11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

A SPATIAL DYNAMIC MODEL TO INVESTIGATE HIP SQUEAKING AND CONTACT POINT PATH IN HIP IMPLANTS

Ehsan Askari [1*], Paulo Flores [2], Danè Dabirrahmani [3], Richard Appleyard [4]

[1] Australian School of Advanced Medicine, Macquarie University, Sydney, ehsanaskary@gmail.com
[2] Department of Mechanical Engineering, School of Engineering, University of Minho, Portugal, pflores@dem.uminho.pt
[3] Australian School of Advanced Medicine, Macquarie University, Sydney, Daneh.Turner@mq.edu.au
[4] Australian School of Advanced Medicine, Macquarie University, Sydney, richard.appleyard@mq.edu.au

Key Words: *Hip Implant, Hip Squeaking, Multibody Dynamic Model, Contact Point Path.*

Ceramic-on-ceramic (CoC) hip arthroplasty has demonstrated very good clinical performance due to its superior wear resistance and low biological reactivity. However the occurrence of audible squeaking in some patients is a cause for concern with a reported prevalence of between 1% and 20% [1]. A possible cause of squeaking in CoC bearings is friction-induced vibration due to stick-slip phenomenon [2] and friction-induced whirl vibration [3]. Weiss et al. [3] found experimentally that in addition to the gross head movement against the liner, there was also a superimposed two-dimensional oscillating motion of micrometer amplitude. However, the reported hip squeaking frequencies were higher than those found in vivo.

In addition to squeaking, friction-induced vibration can also affect the sliding track shape in terms of both macro and micro behaviour, which can cause a huge variation in the wear rate [4]. While previous studies have attempted to estimate sliding distance shape in artificial hip joints [4], the effect of friction on sliding shape of the head inside the cup was only considered by Mattei and Di Puccio [5]. They reported macro alteration in the contact point track on both the cup and head surface.

The present paper hypothesises firstly that stick-slip, negative-damping effects and alteration in contact force induces a three-dimensional vibration of the head within the cup; and secondly that this friction-induced vibration alters the head/cup contact point sliding track in both micro and macro domains. A spatial multibody dynamic approach was developed taking into account three-dimensional physiological forces and motion of the human body. Tangential and normal contact forces were incorporated into nonlinear motion equations as external forces. Governing dynamic equations were solved using numerical methods and FFT analysis used to extract hip squeaking frequencies. The approach was found to be robust and fast with respect to computation time and accuracy and the results validated by comparing with outcomes available in the literature [3]. Moreover, hip squeaking frequencies obtained from the present procedure are consistent with in-vivo results [6].

Results demonstrated that hip squeaking is caused by friction-induced vibration which in turn is induced by stick-slip friction, negative-sloping friction and contact force changes. It was also demonstrated that while the head vibration was three-dimensional, the oscillation amplitude in the *z*-direction (inferior-superior) was much lower than the *x* and *y* directions (Fig.

1). An important finding was that friction-induced vibration affected contact pressure, moments and the sliding track shape considerably which may have a significant effect on hip implant wear rates (Fig. 2).

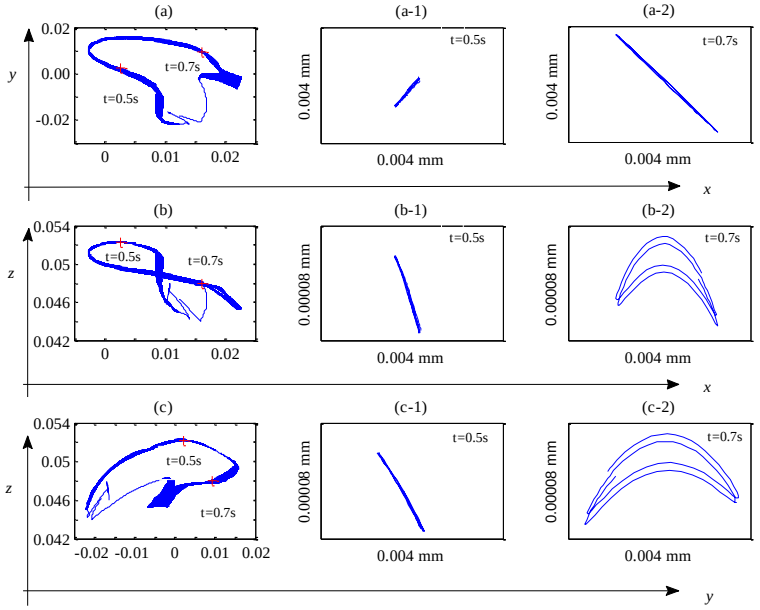

Fig. 1. Contact point path, (a), (b) and (c), and vibration of the femoral head in *x*, *y* and *z* directions; (a-1), (b-1) and (c-1) reveal the head vibration at t = 0.5s and (a-2), (b-2) and (c-2) at t = 0.7s.

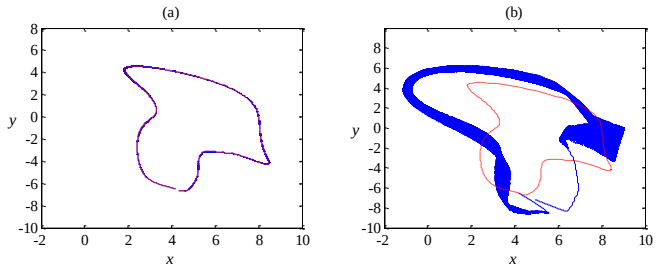

Fig. 2. The track of contact point projected on the *x*-*y* surface. (a) Ideal joint (distinct red line) and clearance joint with low friction (continuous blue line); (b) Ideal joint (distinct red line) and clearance joint with high friction (continuous blue line).

REFERENCES

[1] C. Restrepo, J. Parvizi, S. Kurtz, P. Sharkey, W. Hozack, R. Roth-man, The noisy ceramic hip: is component malpositioning the cause? *Journal of Arthroplasty* Vol. **23**, pp. 643-649, 2008.

[2] J. Currier, D. Anderson, D. Van Citters, A proposed mechanism for squeaking of ceramic-on-ceramic hips. *Wear* Vol. **269**, pp. 782-789, 2010.

[3] C. Weiss, A. Hothan, G. Huber, M. Morlock, N. Hoffmann, Friction-induced whirl vibration: Root cause of squeaking in total hip arthroplasty. *Journal of Biomechanics* Vol. **45**, pp. 297-303, 2012.

[4] V. Saikko, O. Calonius, Slide track analysis of the relative motion between femoral head and acetabular cup in walking and hip simulator. *Journal of Biomechanics* Vol. **35 (4)**, 455-464, 2002.

[5] L. Mattei, F. Di Puccio, Wear Simulation of Metal-on-Metal Hip Replacements with Frictional Contact. *Journal of Tribology* Vol. **135 (2)**, 2013.

[6] W. Walter, T. Waters, M. Gillies, S. Donohoo, S. Kurtz, A. Ranawat, W. Hozack, M. Tuke, Squeaking hips. *Journal of Bone and Joint Surgery-American* Vol. **90 (4)**, 102-111 (2008)