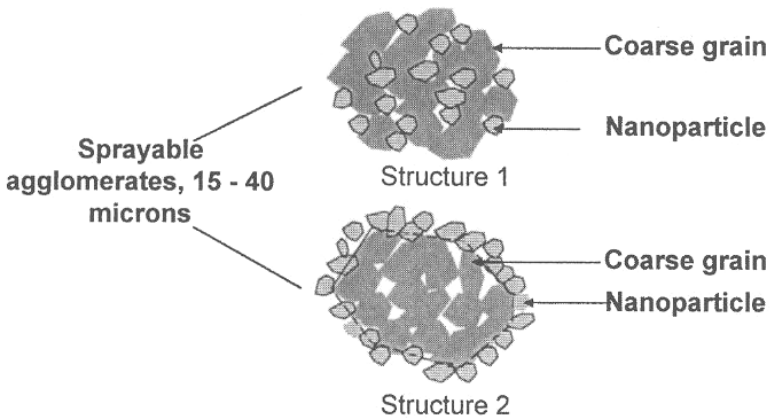
Evaluation of Multimodal WC-Co Coatings Against Erosive and Abrasive Wear

G.E. Kim, R.W. Rigney, R. Shropshire,
R.S. Brunhouse

Work funded under US Navy ONR Contract no. N00014-00-C-0181

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca

MULTIMODAL WC-Co



Ref: G. Skandan et al. (JTST, vol.9 no.3)

FEEDSTOCK POWDER

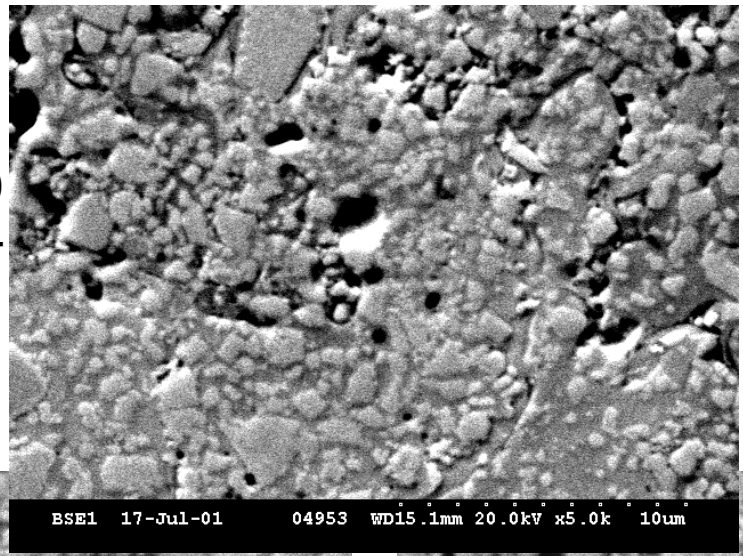
M1: (70 % coarse - 30 % nano) of WC-12Co in structure 1

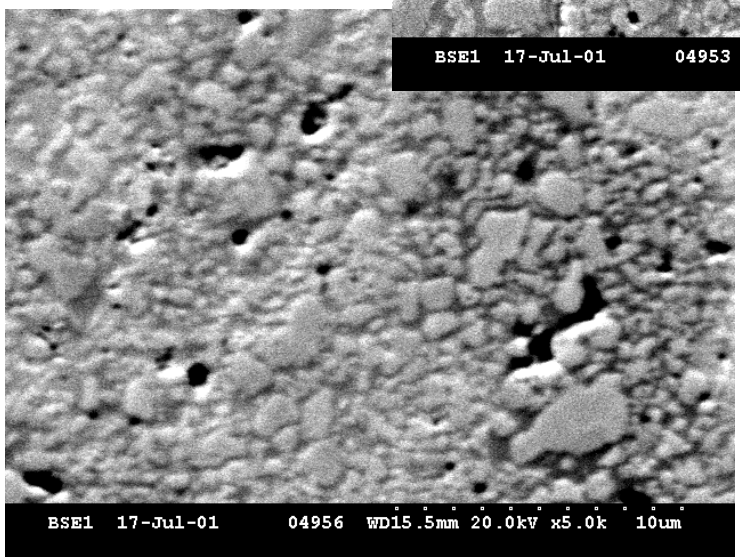
M5: (50 % coarse - 50 % nano) of WC-12Co in structure 1

