

Four - bar linkage mechanisms with continuous friction model in joint clearance

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Research Article

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Abstract

Clearance joint widely occurs in the components of mechanical systems as evidence of manufacturing errors. Since a proper set of parameters in the contact and friction model could lead to a higher precision of clearance analysis, the effect of friction models when surfaces collide with a non-zero tangential velocity is examined. Unlike the crank mechanism, a double rocker four - bar linkage mechanism as a challenging problem in the impact mode is analyzed. An investigation on the dynamic modeling and analysis of double rocker four - bar linkage mechanisms with frictional revolute clearance joints is presented. In the presence of clearance joints, asserting friction force, a novel formulation of the contact model is proposed after exploring the perfect continuous friction models with easy parameterization and analyzing the applicable compliant contact force models. The perfect continuous friction models including stribek effect, static, dynamic, and viscous friction terms are studied, and four friction models (Ambrosio, Threlfall, Anderson and Brown) are thoroughly compared. Using an appropriate model, nonlinear dynamic behaviour is examined and to profit by Poincare portrait; it is proven that either strange chaos exists in the system response. FFT analysis expresses the friction and restitution coefficient influence the nonlinear dynamics of the mechanism significantly. The main consideration here is to present a friction model for improving continuity and computational cost. This paper comes to efficiency of the brown friction model which is used in the clearance joint for first time. The results clearly reveal that the angular accelerations of the links and the contact forces in the continuous friction models are smoother and bounded.

Figures

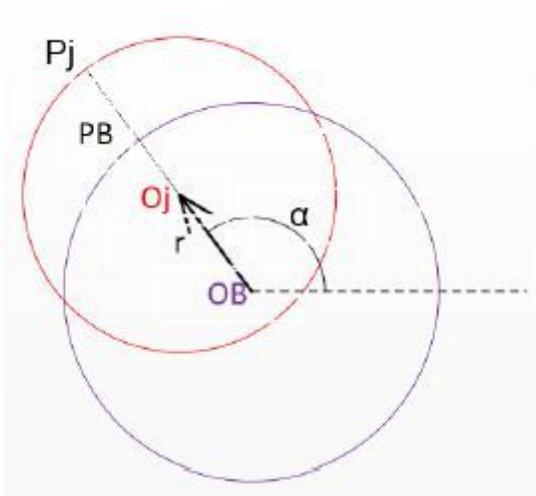


Figure 1

The schematic of the clearance joint

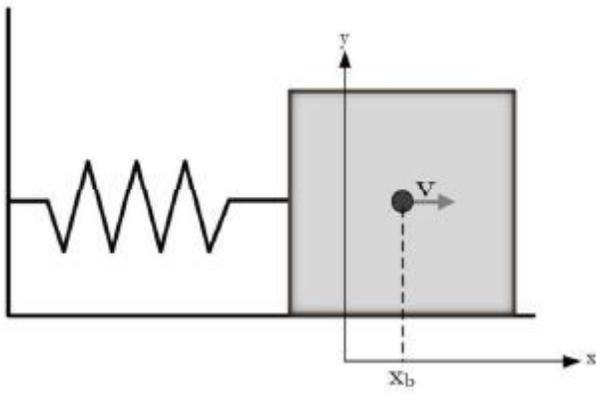


Figure 2

Sliding block with center of mass position x_b and velocity v on a surface with friction

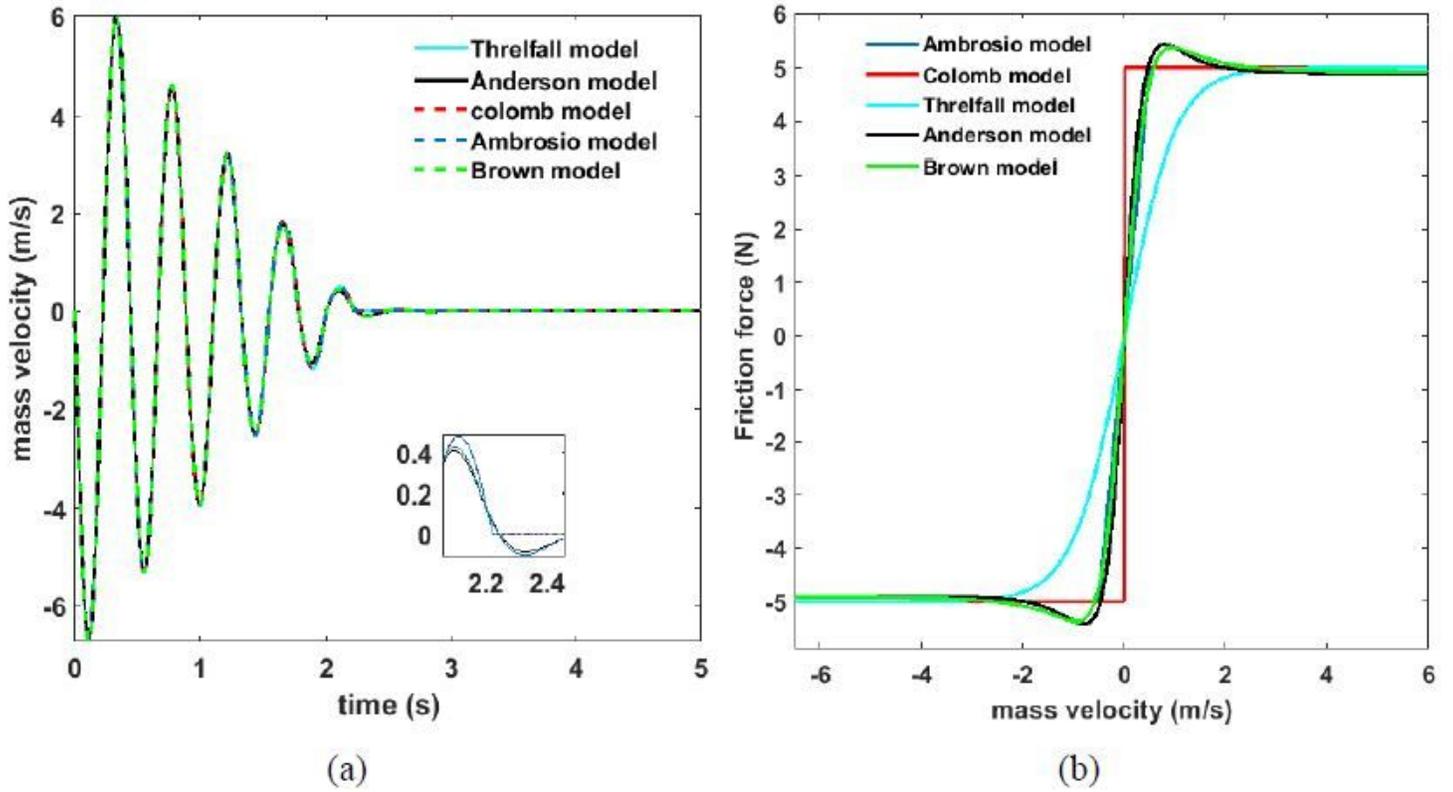


Figure 3

Sliding block behavior (a) center of mass velocity vs time (b) friction force vs velocity

