Experimental Mechanics in Engineering and Biomechanics - Proceedings ICEM20
20th International Conference on Experimental Mechanics, Porto 2-7 July 2023
https://paginas.fe.up.pt/~icem20/proceedings_icem20/

PAPER REF: 19958

FRICTION REDUCTION IN A REVOLUTE JOINT BY THE USE OF AXIAL HIGH-FREQUENCY EXCITATION

Simon Keller(*), Alexander Fidlin

Institute of Engineering Mechanics (ITM), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
(*)*Email:* simon.keller@kit.edu

ABSTRACT

While downscaling gains importance in many technical components, accuracy must increase as well. This is a challenge especially for dry bearings with small tolerances. To suppress friction induced phenomena like stick-slip-motions or break-away-effects, superposed oscillations can be used to specifically influence the friction characteristic. In this context, the present contribution deals with a friction revolute joint with axial high-frequency excitation to reduce friction torque. There is a special focus on the heat generation and its interaction with the system dynamics.

Keywords: friction reduction, high-frequency excitation, revolute joint, thermo mechanics.

INTRODUCTION

Dynamics of friction bearings are highly dominated by the friction induced effects. In positioning applications for example, dry friction can lead to stick-slip-motions or break-away-effects, which negatively influence a process. By the superposition of high-frequency oscillations, the discontinuous friction characteristics can be smoothed and undesired effects can be suppressed [Thomsen, 1999; Storck et al., 2002]. Various publications on this effect devoted to experimental and theoretical investigations show good accordance [Kapelke, 2018; Gutowski and Leus, 2015]. In the present work, the effect of superposed oscillations on the thermo-mechanical behavior of a friction revolute joint is analyzed.

SIMULATION MODEL

In the theoretic model (cf. Figure 1), a bolt with radius R and mass m is modelled as a one-degree-of-freedom oscillator. The excitation by piezo actuators is represented by a harmonic force $F(t)$. The bolt has a sliding contact with the enveloping cylinder, which is rotating with the prescribed velocity v_0/R around the bolt. The block has a radial displacement field $u(r)$ as well as a radial temperature field $T(r,t)$. Due to thermal expansion, the radial strain impacts the normal pressure in the contact area and therefore occurs in the equation of motion of the block. The displacement field, the temperature distribution and

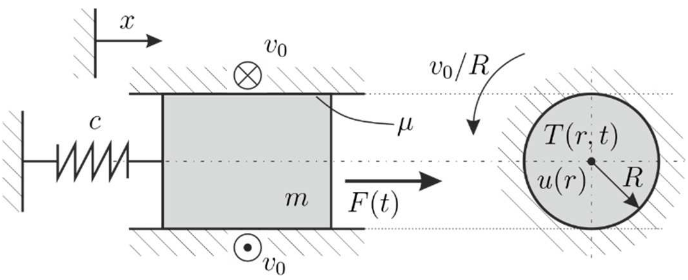

Fig. 1 – Model of the bolt under axial excitation.

the motion of the block are coupled. The impulse balance for the displacement field and the heat equation can be evaluated, so that one Volterra integral equation remains for the mean temperature over the bolt cross section:

$$T_m(t) = \int_0^t g(t-s, T_m(s), \dot{x}(s))ds$$

The equation of motion of the bolt is an ODE where the mean temperature occurs in the friction force:

$$m\ddot{x} + cx + F_r(\dot{x}, T_m) = F_0 \cos \Omega t$$

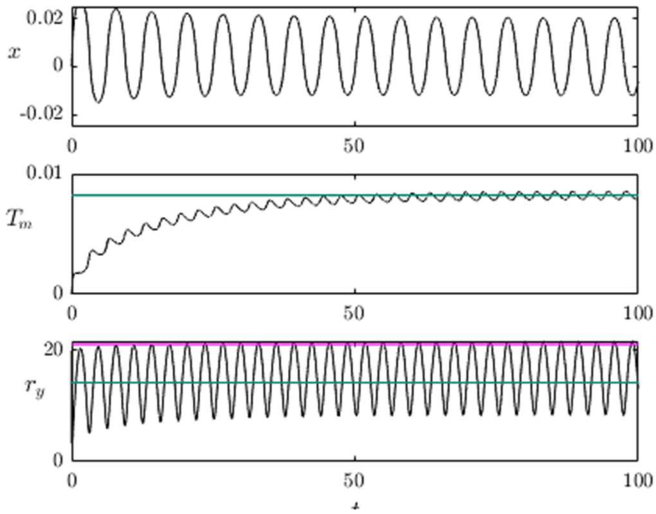

Fig. 1 – Time series of displacement, mean temperature and friction force.

These equations can be transformed to a system of nonlinear, coupled Volterra integral equations, which is then solved numerically by the use of the trapezoidal rule [Awrejcewicz et al., 2009]. The result of the simulation can be seen in Figure 2. A stationary oscillation is reached, as well as a stationary increased temperature. The mean friction force (green) in circumferential direction is still lower than the friction force without axial excitation (magenta).

CONCLUSIONS

The investigation suggests, that superposed vibrations can reduce the friction torque in a revolute joint. However, thermo-mechanical effects diminish the reduction due to thermal expansion. Experimental results from previous research suggest, that thermal effects influence the friction characteristic significantly. To validate the theoretical results, the construction of a test rig is planned. This is an eminent step to revise the model and compare the results.

REFERENCES

[1] Awrejcewicz J, Pyr'yev Y, Nonsmooth dynamics of contacting thermoelastic bodies. Springer Science and Business Media, 2009, Vol. 16, pp.37-41.

[2] Gutowski P, Leus M, Computational model for friction force estimation in sliding motion at transverse tangential vibrations of elastic contact support. Tribology International, 2015, 90, pp.455-462.

[3] Kapelke S, Zur Beeinflussung reibungsbehafteter Systeme mithilfe überlagerter Schwingungen. KIT Scientific Publishing, 2019.

[4] Storck H, Littmann W, Wallaschek J, Mracek M, The effect of friction reduction in presence of ultrasonic vibrations and its relevance to travelling wave ultrasonic motors. Ultrasonics, 2002, 40, pp.379-383.

[5] Thomsen JJ, Using fast vibrations to quench friction-induced oscillations. Journal of Sound and Vibration, 1999, 228(5), pp.1079-1102.