ROLLER CHAIN DRIVES MULTIBODY MODELS USING A GENERALIZED REVOLUTE CLEARANCE JOINT FORMULATION

Jorge Ambrósio* a), Cândida Pereira** & Amilcar Ramalho ***

* *Institute of Mechanical Engineering, Instituto Superior Técnico, Technical University of Lisbon, Av. Rovisco Pais, 1049-001 Lisboa, Portugal*

** *Polytechnic Institute of Coimbra, R. Pedro Nunes, 3030-199 Coimbra, Portugal*

*** *University of Coimbra, R. Luís Reis dos Santos, 3030-788 Coimbra, Portugal*

Summary Roller chain drives can be modelled as a constrained dynamic system composed by a large number of rigid bodies, links, rollers and sprockets, interconnected by multiple ideal or clearance revolute joints. The methodology described for a clearance revolute joint, and particularized for the contact between the pin-link/bushing-link and the bushing link/roller pairs, is generalized to describe the roller/sprocket tooth surface contact pair. The procedure used to establish the geometric contact conditions for each of the different revolute clearance joints is presented as a function of the tooth shape. The methodology describing the tooth profile and allowing for the contact detection uses a tooth fixed coordinate system to evaluate all quantities required by the contact force model. As the contact phenomenon is herein described using the continuous contact force method, the contact force in each contact pair is known at any time during the dynamic simulation.

INTRODUCTION

Chain drives have been recognized as one of the most precise and effective forms of power transmission in mechanical systems. Due to their discrete nature, chain drives are characterized by complex dynamic behaviour dominated i) by the effects of the impacts between the chain links and sprockets and ii) by the fact that even when the driving sprocket of a chain runs at constant speed, the speed of the chain itself is not constant but is subject to periodic fluctuations due to the fact that the chain forms a polygon rather than a circle when wrapped on a sprocket. The combined effect of polygonal action and the occurrence of impacts between rollers and sprockets, at the moment of their engagement, leads to the discontinuities in the system velocities giving rise to transversal and longitudinal vibrations on the spans of the chain. In addition, these phenomena are responsible for part of the noise emitted by mechanical devices that use chains and, ultimately, for the wear of chain drives.

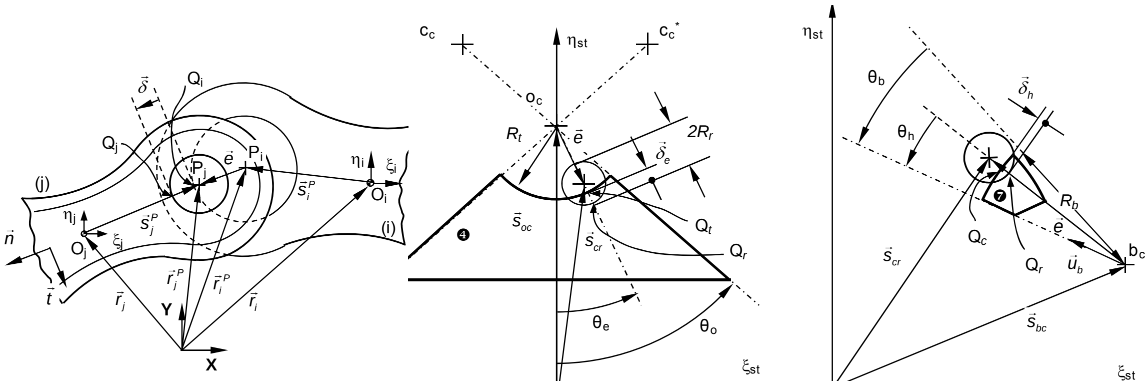
Integrated models that describe the complex dynamics of the roller chain drive, including the detailed description of the nontrivial geometry of the sprocket surface and of the dynamics associated with the polygonal effect, the compliance of the chain, i.e., the flexibility of links, the transversal and longitudinal vibrations, the friction effects, and the impact forces between the chain and sprockets, have been recently proposed by Kim [1], Veikos and Freudenstein [2] and Pedersen and co-workers [3]. However, in most of these models the intentional clearances required to allow relative motion between links and sprockets and to permit the links components assemblage as well and the dimensional variations due to manufacturing tolerances, machining imperfections, material deformations and mechanism wear, which invariably exist in all mechanical systems [4] were neglected. A revolute clearance joint formulation, based on the work by Flores et al. [5], is adopted to obtain a planar multibody mechanical systems model that describe the key elements in the contact of the meshing process of roller chain drives.

METHODOLOGY

A chain drive consists of one or more chains whose links engage with one driving sprocket and one or more driven sprockets. The interaction between bushing, pin and roller is modelled as a classical revolute clearance joint, as the one shown in Figure 1a. The chain engagement on the sprocket results in the contact between the rollers and the sprocket surface. The geometry of the sprocket tooth profile is such that each contact pair can be modelled as an instantaneous revolute clearance joint in which the contact geometry is variable, depending on the region of the sprocket tooth in which contact occurs, as for instance the contacts between roller and seating curve in Figure 1b or with the topping curve of the tooth profile, shown in Figure 1c. The dynamic analysis of roller chain drives is therefore a complex issue, since its behavior is characterized by multiple, simultaneous contacts/impacts. This work proposes to address all contacts in the roller chain drive in a unified form using a generalized revolute clearance joint formulation to represent them.