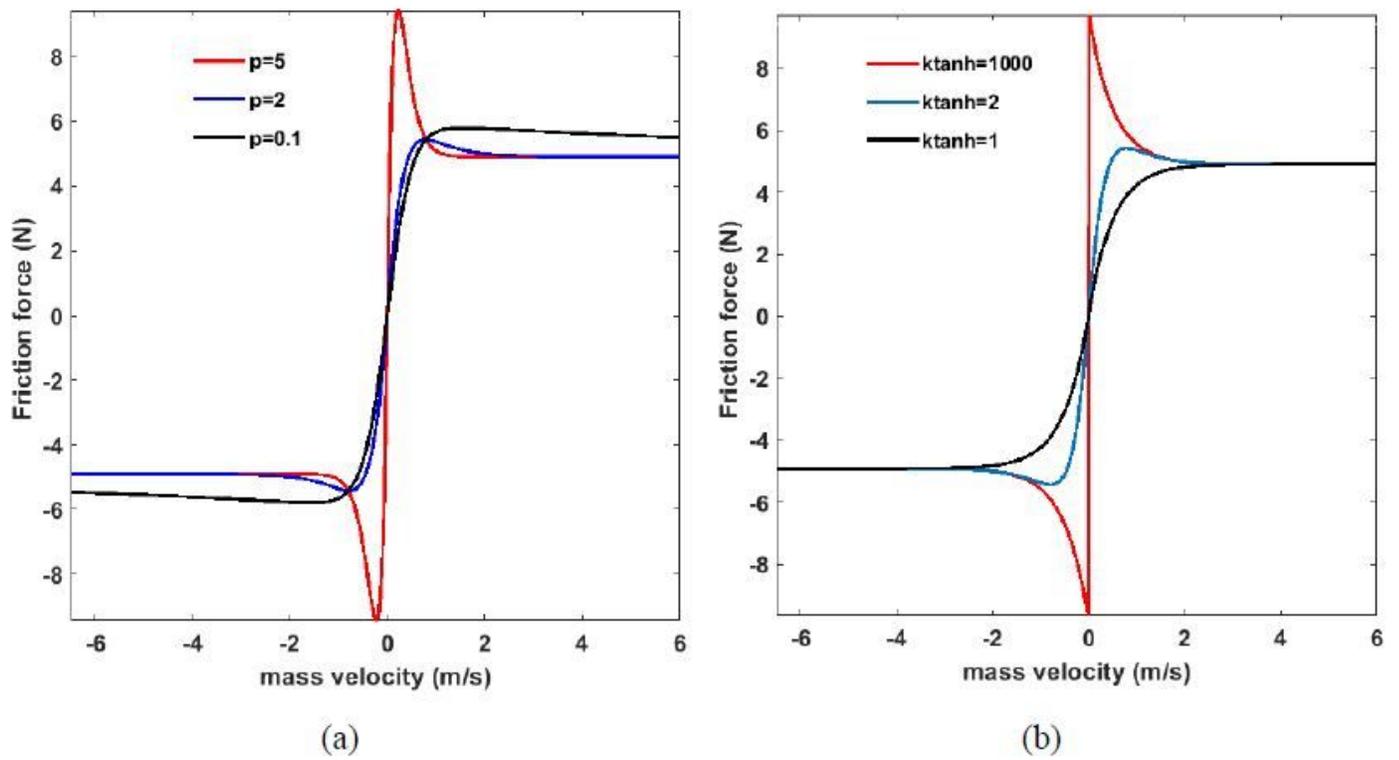


Figure 4

Friction force vs. velocity of sliding block for different parameters of Anderson model (a) p (b) $ktanh$