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca

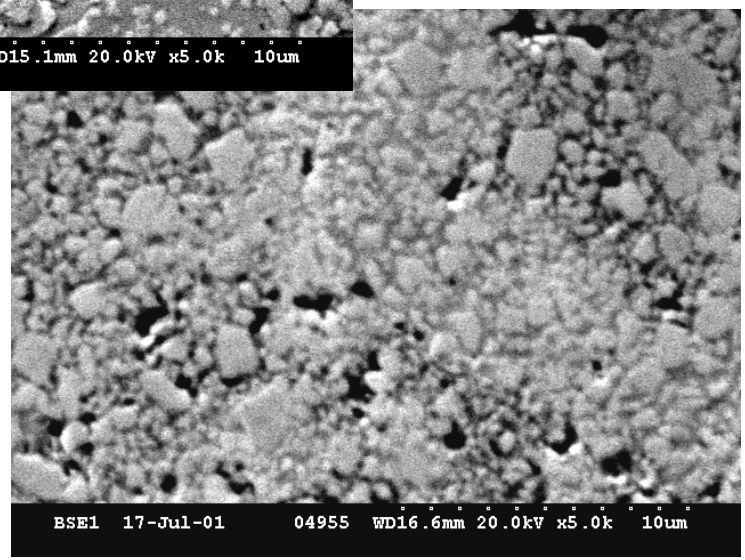
COATING MICROSTRUCTURE AND HARDNESS RESULTS (cont'd)

