate the vibrational energy of the resonator.

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