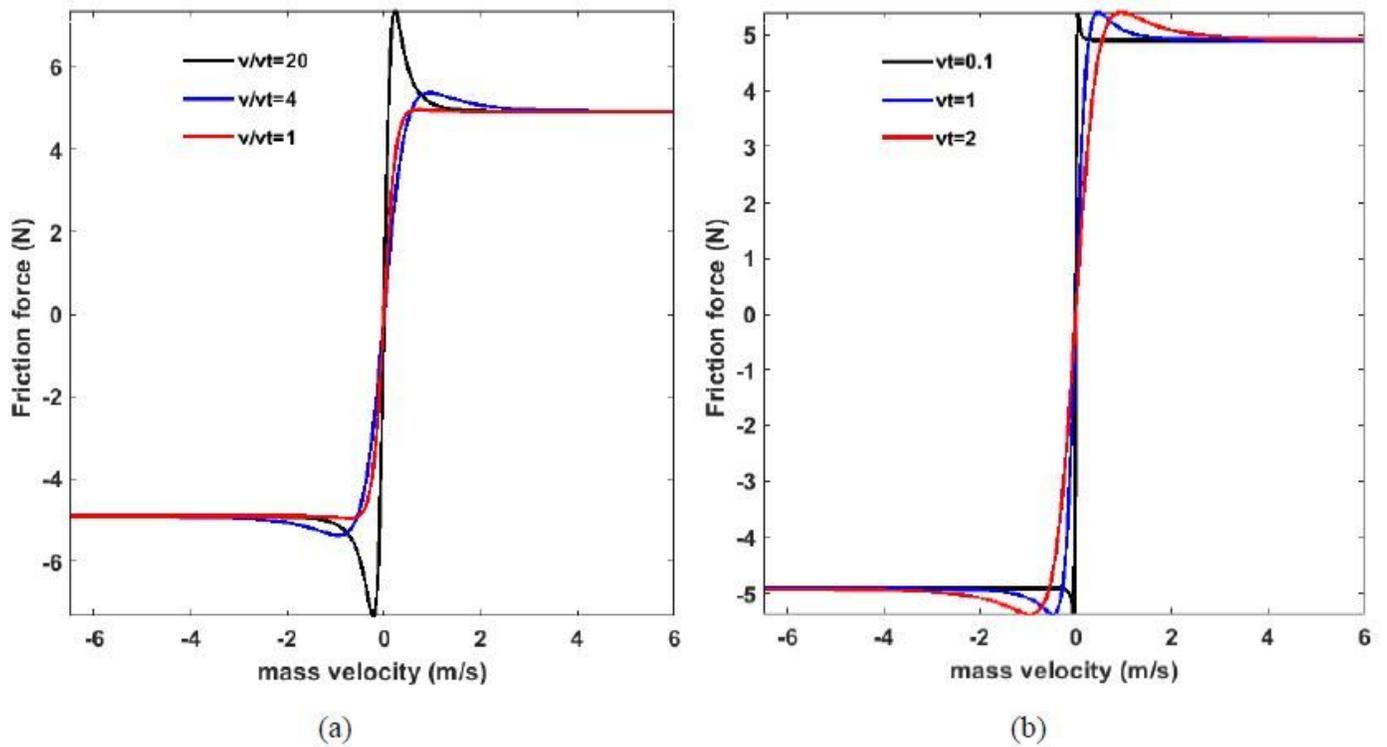


Figure 5

friction force vs. velocity of the sliding block for different parameters of Brown model (a) vvt (b) vt