STANDARD DJ 2700
DIAMALLOY 2004





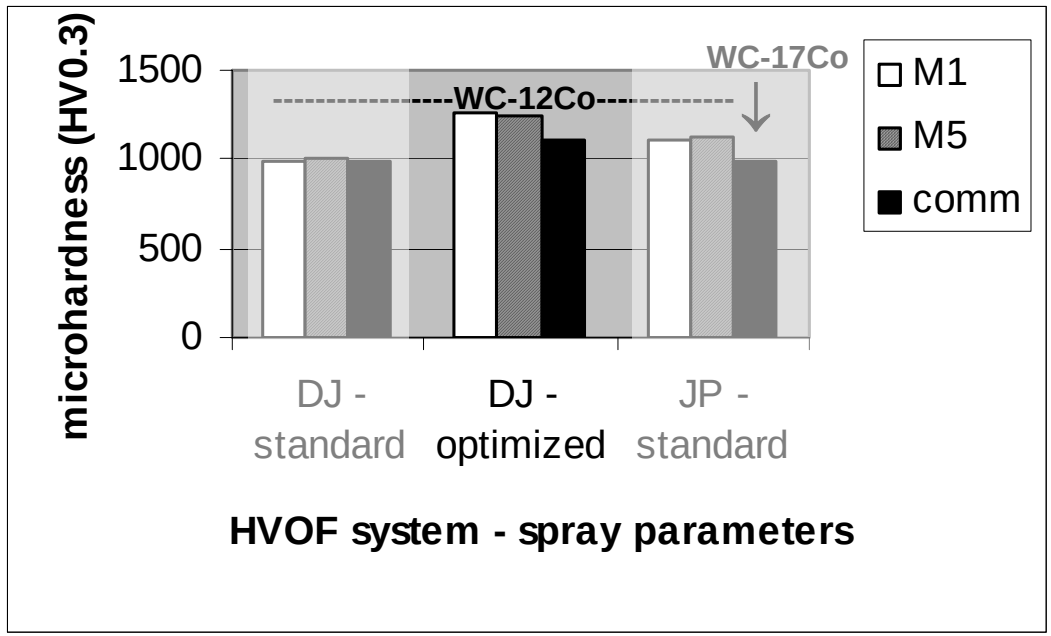
STANDARD DJ 2700
M5



STANDARD JP-5000
M5

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca

COATING MICROSTRUCTURE AND HARDNESS RESULTS



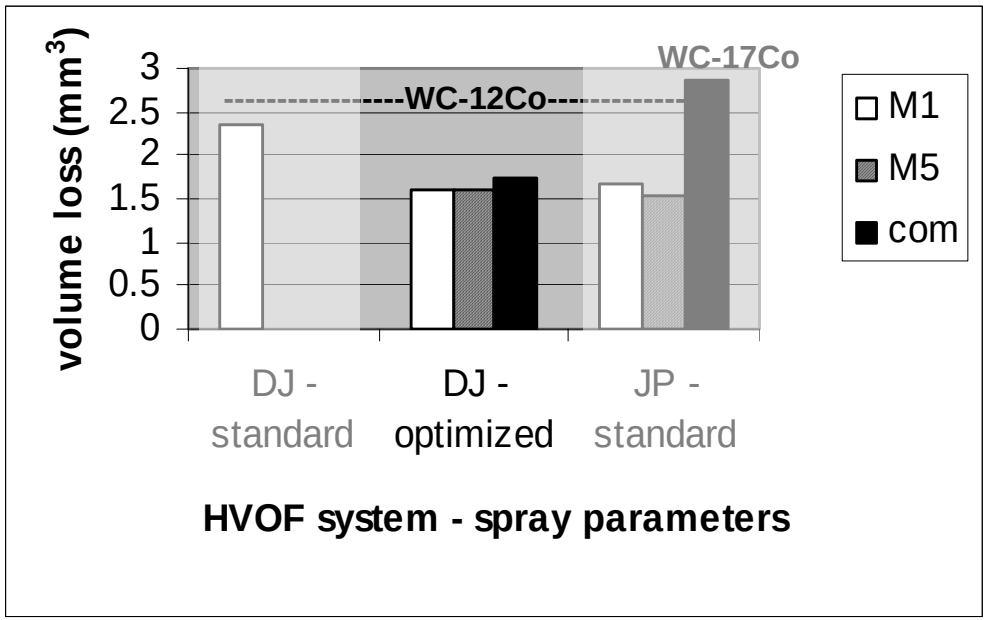
- coatings were relatively dense (< 1% and < 3% porosity for JP-5000 and DJ 2700 coatings, respectively)
- **multimodal WC-Co coatings were as hard as or harder than their commercial counterparts**
- optimizing spray parameters led to greater increase in microhardness for multimodal coatings
- higher hardness on coatings from standard JP-5000 over standard DJ 2700

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca

ABRASION WEAR TEST RESULTS

PROCEDURE E:

- **300 g/min sand flow rate**
- **200 rpm wheel (9” dia.) speed**
- **> 150 µm rounded quartz sand**
- **130 N or 30 lb force**
- **1000 wheel revolutions**



