The 6th Joint International Conference on Multibody System Dynamics and
The 10th Asian Conference on Multibody System Dynamics
November 1-5, 2020, New Delhi, India

# Numerical Considerations for Simulating Wear in Revolute Joints

**Mario López-Lombardero[1], Javier Cuadrado[2], Mario Cabello[1], Felix Martínez[1]**

[1] Ikerlan Technology Research Centre, Basque Research and Technology Alliance (BRTA)
J.M. Arizmendiarreta 2, 20500 Mondragon, Spain
[mlopez, mjcabello, fmartinez]@ikerlan.es

[2] Laboratory of Mechanical Engineering
University of La Coruña
Mendizabal s/n, 15403 Ferrol, Spain
javier.cuadrado@udc.es

**Abstract**

The simulation of revolute joints with clearances in mechanisms has been largely addressed in multibody dynamics. It is worth mentioning the works that, besides simulating the behaviour of the mechanism, predict the wear produced in the joints and the evolution of the clearance gap with time. Relevant studies on dry wear in cylindrical bushings can be found in [1-3]. The wear on the bushing of a revolute joint yields a noncircular shape due to changes in the contact forces. The contour must be discretised to take this effect into account. The problem consists in evaluating the contact at each point of the bushing to obtain the maximum penetration and the direction of the contact force (Figure 1).

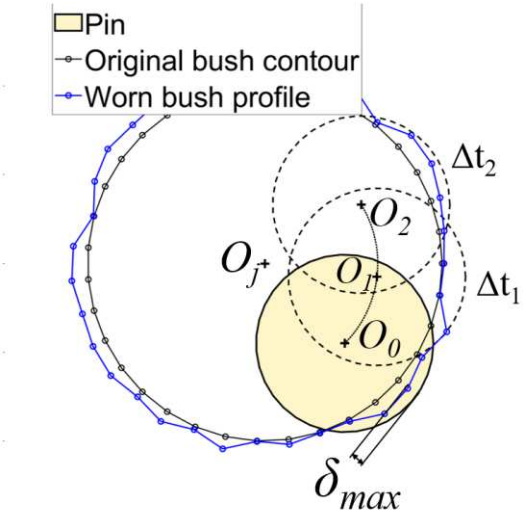


Figure 1: Contact analysis of a revolute joint with a constantly updated wear profile.

Two discretisations are involved when simulating wear: (i) spatial, number of points that describe the bushing contour and approximate the contact area and pressure profile (Fig. 2a); (ii) temporal, time points in which the position of the shaft relative to the bushing changes (Fig. 2b).

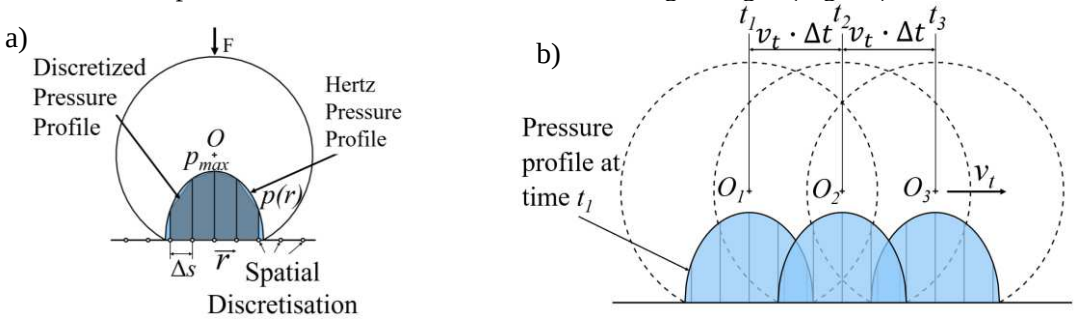


Figure 2: Contact discretisation: a) spatial; b) temporal, with overlap of pressure profiles.