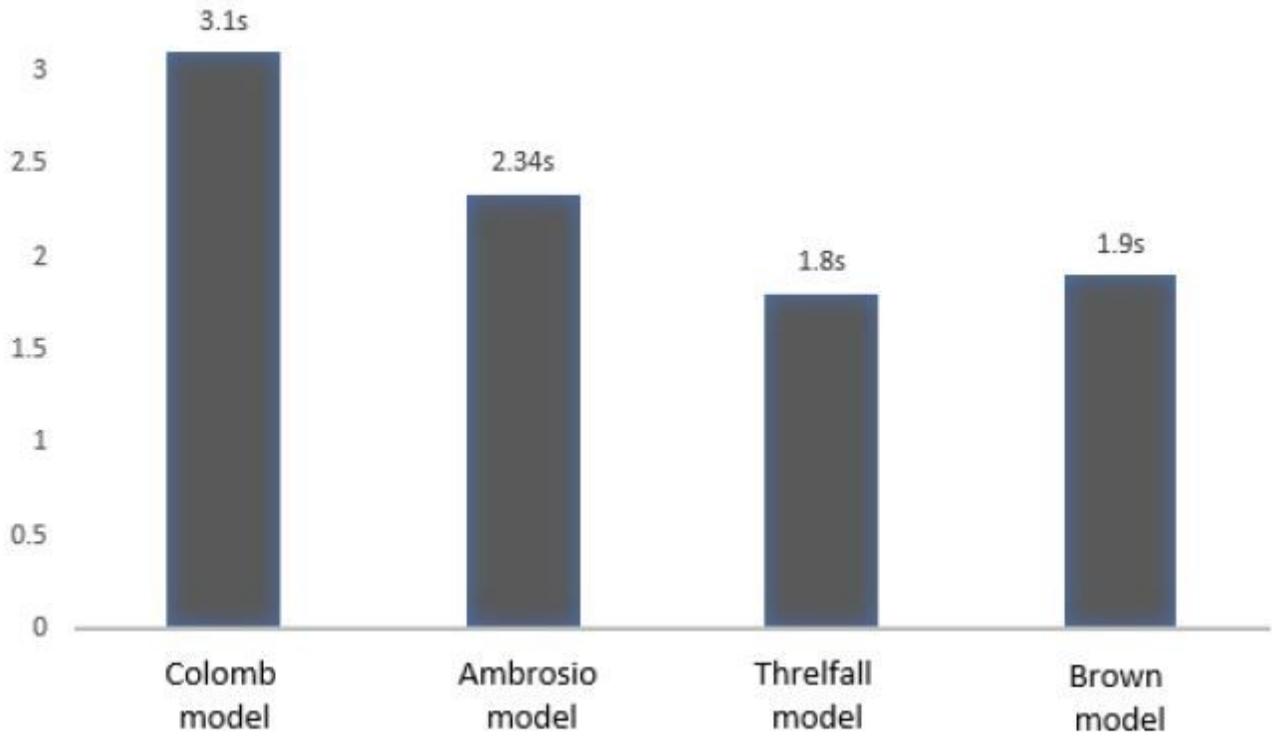


Figure 6

Computing time for different friction models

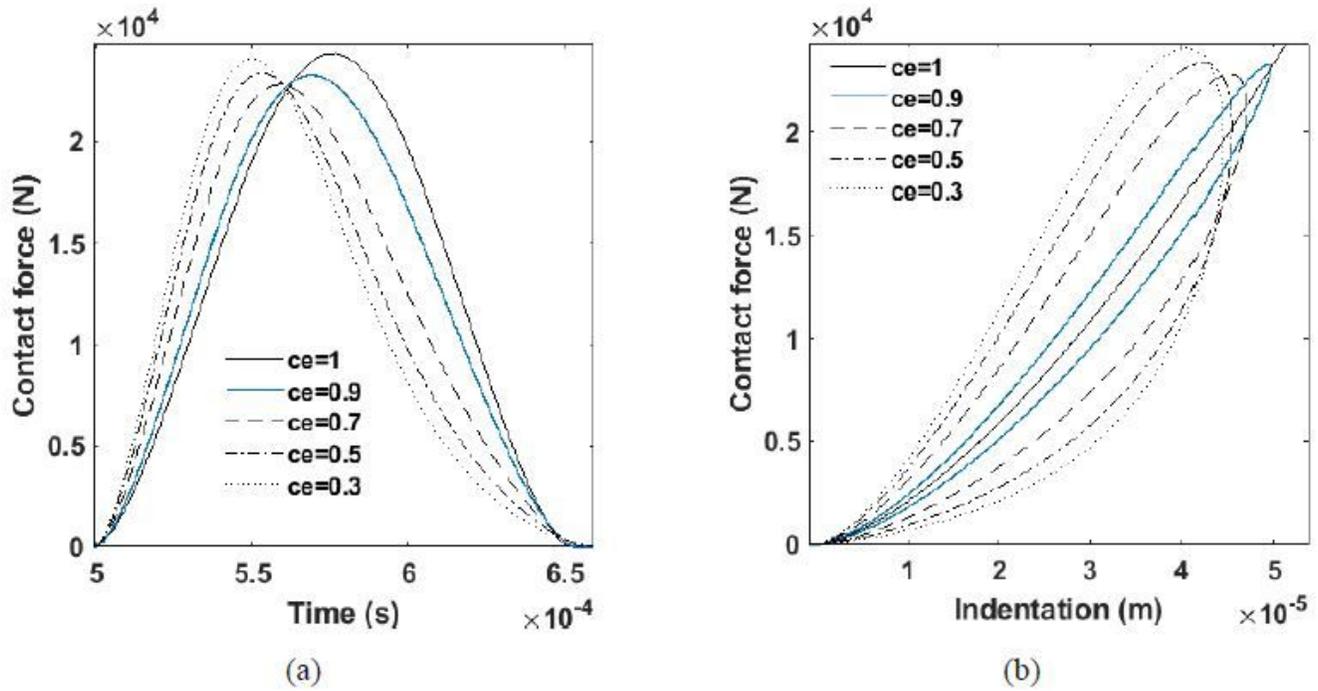
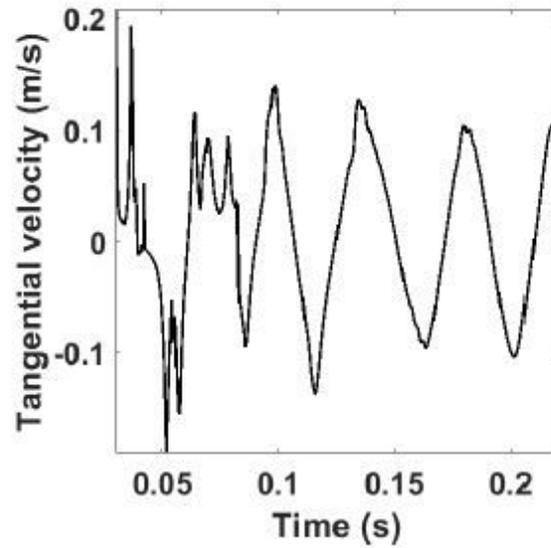
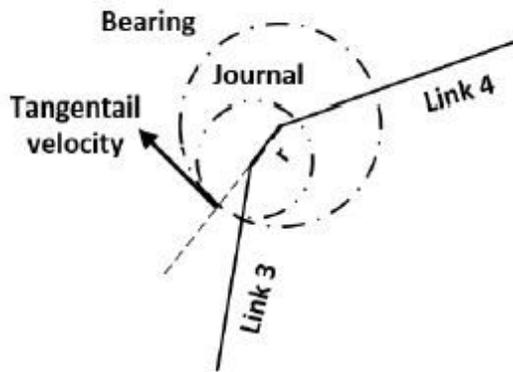


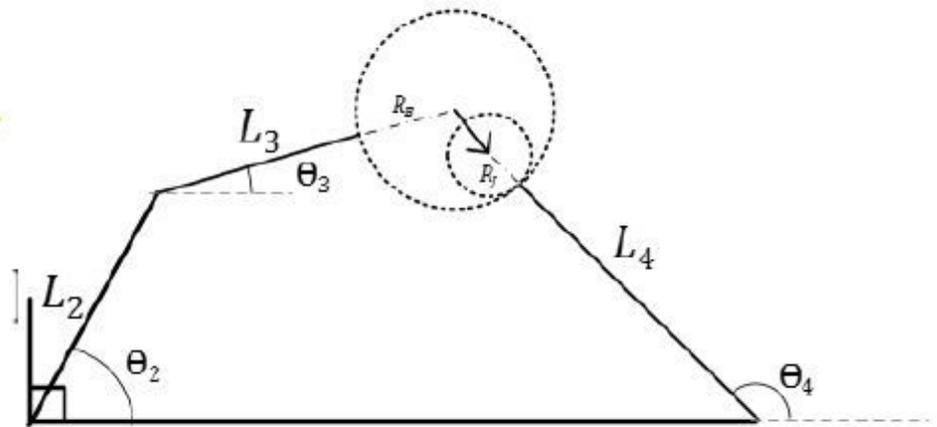
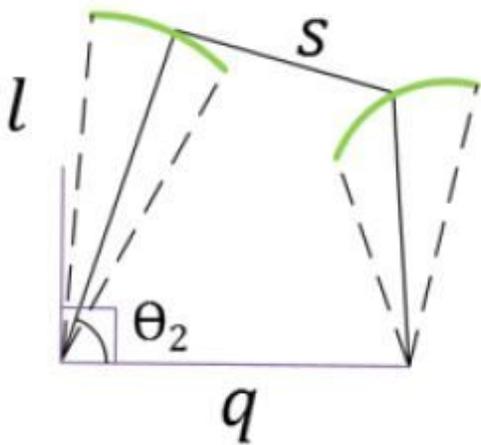
Figure 7

Validation of Lankarani-Nikravesh contact force model. contact force in the clearance joint force – time
 (a) paper results (b) published results, force - indentation (c) paper results (d) published results (first impact)



(a)

(b)



(c)

(d)

Figure 8

Double-rocker four-bar linkage mechanism with frictional clearance joint (a) Clearance joint (b) Tangential velocity (c) Double rocker mechanism (d) clearance joint in mechanism

