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Effect of Surface Roughness on Frictional Sound Generated in Flat on Flat Sliding Contact

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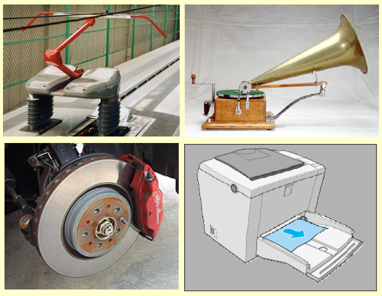
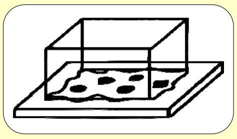
Frictional sound and the contact interface



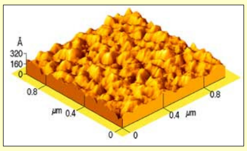


Purpose

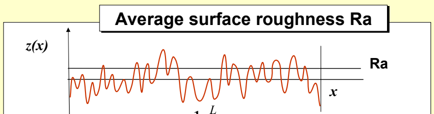
1. To clarify the effect of surface roughness on the frequency spectrum of frictional sound generated in sliding of flat on flat contact.

2. To propose a model of frictional sound generation in sliding.

Evaluation of surface roughness and frictional sound

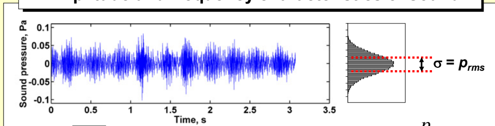


Average surface roughness Ra



$$Ra = \frac{1}{L}\int_0^L |f(x)|dx$$

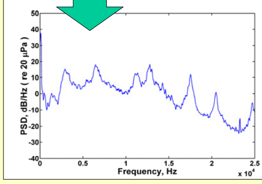
Amplitude and frequency characteristics of sound



$$\text{SPL (dB)} = 20 \cdot \log_{10} \frac{p_{rms}}{(20\ \mu\text{Pa})}$$

SPL – *Sound Pressure Level*

FT



Power spectrum density (PSD)

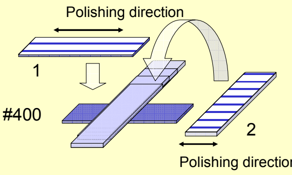
$$\text{PSD} = \frac{\{\text{FT}(x)\}^2}{\text{Frequency range}}$$

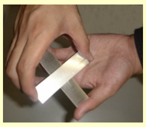
FT – *Fourier transform*

Plate on plate

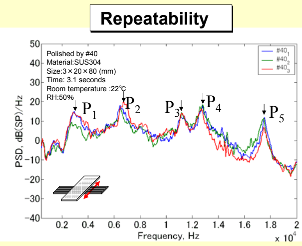
Specimens
Material : SUS304
Size : 3.0 × 20 × 80 mm

Finishing
Emery paper : #40, #100, #400
Rz = 10.9; 6.2; 3.4 µm

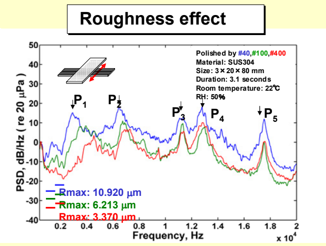


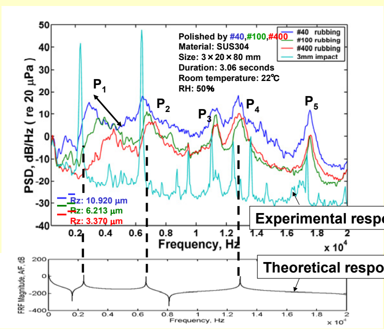


Repeatability



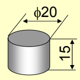
Roughness effect





Peaks in frictional sound spectra appear near the natural frequencies and shift to higher frequency when surface roughness decreases.

