# Wear Resistance Improvement by Laser Deposited Ti/TiC Coating

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**Statement of Purpose:** Osteolysis caused by polyethylene wear debris has been a major problem limiting lifetime and performances of metal femoral head implants on ultra-high molecular weight polyethylene acetabular cup. This leads great research interests to alternative hard-on-hard bearing surfaces. Implants with hard-on-hard bearing surfaces have shown long-term survivorship and less harmful effects [1]. Hard-on-hard bearing surfaces are commonly made from various cobalt-chromium-molybdenum alloy, ceramics, and oxidized zirconium alloy, due to good wear resistance. Surface engineering technologies have been used in many applications for further improved wear resistance of the metallic materials. Recently, an additive manufacturing process, termed Laser Engineered Net Shaping (LENS®), have been applied for coating deposition with various metal powders. In this research, the feasibility of depositing coating with LENS on a metal substrate for improved wear resistance was investigated.

**Methods:** In this study, an Optomec 750 LENS® machine (Optomec Inc., New Mexico, USA) was utilized for coating deposition. Materials used were mixture of Ti-6Al-4V (Ti64) powders (nominal composition (wt%): Ti-6.37Al-4.20V, Argon atomized, from Crucible Research)and Titanium Carbide (TiC) powders (99.9% purity, from Atlantic Equipment Engineers). Five different powder mixtures were prepared and used for deposition (Table 1). A pin-on-disk wear test was conducted to evaluate the wear resistance of deposited coatings (load: 136.2 ± 4.1 N). Models of the pin and disk samples are shown in Figure. 1. The samples were made from Ti-6Al-4V and coated with Ti/TiC using LENS. The samples were tested for a 50 km sliding distance. After each 10 km, the samples were cleaned, dried and weighed. CoCrMo pins and disks were also tested as control.

Table 1. Powder used for deposition

| ID | Powder mixture [ vol.% ] | Powder size [ μm ] |
|---|---|---|
| 1 | 40% Ti64/60% TiC | 45~150 (Ti64) + 45~150 (TiC) |
| 2 | 50% Ti64/50% TiC | 45~150 (Ti64) + 45~75 (TiC) |
| 3 | 60% Ti64/40% TiC | 45~150 (Ti64) + 45~75 (TiC) |
| 4 | 60% Ti64/40% TiC | 45~150 (Ti64) + 20~45 (TiC) |
| 5 | 70% Ti64/30% TiC | 45~150 (Ti64) + 20~45 (TiC) |

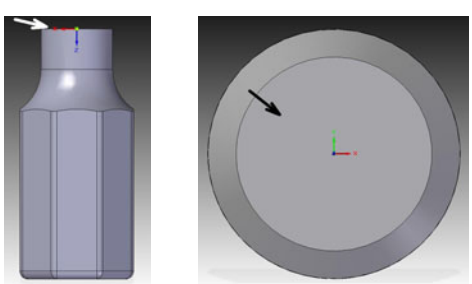

**Figure 1.** Pin sample (left, side view) and disk sample (right, top view), arrows indicate coated surfaces.

**Results:** In 4 out of 5 parameter sets (as shown in Figure 2), the LENS deposited samples had significantly less weight loss over 50 km sliding distance than the control samples. The CoCrMo samples had approximately 15 times the weight loss compared to sample sets #1-#4. Microstructures of the samples were examined following common metallurgy practice. Large cracks through coating thickness were noted in sample sets #1 and #2, which have TiC concentration of 60% and 50% respectively. Enhanced TiC precipitation due to the increased TiC percentage caused the cracks in the samples. For the sample sets #3 and #4, solid and defect-free deposits were observed as shown in Figure 3. Unmelted carbide particles, as well as tightly packed resolidified TiC dendrites were identified.

**Conclusions:** In the current study, a laser-based metal powder deposition process, LENS, was utilized to deposit Ti/TiC coating on disk and pin samples for wear test. In 4 out of 5 sets of LENS-deposited Ti/TiC samples, over 15X less weight loss than CoCrMo was noted, which indicates LENS is a potential process for wear resistance improvement for hard-on-hard bearing surfaces.

**Reference:**[1]. Dumbleton, J.H., and Manley, T.M., J Arthroplasty, 2005; 20:174-188.

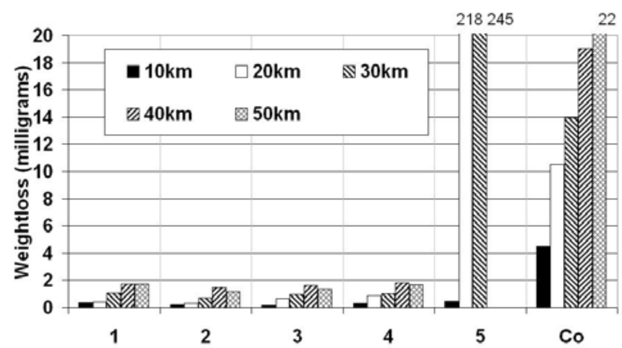


**Figure 2.** Average weight loss (disk plus pin samples)

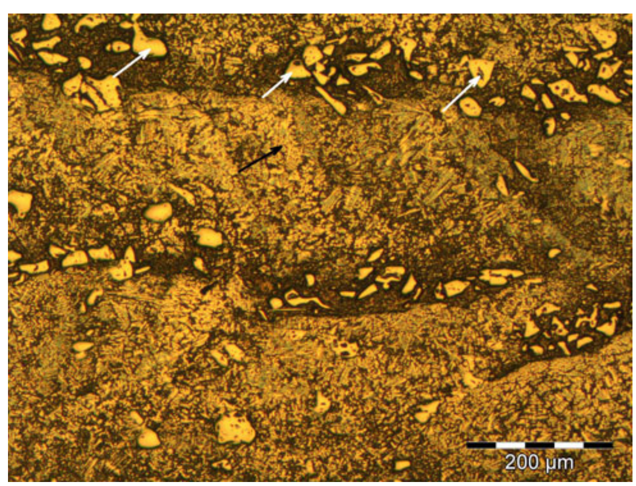


**Figure 3.** Microstructure of deposit #4 (WHITE arrows indicate unmelted carbide, BLACK arrow indicates packed resolidified carbide dendrites)