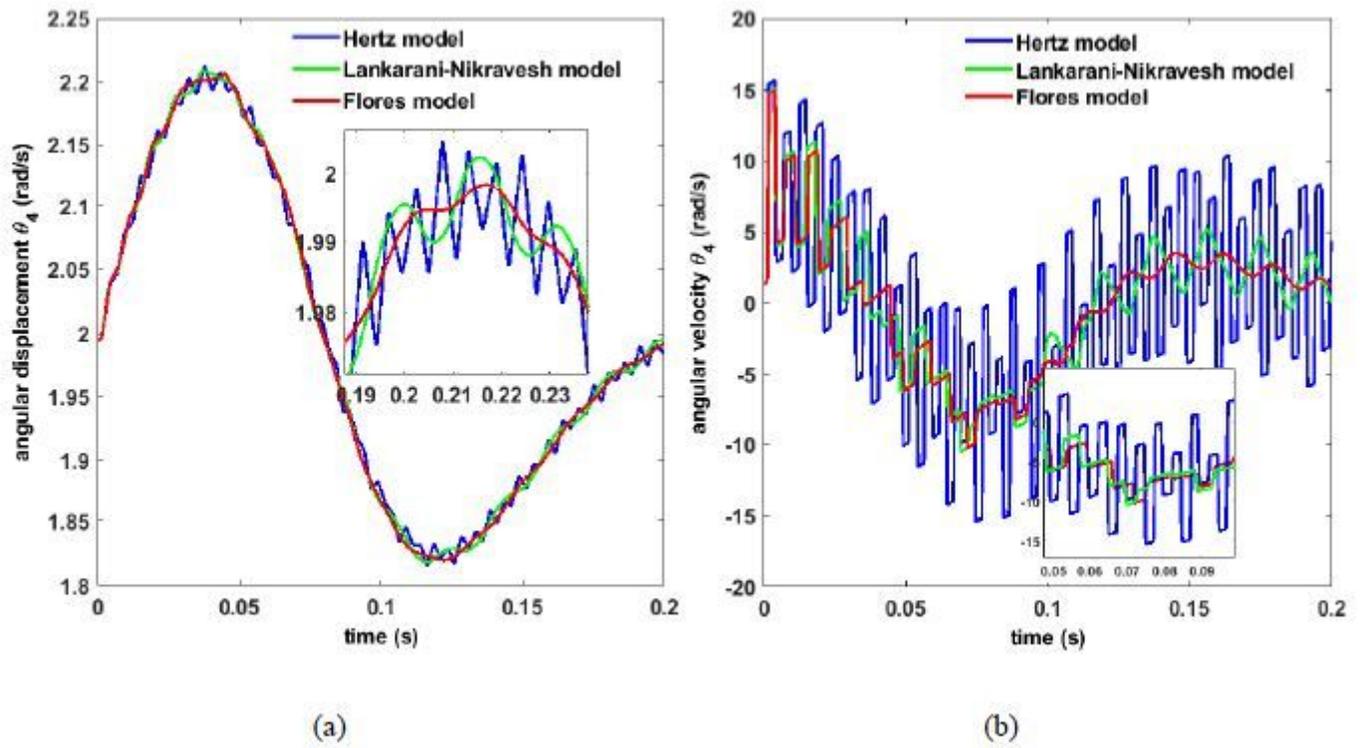
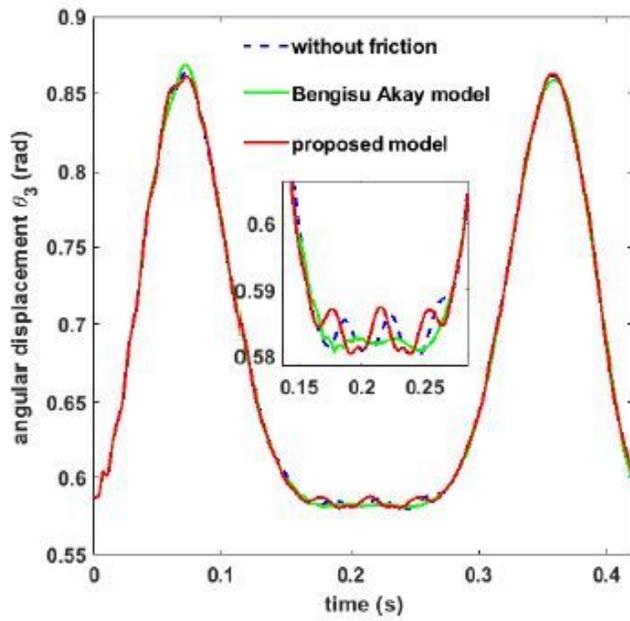
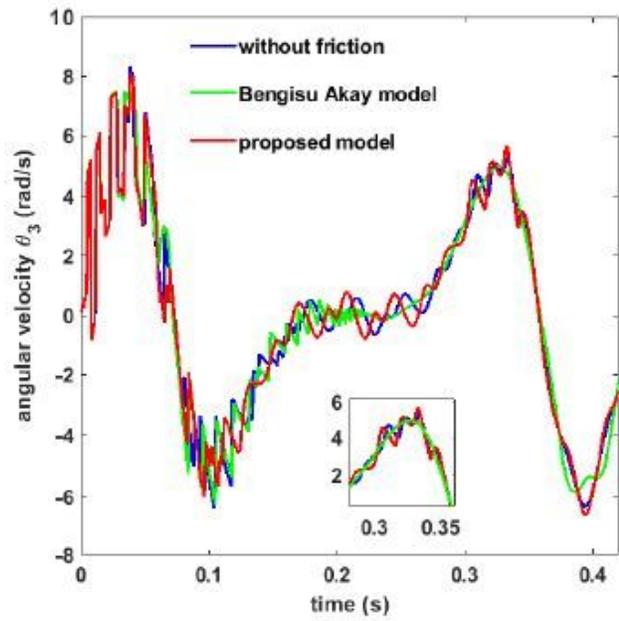


Figure 9

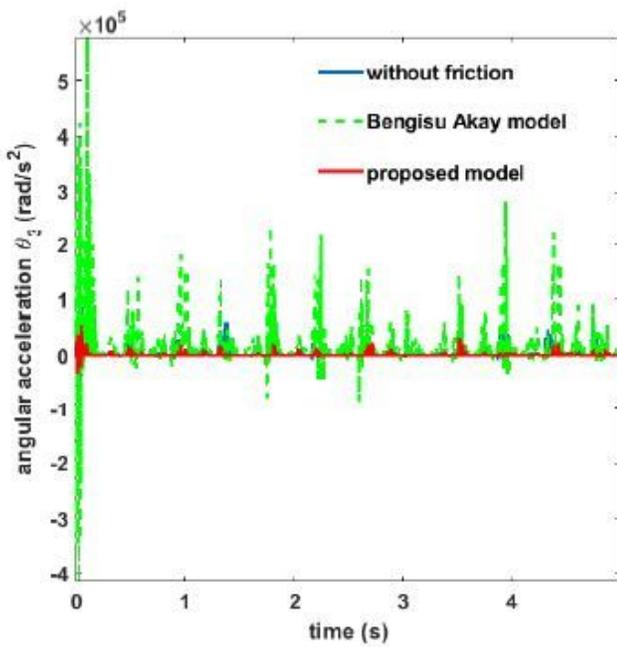
The dynamic behaviour diagram of the four-bar mechanism with a clearance joint based on several contact model (a) Angular displacement (b) Angular velocity of link 4