Disk on disk

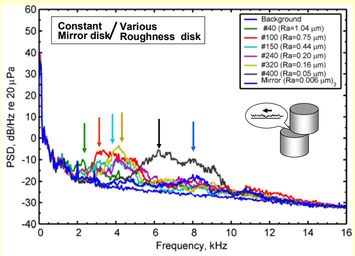


Disk surface

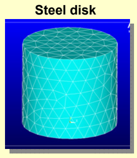
Ra,µm	Finish	
1.19	Sandpaper	#40
0.71		#100
0.48		#150
0.22		#240
0.15		#320
0.06		#400
0.01	Buff polish	

Initial surface preparation

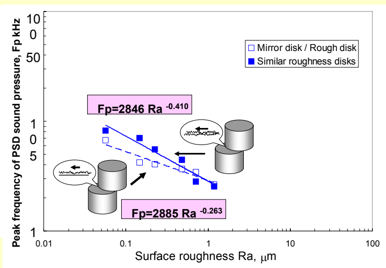
Finishing method		#40 sandpaper	#100 sandpaper	#150 sandpaper	#240 sandpaper	#320 sandpaper	#400 sandpaper	Buff polishing (0.05µm)
		Ra= 1.19µm	Ra= 0.71µm	Ra= 0.48µm	Ra= 0.22 µm	Ra= 0.14µm	Ra= 0.05µm	Ra= 0.006 µm
#40 sandpaper	Ra= 1.19 µm							
#100 sandpaper	Ra= 0.71 µm							
#150 sandpaper	Ra= 0.48 µm							
#240 sandpaper	Ra= 0.22 µm							
#320 sandpaper	Ra= 0.14 µm							
#400 sandpaper	Ra= 0.05 µm							
Buff polishing (0.05µm)	Ra= 0.006 µm							



Steel disk



First mode @147 kHz



The frequency of the peak follows a power law of the form:

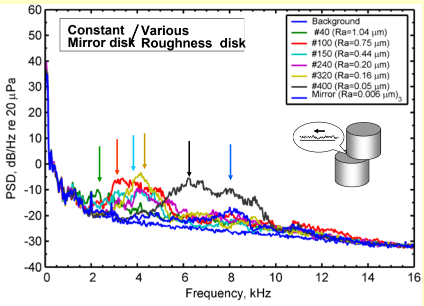
$$F_p = A_f\,(Ra)^{B_f}$$

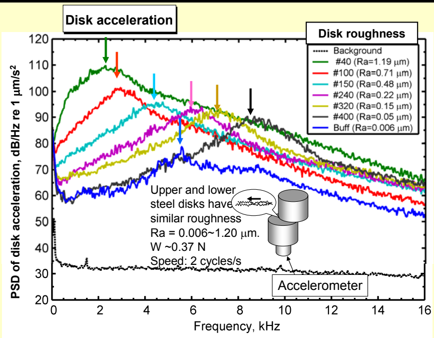
A_f, B_f - experimental constants

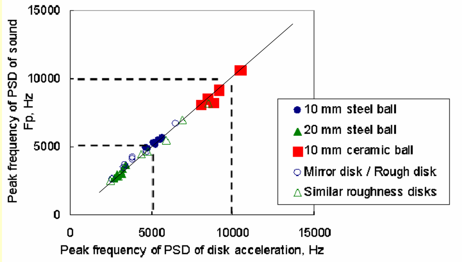
What is the mechanism?

Frictional sound and friction induced vibration

Sound

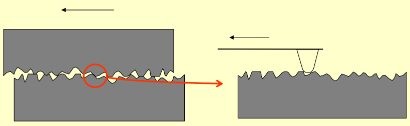






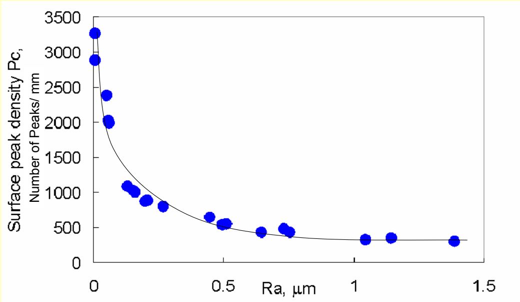
Hypothesis A: Frequency of asperity interaction

