34th Danubia-Adria Symposium on Advances in Experimental Mechanics
University of Trieste, Italy, 2017

EXPERIMENTAL INVESTIGATION OF FRICTION REDUCTION BY SUPERIMPOSED VIBRATIONS

Martin Meindlumer[1], Helmut J. Holl[1], Viktoria Simader[1], Dominik Schnürer[1], Andreas Brandl[1]

[1] Johannes Kepler University Linz, Department of Technical Mechanics, Altenberger Straße 69, A-4040, Linz, Austria. E-mail: martin.meindlhumer@jku.at

1. Introduction

The presence of friction in machines and devices causes energy dissipation and frequently stick slip vibrations and acoustic emission are excited. It is important to understand the macroscopic behavior of friction in contact areas, which is present and relevant in a lot of technical applications. Energy dissipation and wear results from this friction model. A reduction of the effects of friction is possible with suitable superimposed vibrations. An experimental setup was designed and constructed to evaluate the possible reduction of friction by superimposing vibrations to a defined motion in a certain frequency range. Various frequencies and vibration amplitude parameters can be adjusted in the experimental setup where cutting and friction forces are studied.

2. Mechanical model for a contact with friction

For a friction model considering the direction of the relative velocity between the particle under consideration and the moving base, see the sketch of the contact pair in Fig. 1, the direction and amplitude of the friction force can be calculated for a given contact force F_N. It is assumed that the friction coefficient μ of the Coulomb friction is constant and independent of the absolute value of the relative velocity.

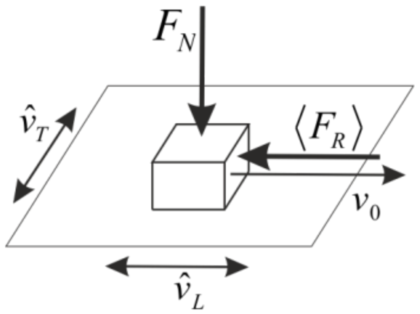

Fig. 1. Sketch of the contact pair

In [1] a similar friction model is demonstrated for two orientations of the relative motion and a constant as well as a harmonic velocity profile excited by a piezoelectric actor was used. The equations for the reduction of friction force depend on the ratio between average transport speed and the amplitudes of longitudinal and transversal vibrations considering the relative speed direction and the resulting direction of the friction force.

For longitudinal vibrations of the particle the average friction force $\langle F_R \rangle$ can be computed based on one vibration period and is given by

$$\langle F_R \rangle = \begin{cases} \dfrac{2\mu F_N}{\pi} \arcsin\left(\dfrac{\hat{v}_L}{v_0}\right) & \text{for} \quad v_0 < \hat{v} \\ \mu F_N & \text{for} \quad v_0 > \hat{v} \end{cases}, \qquad (1)$$

where F_N is the normal force between the contact pair, μ is the friction coefficient (Coulomb friction), v_0 is the average velocity between the contact pair and $\hat{v}_L$ is the velocity amplitude of a longitudinal harmonic vibration superimposed to the average movement between the contact pairs .

For harmonic transversal motion of the specimen the average friction force over one oscillation period is given by

$$\langle F_R \rangle = \frac{\mu F_N}{2\pi} \int_0^{2\pi} \frac{d\xi}{\sqrt{1 + \left(\dfrac{\hat{v}_T}{v_0} \cos \xi\right)^2}} . \qquad (2)$$

in the form of a Jacobian elliptic integral. In the equations the relation of absolute values of the amplitudes of the harmonic speed $\hat{v}_L$ and $\hat{\boldsymbol{v}}_R$ and the base motion v_0 is present. For high frequencies small vibration amplitudes and for low frequencies higher amplitudes are necessary. For the above friction model the average power consumption is computed and it can be shown that there is no reduction.