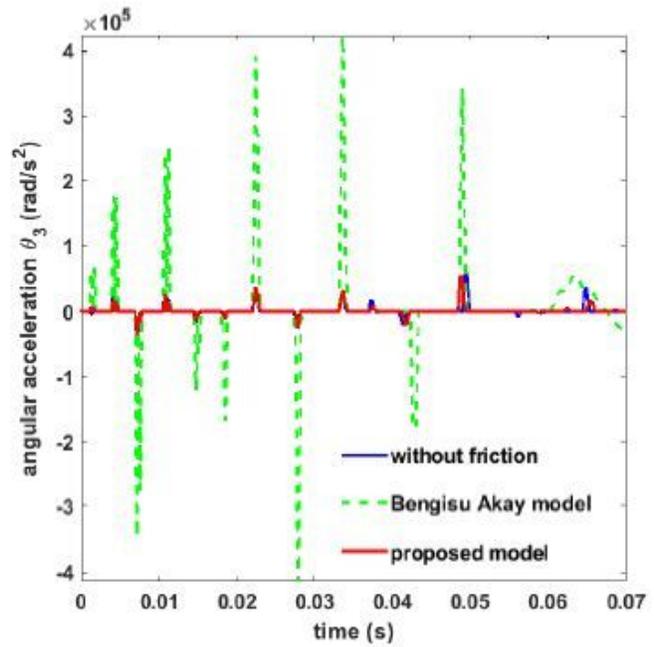
(a)



(b)



(c)



(d)

Figure 10

The dynamic behaviour diagram of the four-bar mechanism with a clearance joint (a) Angular displacement (b) Angular velocity of link 3 (c) Angular acceleration (d) Angular acceleration detail

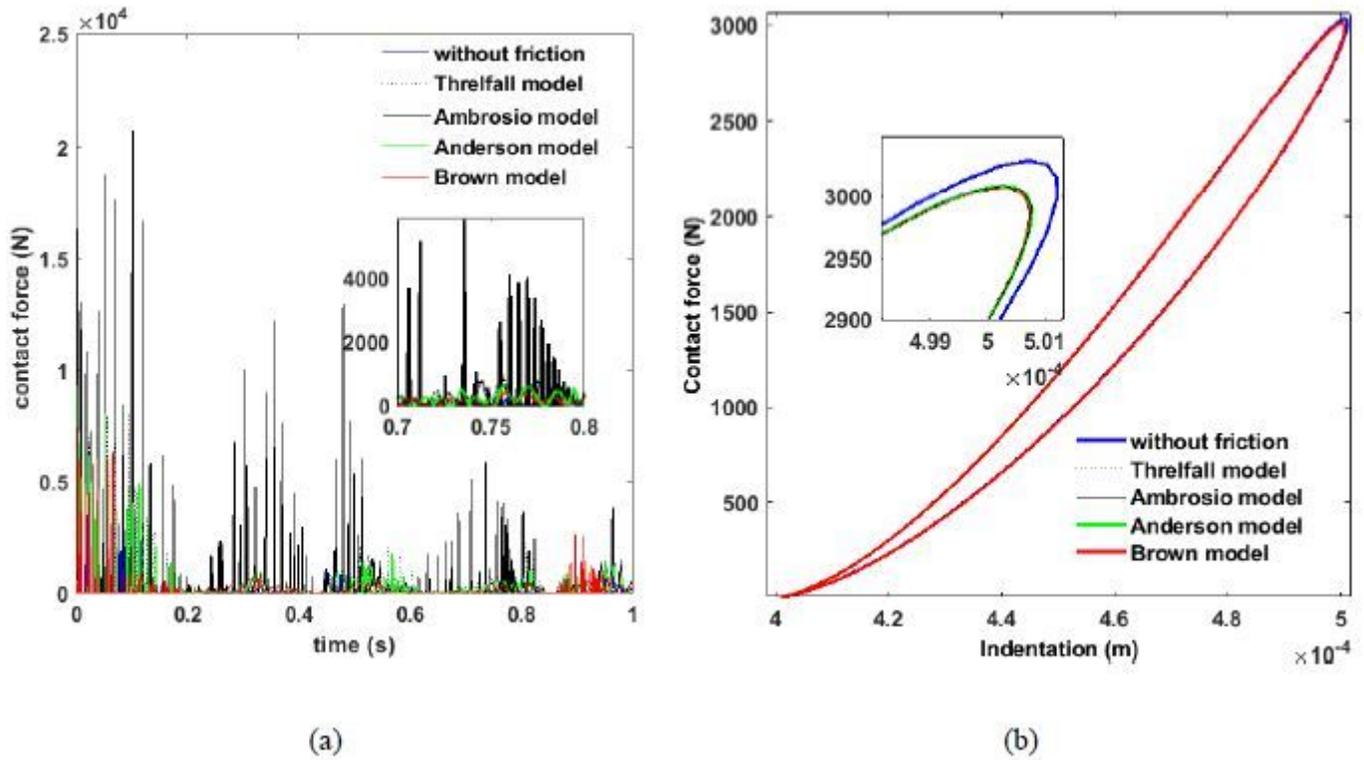


Figure 11

contact force in the clearance joint (a) force - time (b) force - indentation (first impact)