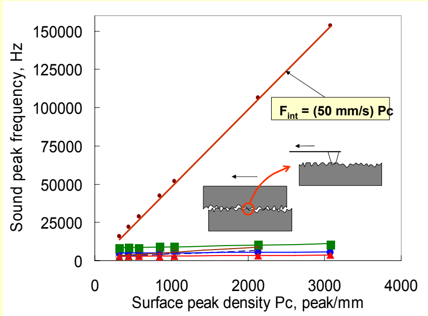
Single asperity contact model



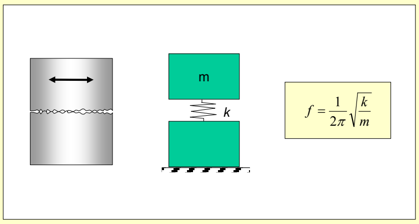
$F_{int} = V_{sl} \cdot Pc$

F_{int} - frequency of asperity interaction, [Hz]
V_{sl} - sliding speed, [mm/s]
Pc – peak density , [No. peaks/ mm]

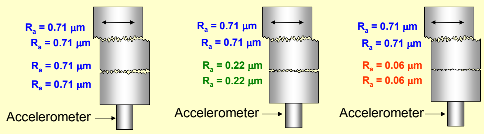


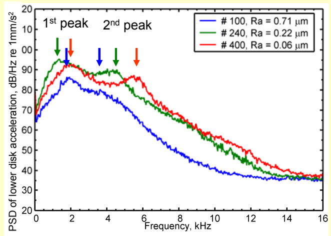


Hypothesis B: Stiffness of the contact interface

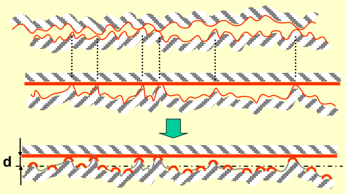


$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$





Greenwood-Williamson contact model



Greenwood and Tripp (1970)

Greenwood and Williamson (1967)

$$W(d) = \frac{4}{3}\beta E_{eq} A_n \sqrt{\frac{\sigma}{\rho_{av}}} F_{\frac{3}{2}}(d)$$

W – load supported by elastic deformation
d – separation between the surfaces

$$F_n(d) = \int_d^\infty (z-d)^n \phi(z)dz$$

$$\phi_G(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}$$

$\beta = \eta \cdot \rho_{av} \cdot \sigma$

$E_{eq} = (E_1 \cdot E_2)/(E_1 + E_2)$

Model Parameters:
σ - Std. deviation of asperity heights
ρ_{av} - Average asperity curvature
η – Asperity areal density
A_n – nominal contact area
E_1, E_2 – Young modulus

Additional assumptions

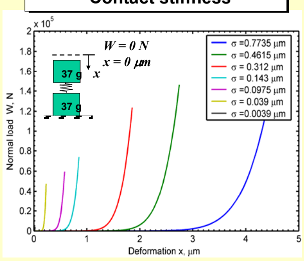
1. σ = ½ std. deviation of measured profile
2. Average asperity curvature related to the spacing between asperities:

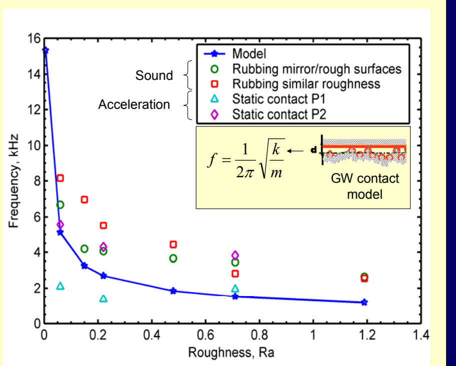
$\rho = c_1 \cdot Sm$

3. Peak areal density for anisotropic surface dominated by the roughness across the lay.

$\eta = Pc \cdot (c_2 \cdot Pc)$, $c_2 \sim 100$

Contact stiffness





Conclusions

1. It was found that peak frequency of frictional sound shifts by surface roughness following a power law of the form:

$$Fp = A_f(Ra)^{Bf}$$

2. The proposed model explaining the effect of surface roughness on frictional sound by change of contact stiffness and natural frequency of the system is in good qualitative agreement with the observed peak shift.