Incremental Cyclic Fretting Corrosion and Micromotion Test of Hip Implant Head-Neck Tapers

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Statement of Purpose: Mechanically assisted crevice corrosion (MACC) continues to be a major concern in total joint replacements. Significant levels of corrosion continue to be seen in a wide variety of implant designs and recent clinical studies have reported an increase in corrosion-related adverse local tissue reactions[1]. Current bench-top MACC test methods for taper junctions in conventional hip implants are limited in their ability to assess materials and design and characterize the interactions between corrosion and fretting motion. We present a method where electrochemical and micromotion data are concurrently captured during an incremental, short-term cyclic fretting corrosion testing of hip stems. The goal of this study is to describe this complimentary collection method and to evaluate the performance of three different designs by one manufacturer.

Methods: Three different Stryker implant designs (n=6 or more) were investigated: G1) Accolade II with V40 Taper and LFit Anatomic head (Ti-6Al-4V/CoCr), G2) Secure Fit with C Taper and LFit Anatomic head (Ti-6Al-4V/CoCr), and G3) Accolade TMZF with V40 Taper and LFit Anatomic head (TiMoZrFe/CoCr). The femoral stems were mounted in an acrylic base (Lang Dental) oriented 10 degrees valgus to the vertical. Polypropylene bowls were fixed to the mounting using silicone to serve as an environment chamber in which phosphate buffered saline (PBS, Room T) was placed just above the level of the taper junction. Two non-contact eddy current sensors were mounted to the stem while an electrically isolated aluminum target plate was mounted to the head. The sensors were mounted superiorly (Sensor 1) and inferiorly (Sensor 2) to the head-neck taper (Fig. 1) and measured the micromotion associated with the head and neck of the devices during cyclic loading and were comprised of both elastic and rigid-body motions.

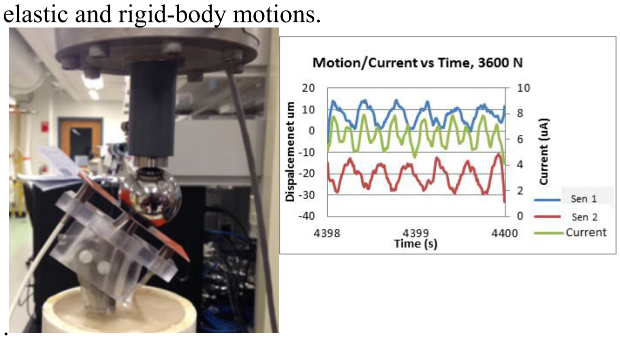

Fig. 1: Systemic setup of implant sample on Instron and snap shot of sensor motion and current data during load

Head seating, followed by an incremental cyclic fatigue loading (R=0.1, 3Hz, 3 min intervals) was applied and loads, motions and fretting corrosion currents were measured potentiostatically (-50 mV vs Ag/AgCl). Heads were seated using an anatomically oriented loading ramp of 200 N/s from 10N to 2000N while seating motion was recorded. The incremental cyclic fatigue tests were applied in 100 N increments from 100 to 1000 N and then 200 N increments up to 4000 N. Cyclic load-corrosion-micromotion data were continuously captured and subsequently analyzed. Elastic deformation-based motions were accounted for by stiffness measurements of the system after testing and the elastic portions of the motion were subtracted from the total motion to obtain the rigid body subsidence of the head on the neck as well as the rigid-body micromotion for each cycle. Correlations between fretting currents and cyclic motions were obtained (Fig. 1). Fretting corrosion onset loads, currents at max loads, and micromotion data were analyzed statistically w/ ANOVA ($P<0.05$ is significant).

Results: Fretting corrosion currents at 4000 N cyclic load were not significantly different in each group (Fig. 2.).

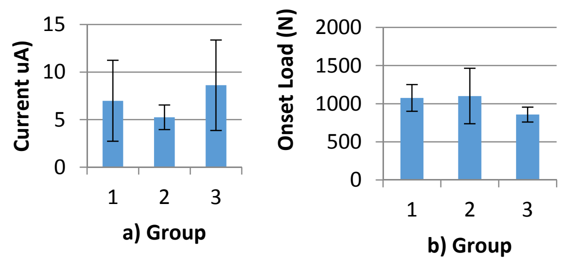

Fig. 2: a) Fretting currents at 4000 N (n=6) b) Onset loads.

Onset loads for fretting corrosion for G3 were lower (857 N) than G1 or G2 (1070, 1100 N) ($P<0.05$) but similar to earlier tests[2]. Head-neck interfaces exhibited both subsidence (permanent displacement of head on neck) and micromotions during loading (Fig. 3) but none were significantly different ($P>0.05$).

Discussion: These tests are a rapid and highly informative approach to taper design testing that can promptly assess materials and design elements without having to perform long-term fatigue tests. These tests are not meant for assessment of long-term performance but focus on quick assessment of design elements. Correlations of mechanical factors (e.g., stiffness, micromotion, subsidence) with fretting currents can be assessed with this test.

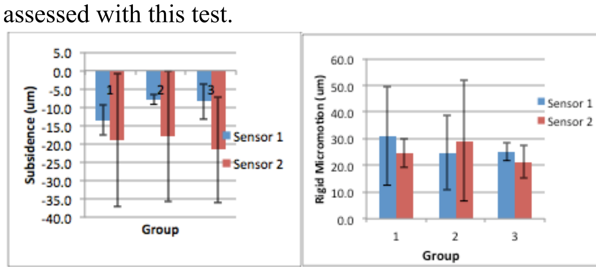

Fig. 3: a) Average subsidence and b) Average micromotion at 4000 N.

Conclusions: A short-term micromotion-fretting corrosion test method was developed that concurrently captures and correlates taper motions with currents. Three different Stryker implant systems had similar fretting currents at 4000 N and slightly lower onset load for fretting for G3. **Acknowledgements:** Supported by Stryker Orthopedics. **References:** 1. Cooper et al., JBJS-A 2013, 2. Goldberg and Gilbert, JBMR-B, 2003

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