Journal of Mechanical Design

Guest Editorial

Design of Direct Contact Mechanisms

It is with great pleasure that we introduce this issue of the Journal of Mechanical Design entirely dedicated to the Design of Direct Contact Mechanisms. This is a first for JMD both as an entire themed issue along with the switch from bimonthly to monthly issues. Editor J. Michael McCarthy articulated the importance of the science of gearing to this journal and felt that a special issue emphasizing its role to JMD is warranted. More than a year ago we agreed to work with Editor McCarthy to realize this special issue. As we collaborated to refine the scope of this special issue, we concluded that gearing is part of the broader classification that we refer to in this issue as the Direct Contact Mechanisms.

Direct Contact Mechanisms consists of gear pairs, cam systems, threaded fasteners, power screws, and certain unique drive systems. These fundamental machine components remain indispensable within the automotive, marine, aerospace, and industrial sectors. Traditionally, these components are treated separately and each component commands its own nomenclature, design and manufacturing methodologies, and standards. Geometrically, threaded fasteners, power screws, and gears are similar, each sharing common nomenclatures; whereas functionally, gears and cam systems each ascribe to motion and/or function transmission between two rotating axes. New methodologies to improve design, lower costs, increase efficiency, reduce noise, extend life, and predict failures of these components are critically needed. Novel applications involving these components are also emerging in the MEMS (micro-electromechanical systems) community. Associated with these new applications and dimensions are challenges in fabrication, assembly, and modeling that require a more thorough understanding of the underlying physics of direct contact mechanisms.

In order to capture the spirit of mechanical design as manifested in direct contact mechanisms, a call for papers was issued in fall 2005. Solicited topics for this special supplement include:

Geometric design of direct contact mechanisms

- Cam systems
- Bolted joints/power screws
- Gear pairs and systems

Performance of direct contact mechanisms

- Wear prediction (also lapping)
- Efficiency (mesh, bearing, and windage losses)
- Pitting and scoring
- Noise, vibrations, and harshness
- Dynamics and impact loading

Micro/nano direct contact mechanism design

Five articles by invited authors combined with ten manuscripts define this special issue. Each paper followed the standard journal manuscript review process and was critiqued by at least three anonymous experts. Four categories are established based on the original call for papers and the evaluations of the submitted manuscripts; these categories are *geometry*, *performance*, *specialized mechanisms*, and *technical brief*. Presented is a brief synopsis of the included papers with a discussion on the merit of the research.

In the category of *geometry*, we have five excellent papers. The first paper is by Chen and Angeles on the optimum design of drives for wheeled mobile robots based on cam-roller pairs. This paper is a result of an invitation sent to Professor Angeles, who has directed many studies on robotic systems and precision machines comprising of cams and gears. In this study, the authors cleverly develop and optimize an efficient, low friction, high-stiffness, precision cam-roller transmission.

Fuentes was invited to contribute to this special issue based on his research and coauthorship of *Gear Geometry and Applied Theory* with Professor Litvin. Together with Yukishima and Gonzalez-Perez, they investigated a particular class of worm gear drives. This research establishes the local contact conditions for worm gear drives fabricated with an oversized hob-cutter in addition to a misaligned hob-cutter. These relations are applied to a conventional right angle drive as well as a nonorthogonal worm gear drive with a crossing angle of 85 deg.

The following three papers complete the *geometry* topic. In the next paper, Hiltcher and his coauthors, Guingand and de Vaujany, perform an in-depth study of the load sharing of a worm gear in mesh with a plastic wheel. Due to the unique contact problem involving very dissimilar materials as seen in this type of drive, the authors rely on a combined analytical, computational, and experimental approach to tackle the quasi-static loaded behavior.

Fan presents a generic algorithm to determine the localized contact conditions for spiral bevel and hypoid gear drives. This algorithm uses the universal motion concept as applied to face milled and face hobbed manufacturing procedures. The number of iterations, as compared with existing techniques, necessary to determine contact conditions is reduced using this technique. This approach bypasses the intermediate approach of determining gear tooth curvature.

