**Introduction:** In recent years there has been revived interest in metal-on-metal implants due to the association of osteolysis with polyethylene wear debris (1). Osteolysis can lead to aseptic loosening causing pain and revision of the total hip arthroplasty.

Previous experiments using an as-cast low carbon content CoCrMo alloy produced high wear rates (2), but in contrast, as-cast high carbon CoCrMo alloy proved to be a good bearing material (3). Heat treatment, solution annealing and hot isostatic pressing (HIP) cause the hard blocky carbides in high carbon CoCrMo to diffuse into the softer matrix material. Fin-on-plate studies have been completed to assess whether different amounts of heat treatment of CoCrMo alloys change the wear rate and wear mechanism.

**Materials and Methods:** High carbon (0.266wt% C) CoCrMo specimens have been tested on a pin-on-plate test rig in one of 3 different conditions; as-cast, single heat treated and double heat treated material.

For each specimen five pin and plate pairs were tested on the Durham pin on plate machine to 3 million cycles. Four of the pins and plates underwent rotation and reciprocation at a frequency of 1 Hz and the final pair was used as a control. The stroke length was 18mm and the load on the pins was 40N. Surface topography was measured at the start and end of the test. The method described and equipment used was identical for each of the 3 tests performed.

The pins and plates used were manufactured from the same material as the as-cast CoCrMo material used for Birmingham hip resurfacing (BHR) devices. The pins were 6mm diameter, cylindrical in shape and the bearing end was hemispherical. The plates were 25mm diameter with a segment ground off on one edge to hold them with a grub screw in the lubricant bath. These were made from the same materials as the pins. All three materials were chemically identical to each other, although the materials underwent various heat treatments to alter the metallurgical structure.

Specimens were cleaned and weighed initially (ISO 14242-2) and after each period of approximately 250 000 cycles of wear. The volume loss was calculated using the density of the material (0.0082g/mm3) and the serum was collected at each of these intervals and analysed.

The test was carried out at 37°C in bovine serum lubricant (batch number 5030401, Harlan Sera-lab, total protein content 56g/l) diluted to 25% with distilled water. Added to this was 0.2% sodium azide and 20mM EDTA (ethylenediaminetetraacetic acid) to help resist biodegradation of the lubricant and calcium deposit formation respectively. The unused serum was kept frozen at -20°C and made up as needed, after which it was kept refrigerated at 4°C.

Analysis of the particles in the serum involved digesting the protein using Papain and Protease K. Deionised water, sodium dodecyl sulphate, acetone and buffers were used to wash the particles before and after the protein digestion. Subsequently the particles were separated from the solution in an ultracentrifuge. This pellet was re-suspended in 1.5 ml of water and analysed using a Nanosight LM10. The LM10 estimates the size of the particles by tracking their movement as they scatter a laser beam. The particles move due to Brownian motion and if the temperature is known the Stokes-Einstein equation can be used to compute the size of the particles from their paths.

**Results:** Figure 1 shows the wear rate of the pins, the plates and the total wear rate over 3 million cycles for the 3 different CoCr microstructures.

![Figure 1](https://example.com/figure1.png)

Figure 1. Comparison of the CoCr wear with various carbide volume fractions.

The error bars indicate one standard deviation. Average wear rates for the as-cast (high carbide), single heat treated (medium carbide) and double heat treated (low carbide) are 1.69x10^-6 mm^3/Nm, 2.1x10^-6 mm^3/Nm and 2.41x10^-6 mm^3/Nm respectively.

**Discussion:** The wear results show that the as-cast material gave the lowest total wear (1.69x10^-6 mm^3/Nm). The plates were very little in this study.

The as-cast material was the lowest wearing of the three materials tested. Surface assessment of the as-cast CoCrMo indicated that the wear regime was mainly abrasive wear. The medium carbide material was the next lowest wearing and surface analysis indicated both abrasive and adhesive wear. The low carbide material had the greatest wear and surface analysis indicated mainly adhesive wear.

High carbide (as-cast) material produced wear particles of a similar size over the 3 million cycles typically less than 400nm. There was very little variation in size distribution and concentration. Low carbide (double heat treated) material produced an initially low concentration of particles whose sizes were distributed over a large range. As the test progressed the concentration increased and the average size reduced.

**References:**

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