3. Experimental setup

In order to verify the computed results an experimental setup was constructed. A special cutting tool was specially mounted on a crank shaft mechanism, which is driven by an induction motor, in order to introduce vibrations excited with various parameters. As a reference material for the specimen several layers of bast fiber were used and mounted on a linear guide unit, which provides (adjustable) constant velocity of the specimen during the experiments. In a first step cutting and friction forces are measured together. In a second step the cutting tool is driven once more through the die clearance so that only the friction force is measured separatly. The velocity of the linear guiding unit and the speed of the induction motor are fixed during one run of the experiment. In the results of the low pass filtered measurement date shown in Fig. 2 five different speed ratios were used.

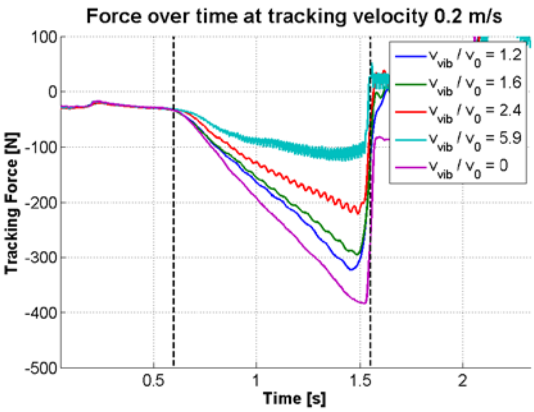

Fig. 2. Representative tracking force functions.

In Fig. 2 representative time functions of tracking forces for a tracking velocity of 200 mm/s and for different ratios of transport to oscillation velocity are shown. Power consumption and tracking force are averaged in time for the range between the dashed lines in Fig. 2 for the performed experiments. The driving force of the linear guiding unit, accelerations of one point of the cutting tool and the power consumption of the induction motor were measured. Idle power consumption of the whole setting measured and is subtracted in the results.

4. Results

The tracking force and the power consumption are averaged over one period related to the corresponding values without a vibrating tool for the tracking velocity and are shown in Fig. 3 and Fig. 4. The dots mark the average reduction and the colored area marks the 90% confidential area. In the results a reduction of the traction force similar to the values predicted by the theory can be seen.

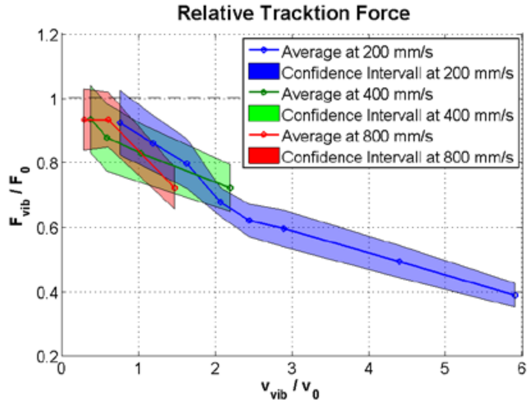

Fig. 3. Relative traction forces over velocity ratio

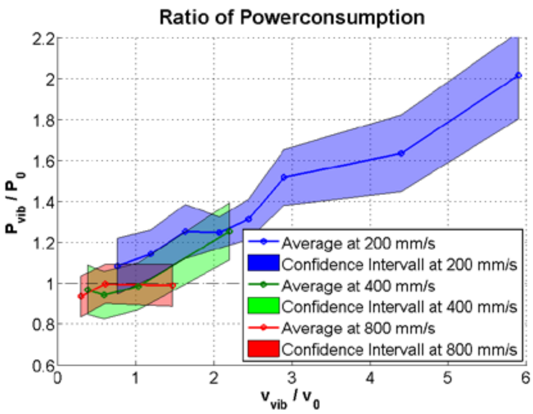

Fig. 4. Relative power consumption over velocity ratio

5. Conclusion

A model for friction and cutting evaluated was derived and the measurements have been carried out for a lot of selected parameters. The traction force was reduced to 50 % of its value without vibrating tool and the power consumption of the setup increases.

Acknowledgements

The support of this work in the framework of the Comet-K2 Austrian Center of Competence in Mechatronics (ACCM), Area 2, Mechanics and Model Based Control, is gratefully acknowledged.

References

[1] Popov, V.L, Contact Mechanics and Friction. Springer Heidelberg Dordrecht London New York, 2010.