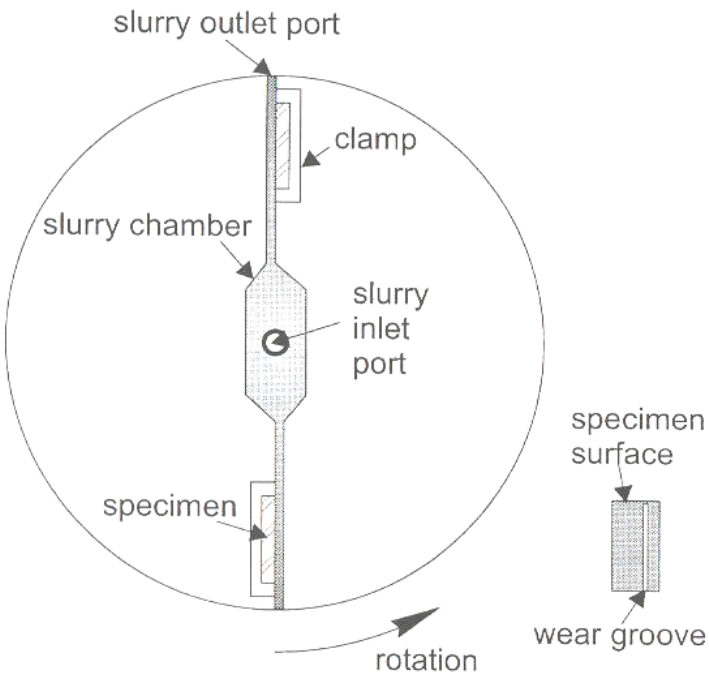
“Wear resistance is high enough to warrant the use of Procedure A (6000 wheel revolutions) for better accuracy”

- **optimized spray parameters led to superior wear result for DJ 2700 M1 coating**
- **no significant difference in abrasion resistance between multimodal and commercial coatings**
- **greater abrasion resistance of M1 multimodal coating when sprayed with JP-5000 over DJ 2700 using standard parameters**

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca

CORIOLIS SLURRY EROSION TEST

Ref: Y. Xie et al. Wear 225-229 (1999)



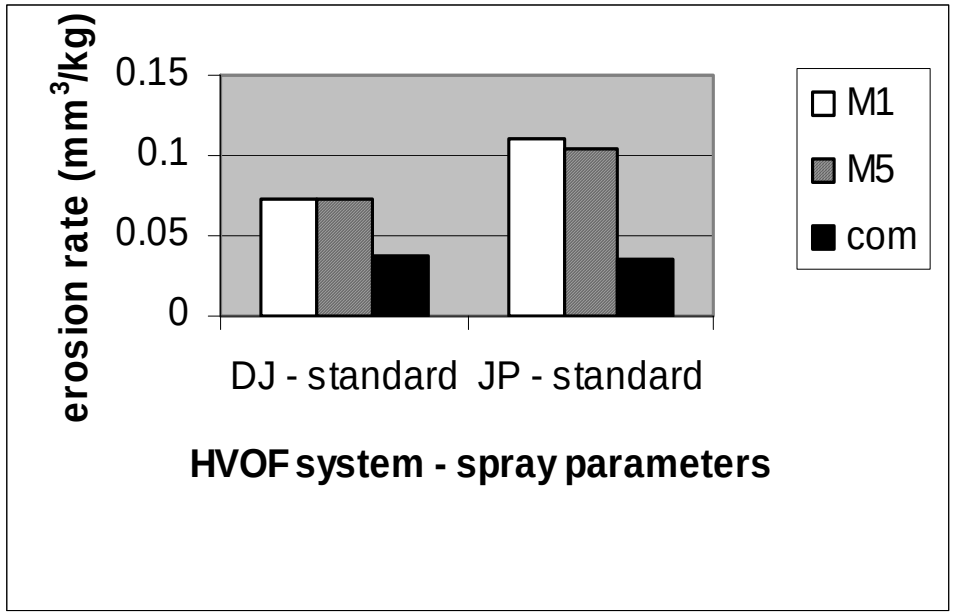
Erosion Rate - ER (mm^3/kg)

total scar wear volume / mass erodent

- **150 mm diameter rotor**
- **1 mm x 6.3 mm channels**
- **14 mm slurry inlet port diameter**
- **specimen leading edge is 39.5 mm from rotation center**
- **constant erodent (200 µm Al_2O_3) feed**
- **constant slurry flow (30 ml/s)**
- **constant slurry concentration (10 wt%)**
- **5000 rpm**
- **optical profilometry used for wear scar cross-section measurement**