Fong and Shih propose a mathematical model for face milling and face hobbing of spiral bevel and hypoid gears. Three modules are used to define this universal mathematical model. One feature of this model is the OOP or object oriented programming aspect that enables packaging of the results for use with exiting software packages. An illustrative example is included to demonstrate the model.

Presented in the *performance* category are seven papers. Singh, who directs the OSU Acoustics and Dynamics Laboratory, was invited to make a special contribution. In this study, He, Gunda, and Singh examine friction excited vibrations for helical gears. A time-varying nonlinear 12 degree-of-freedom model using finite elements to determine tooth compliance was developed to simulate the dynamic response.

Kahraman, who is the current Director of the OSU Gear Dynamics and Gear Noise Research Laboratory, was invited to discuss the mechanical efficiency in gears. The final manuscript is coauthored by Xu, who was Kahraman's advisee, along with Anderson and Maddock. Their paper applies a non-Newtonian thermal elasto-hydrodynamic lubrication (EHL) model along with a multivariate linear regression analysis to predict friction-related mechanical efficiency losses in geared rotor systems.

Pedrero, Vallejo, and Pleguezuelos introduce a nonuniform model for load distribution in spur and helical gear elements, and investigate the contact and fillet stresses for gears with contact ratios between 2 and 2.5. They model these stress relations using an elastic potential criterion and compare their results to the ISO 6336 International Standard. Hundreds of design scenarios were analyzed. Recommendations for reducing tooth root stress and contact stress are made based on this analysis.

Another gearing performance paper by Tamminana, Kahraman, and Vijayakar examines the relationship between dynamic factor and dynamic transmission error of spur gears. This paper highlights many of the critical issues related to gear dynamics and, in particular, the rich nonlinearity that arises under certain operating conditions.

Singh contributed a paper that discusses the influence of bearings on the performance of planetary gear systems. The paper introduces a specialized finite element model with contact capability to show the complexity of the interaction between contacts that occur in gears and bearings. The parametric analysis performed in this study clearly reveals critical design parameters that control the severity of dynamic response.

Another planetary system paper was offered by Abousleiman, Velex, and Becquerelle. In their study, a substructure finite element method was employed which enables a highly accurate and efficient representation of the geared drives. The study plainly demonstrates the suitability of the proposed model for quantifying the major design parameters influencing planetary gear dynamics.

The final *performance* paper by Chen and Angeles describes the virtual-power flow and efficiency of epicyclic gear trains applying a novel computational algorithm based on virtual-power balance and ratio. This paper concludes with an analysis of three different types of applications.

Two papers are included to bridge the nanoscale with the microscale in the *specialized mechanisms* arena. For this category, Ananthasuresh was invited to contribute to this special issue. Together with Mankame, the two researchers introduce a device with intermittent contact used for double cycling. This device incorporates both rigid and compliant elements to double the frequency of an input. Nonlinear finite element analysis was chosen to model the device's dynamics behavior. The theoretical work is complemented by a prototype and test results.

The work by Luo, Wu, Yu, and Zhu focuses on a highly specialized mechanism employing friction drive with magnetized metal belt drives. The paper takes us through a theoretical analysis employing friction and electromagnetism theories that is then followed by an experimental study. The paper reports on very promising efficiency and other performance metrics including precision, power transfer, component stress, and life.

Lastly, a *technical brief* by Changenet and Velex tackles the challenging task of predicting churning losses in geared transmissions. They combine dimensional analysis with experiments to establish a set of formulas to predict churning losses of a gear element partially submerged in a lubricant.

The guest editors want to especially acknowledge the reviewers of this special issue for providing detailed and timely evaluations of the included manuscripts. We hope that the readers will find that the manuscripts in this issue capture the latest technological trends in direct contact mechanisms and spawn additional research questions. We are very fortunate to have the opportunity to work with Editor McCarthy, and we greatly appreciate his confidence in our capacity to design this special issue on direct contact mechanisms.

David B. Dooner
Teik C. Lim