INTRODUCTION  Femoral modularity of total hip implants gained popularity because of clinical flexibility and material versatility. However, corrosion related phenomena have been reported at the taper interface of modular femoral stems and heads. The corrosion may result from fretting, crevice and coupling of mixed materials at the modular interface. The performance of the modular hip implants may also be affected by the assembly conditions as the assembly and disassembly forces depend upon the surgeon and the taper surface condition (dry, wet with fat or blood, etc.). A previous study has examined fretting and anodic current of modular hip implants of different material combinations in short term fatigue tests. Hip stems made of titanium showed higher fretting current at the taper interface than those made of cobalt chromium and high nitrogen stainless steel. Using hip stems and heads of a single material combination, the current study assessed the effects of assembly condition and head neck length upon the fretting current of modular hip femoral components during short and long term fatigue tests.

MATERIALS AND METHODS  Centerpulse Orthopedics AG Alloclassic™ hip stems (size 5, Ti-6Al-7N, ASTM F 1295) and Metasul™ femoral heads (28 mm, CoCr, ASTM F 1537) were studied. All stems and heads had a 12/14 taper (5°38’, no angle mismatch). The head bores had two neck offsets: long neck (+4 mm) and short neck (-4 mm); the short neck bore had a larger contact area with the stem cone than the long neck bore (13.2 mm vs. 9.2 mm in contact length). The stems and long neck heads were assembled in three conditions: 1) dry and under 2000 N, 2) wet with bovine serum and under 2000 N, 3) dry and put on by hand. The stems and short neck heads were only assembled in condition 1. Each of the stem/head assemblies was mounted on a fatigue test machine per ASTM standard F1875 and subjected to two phases of fatigue tests under 40 – 2040 N. 1) Initial phase was performed for three runs at 1 Hz and three runs at 2 Hz. Each run lasted for 600 seconds with a five minute no loading period between the runs. 2) Long term phase was performed at 15 Hz for up to ten million cycles (MC). The fretting current generated on the taper interface was measured using an EG&G APR potentiostat. The stem and head assembly was the working electrode, while a hip stem identical to the test stem was employed as the counter electrode. Both working and counter electrodes were immersed in 500 ml Ringer’s solution at pH=4 and room temperature. Fretting current was measured during each of the initial six runs and was measured for 600 seconds at about every one MC up to 10 MC in the long term phase test. In addition, fretting current was measured during a long term test period when the maximum fatigue load varied from 1020 through 3065 N. At least three assemblies in each condition were tested.

RESULTS  During the initial phase, the fretting current of all assemblies subsided from the first run to the third run of the cyclic loading at 1 Hz as well as from the fourth run to the six run at 2 Hz (Fig. 1). The frequency increase from 1 Hz to 2 Hz at the fourth run caused the current to be higher than the value at the third run, but still lower than the value at the first run. During the long term phase, the fretting current showed a trend of increasing with increased cycle number and its values were generally higher than those in the initial phase (Fig. 2). The fretting current of different stem/head couples was assessed by listing its mean values (measured at the end of each 600 second scanning) in each condition in four fatigue test periods (Table). For the long neck stem/head couples, the assembly force (2000 N or by hand) did not substantially affect the fretting current. This finding is consistent with the insignificant influence of the magnitude of the maximum fatigue load when it was equal to or greater than 2040 N (Fig. 3). On the other hand, the wetting of the taper with bovine serum contributed to pronounced reduction of the current during the initial fatigue testing (1st and 6th runs). The influence of the assembly conditions was minimized after the stem/head couples experienced the long term fatigue loading. Compared with the long neck stem/head couples, the short neck couples did not show pronounced differences in the four test periods (Table).

DISCUSSION  Fretting or micro-motion at the taper interface creates fresh surface areas that contribute to an increased current. This effect was demonstrated by the current jump when the cyclic loads started. Although the increased amount is small, fretting current tends to increase as the assemblies are subjected to long term fatigue. The assembly condition of the stem/head couples affected the fretting current in the initial fatigue loading, but did not affect the current significantly in the long term run. Along with the plateau effect of the fatigue load magnitude, this suggests the “self lock” characteristic of the Morse taper. It can be inferred that the long term performance of the modular hip taper of the stem implant system will not be affected by the initial assembly condition in the operating room. Although the couples with the short neck bores had much larger contact area than those with the long neck bores, the fretting current was not significantly different between these two groups. That demonstrates the Morse taper is very stable and the micro motion is not strongly dependent upon the contact area. Since the material combination of the taper interface affects the fretting current greatly, further studies are necessary to determine if the findings in this study are applicable to other material combinations.

** Centerpulse Orthopedics AG, Winterthur, Switzerland