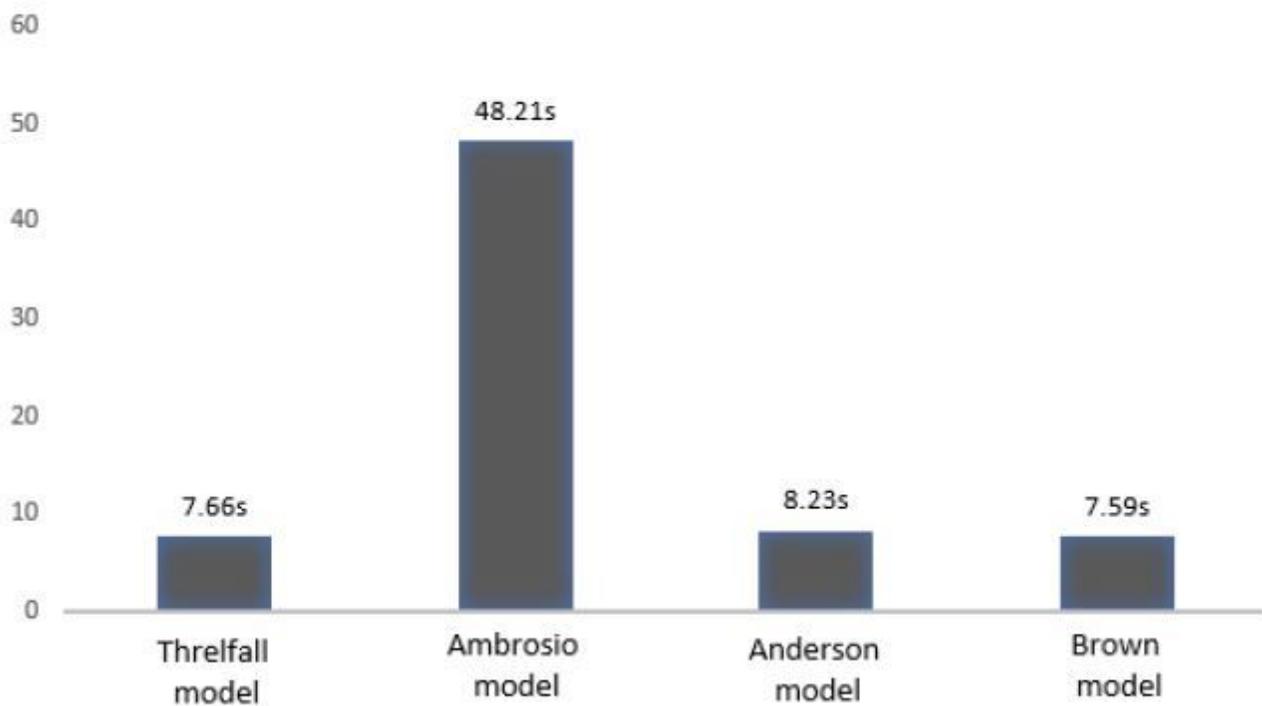


Figure 12

Computing time for different friction models

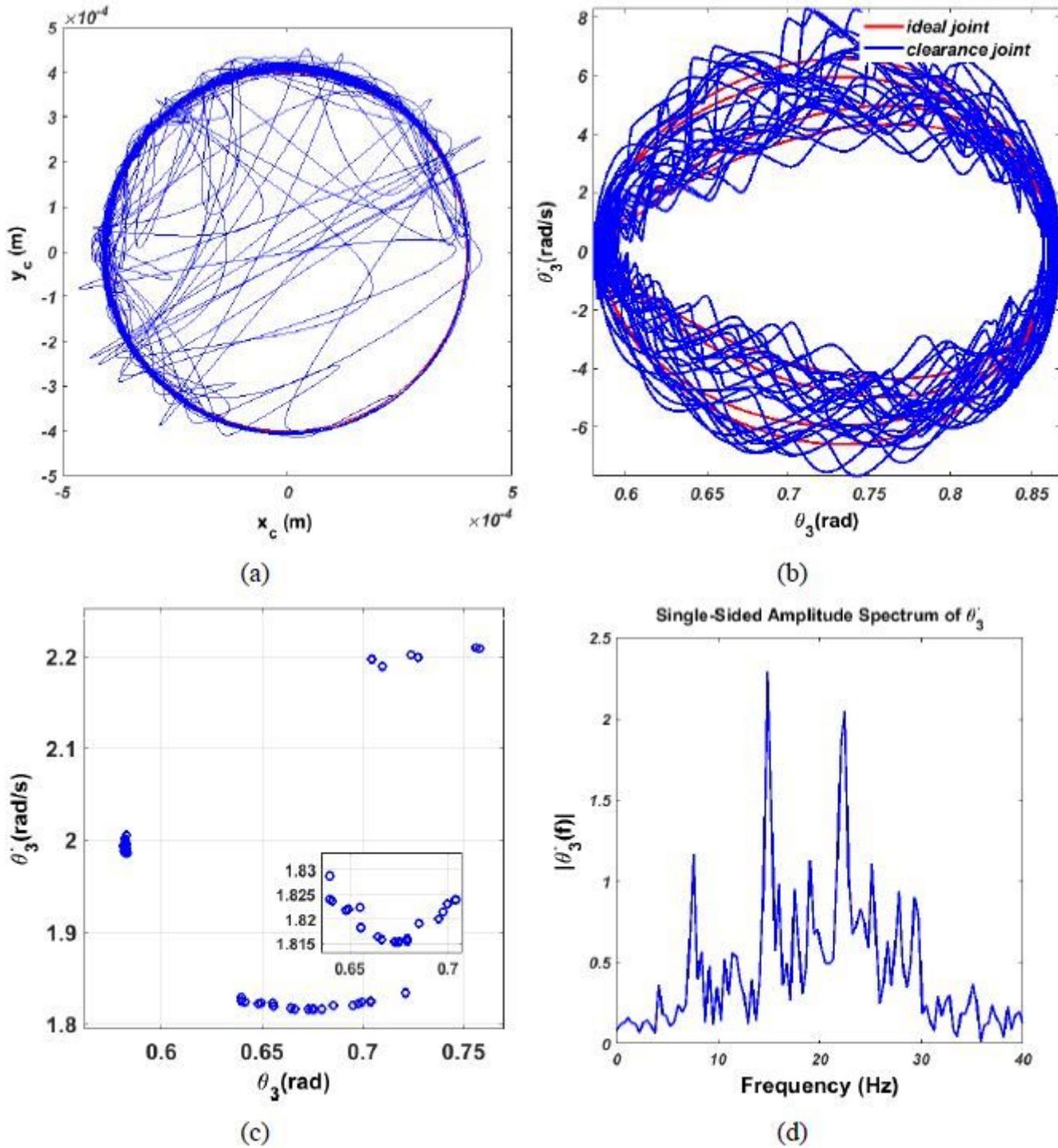


Figure 13

Nonlinear dynamic behaviour diagram of the four-bar mechanism with a clearance joint (a): Journal center trajectory relative to bearing (clearance circle is shown with a red line) (b) Phase diagram (c) Poincaré section of mechanism (d) FFT analysis of θ_3