The Hertz contact law of an outer cylindrical surface against an inner cylindrical surface has been considered, which results in an elliptical pressure distribution, as suggested in Fig. 2. Both the time discretisation of the simulation and the spatial discretisation of the contour of the bushing are important, since they have implications in the accuracy and computational cost of the simulation [1, 4]. This work studies the effect of both discretisations in wear modeling when applying the Archard model for a 10-

mm-diameter bushing with a clearance of 0.1 mm with respect to its shaft. The shaft rotates at a speed of 10 rad/s and is subject to a constant force of 1 kN, while sliding along the full perimeter of the bushing. With this force, the contact area covers an arc of approximately 32°. Several models have been considered, increasing the spatial discretisations from 24 to more than 300 points, uniformly distributed over the whole bushing. In addition, the temporal discretisations have been varied from 0.001 s to 0.05 s. The obtained results can be seen in Figure 3.

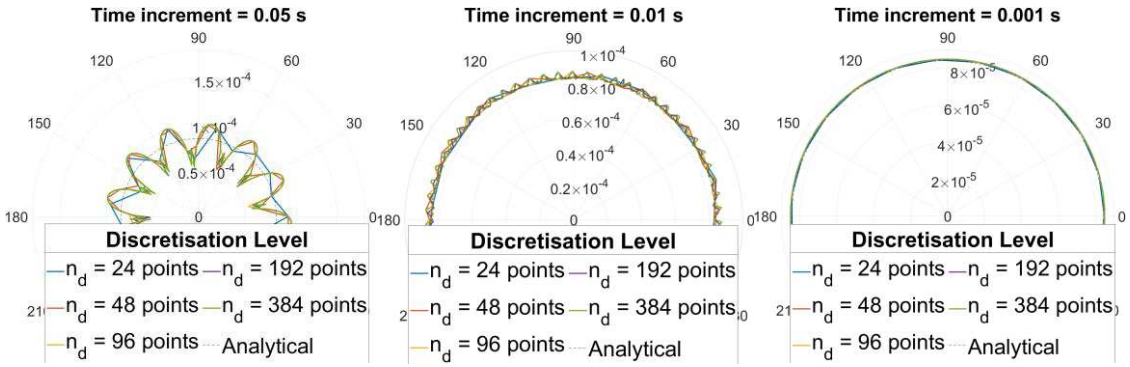


Figure 3: Study on time and space discretization ($n_d$ points) of a pin-bushing contact.

It is concluded that the critical issue is time discretisation, the reason being the overlapping of the contact pressure profiles (Fig. 2b). To obtain an accurate worn contour, the pressure profiles of consecutive time steps should overlap in more than 98%. Since the contact profile is function of force, and the overlap between the contact pressure profiles at different time instants is function of velocity, the force and velocity values will determine the discretisation criteria. The optimal time step as function of the applied force and the rotational speed can be seen in Figure 4.

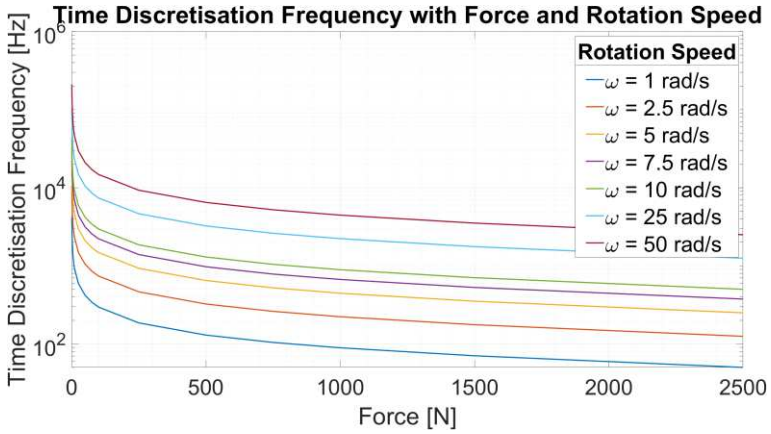


Figure 4: Optimal time step size as function of the contact force and the rotational speed.

## References

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