Another important aspect is the representation of the contact force as a function of the relative kinematics between the contacting surfaces. In all contacts for which the clearance revolute joint model is used the contact force is represented by a new enhanced cylindrical contact model with energy dissipation. The continuous force contact model, first proposed by Pereira et al. [6], is suitable for internal and external cylindrical contacts for small and large clearances.

a) Corresponding author. Email: jorge @dem.ist.utl.pt.



(a) (b) (c)

Figure 1 – (a) classical clearance revolute joint; (b) contact with the seating curve; (c). contact with the topping curve.

APPLICATION RESULTS

In the application a small chain with nine links unwraps about a sprocket, as depicted in Figure 2. The initial conditions for this scenario include an initial angular velocity of the sprocket of 1.257 rad/s being the links of the chain wrapped around the sprocket. The system is only subject to the gravitational forces acting downwards. Figure 2 shows that the kinematics of the chain is characterized by the unwrapping of the lower part of the chain, almost as a pendulum. As the rotation of the sprocket progresses, the different bushings of the chain start sliding down on the teeth profiles until the chain breaks lose.

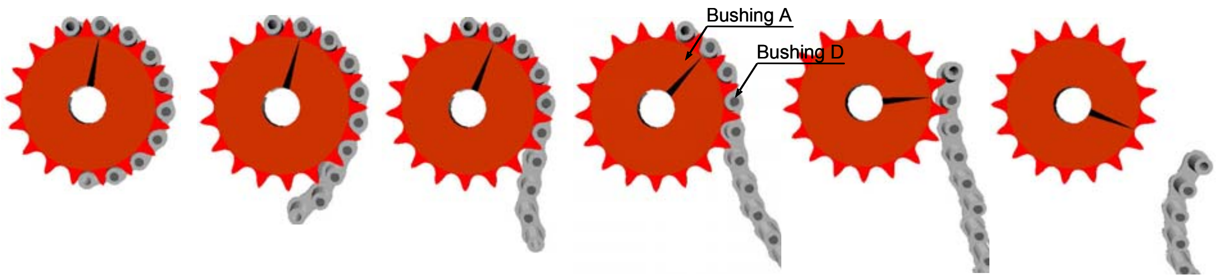


Figure 2 - Sequence of images displacement of the chain and sprocket.

The contact forces acting on bushings A and D, identified in Figure 2, are presented in Figure 3. It can be observed that the contact forces are initially characterized by successive impacts and rebounds but a continuous contact develops afterwards. Although not shown in this application, the pretension in the chain has a stabilizing effect on the contact force.

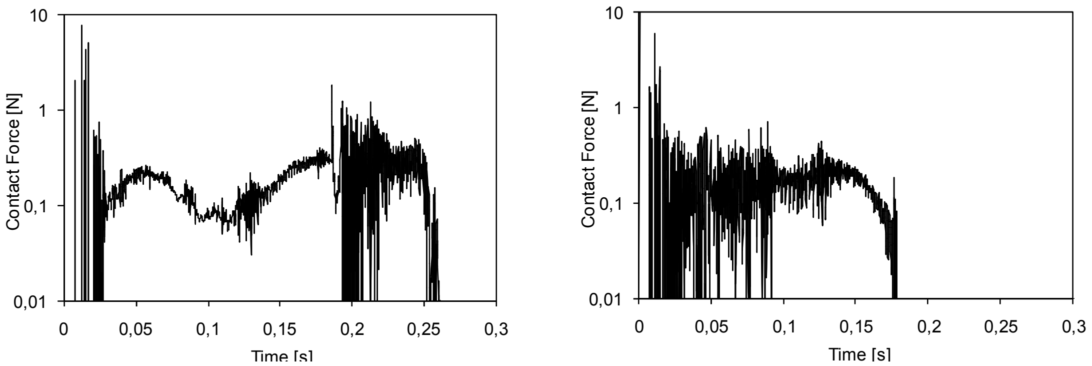


Figure 3 - Contact forces on bushing A and D.

References

[1] Kim, M.S.: Dynamic Behavior of Roller Chain Drives at Moderate and High Speeds, *Ph.D. Dissertation*, University of Michigan, Ann Arbor, 1990.

[2] Veikos, N.M. and Freudenstein, F.: On the Dynamic Analysis of Roller Chain Drivers, *Mechanical Design and Synthesis*, **46**:431-439, 1992.

[3] Pedersen, S.L., Hansen, J.M. and Ambrósio, J.: A Roller Chain Drive Model Including Contact with Guide-Bars, *Multibody System Dynamics*, **12**(3):285-301, 2004.

[4] Flores, P., Ambrósio, J., Claro, J. C. P. and Lankarani, H.: Kinematics and Dynamics of Multibody Systems with Imperfect Joints: Models and Case Studies, Springer, Dordrecht, The Netherlands 2008.

[5] Flores, P., Ambrósio, J., and Claro, J. C. P.: Dynamic Analysis for Planar Multibody Mechanical Systems With Lubricated Joints, *Multibody System Dynamics*, **12**:47-74, 2004.

[6] Pereira, C., Ramalho, A. and Ambrósio, J.: An Enhanced Cylindrical Contact Force Model, *Multibody System DynamicsI*, (submitted), 2012.