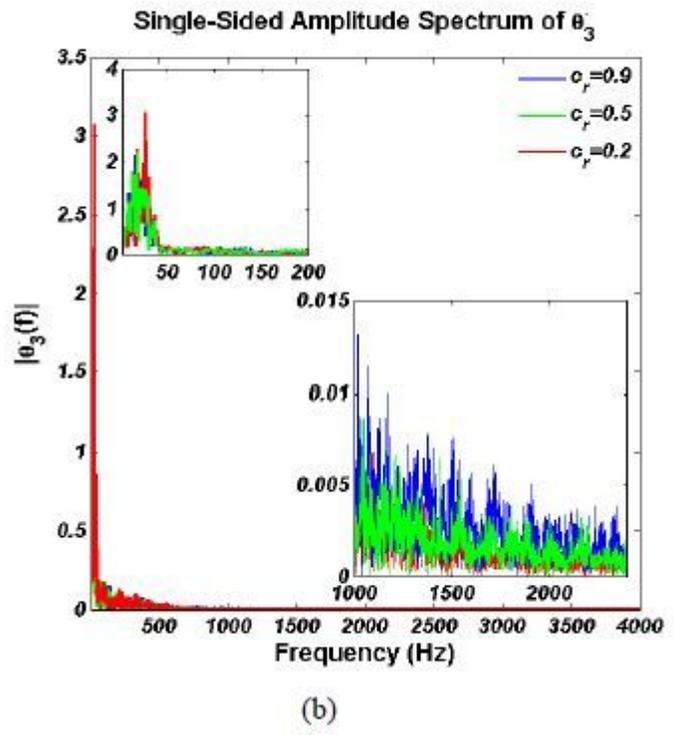
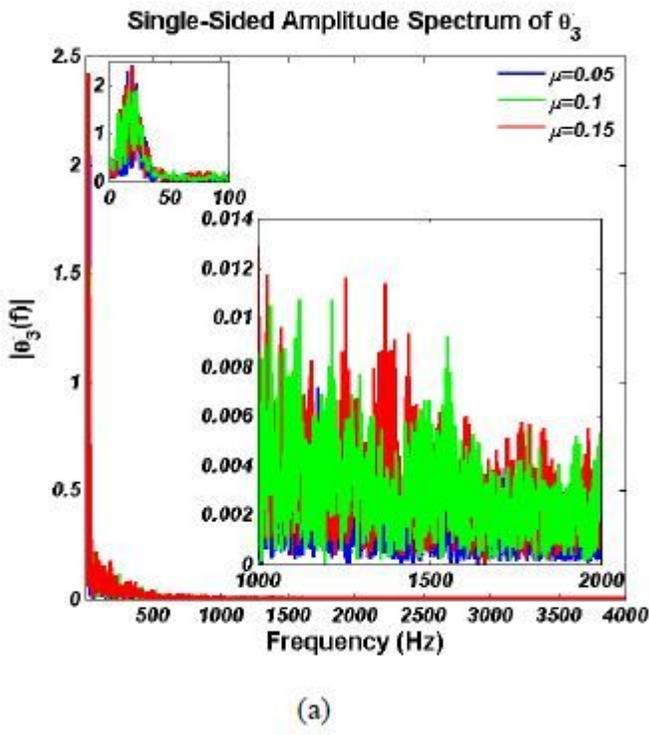


Figure 14

FFT analysis of coupler angular velocity for (a) different kinetic coefficient of friction (b) different restitution coefficients

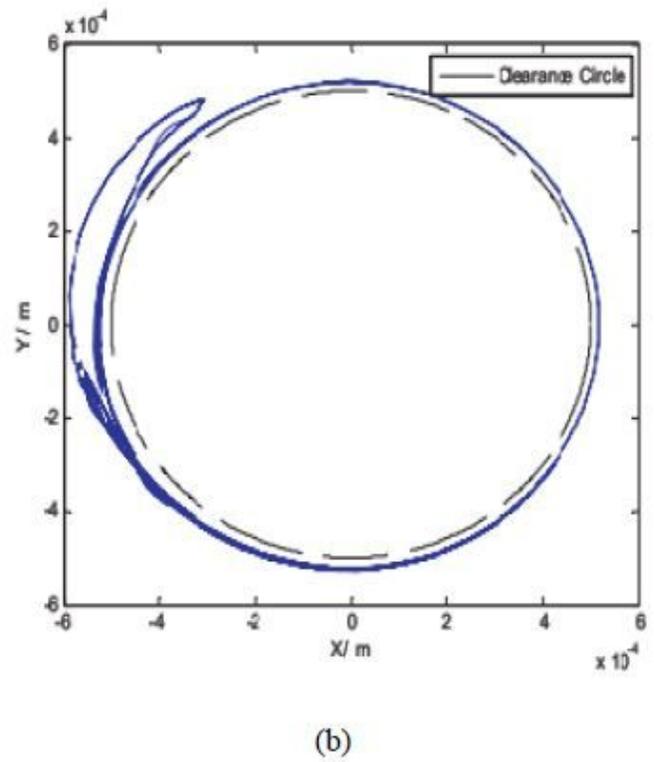
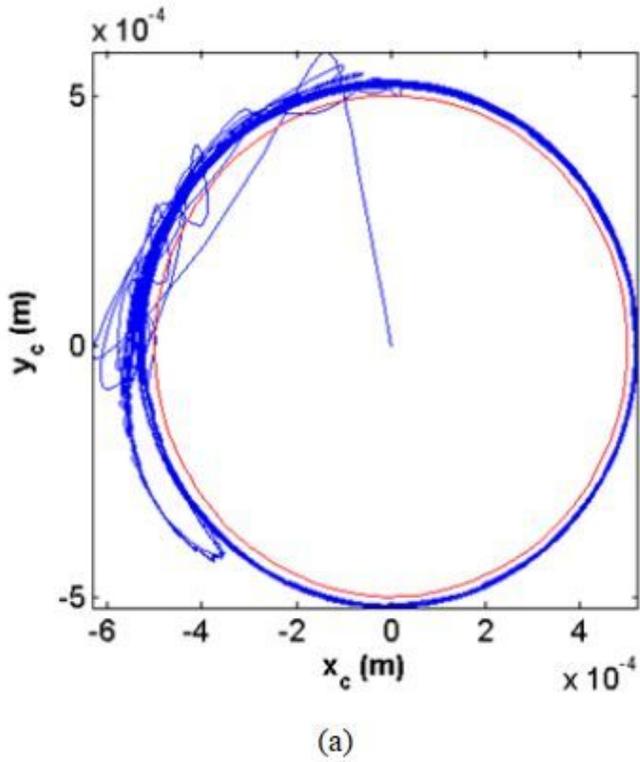


Figure 15

Journal center trajectory relative to bearing in (a) our study (b) verified with the result in [42]