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca

CORIOLIS SLURRY EROSION TEST RESULTS

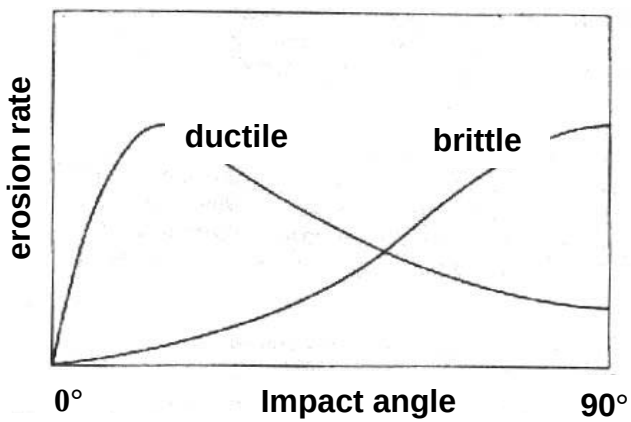


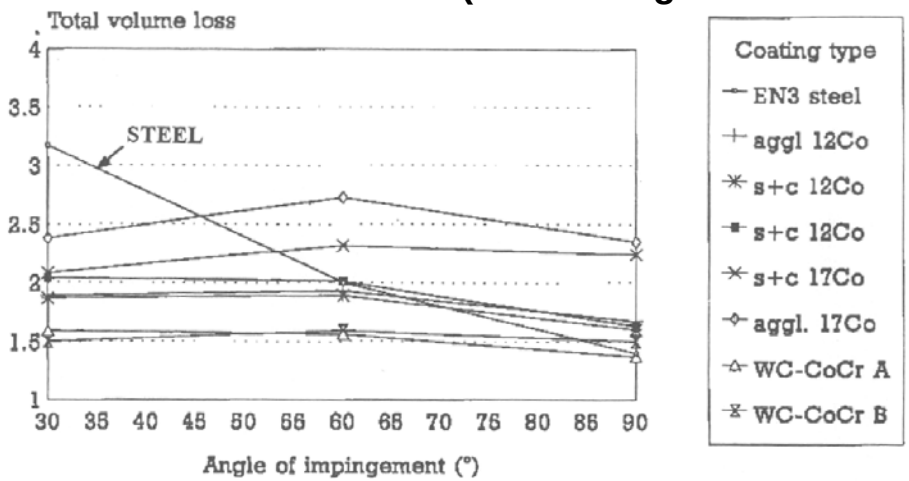
- **multimodal coatings had at least twice the erosion rate of the commercial coatings for the same composition**
- **multimodal coatings from standard JP-5000 had a notably higher erosion rate over those from standard DJ 2700**
- **commercial WC-12Co coatings applied via the two systems had similar erosion rates**

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca

ANALYSIS OF CORIOLIS EROSION RESULTS

Ref: De Villiers et al.
(Proceedings of 15th ITSC)





- **multimodal coatings have relatively lower resistance to low angle erosion (typical of ductile material)**
- **commercial WC-Co coatings have resistance to both low and high angle erosion**

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca

ANALYSIS OF CORIOLIS EROSION RESULTS (cont'd)

EROSION RESISTANCE OF SINTERED ULTRAFINE WC-Co COMPOSITES

Ref: V.A. Pugsley and C. Allen (Department of Materials Engineering, University of Cape Town, S. Africa)

MATERIALS

- **Varying WC sizes**

  ~4 µm (coarse) ~1.2 µm (standard)

  ~ 0.8 µm (fine) ~ 0.3 µm (ultrafine)

- **matrix of 6-15 wt%Co**

SLURRY EROSION PARAMETERS

- **18 mm disc samples polished to 3 µm finish**
- **500 µm silica sand**
- **75° and 90° impact angle**
- **16 wt% slurry concentration**
- **16.4 m/s impact velocity**

ANALYSIS OF CORIOLIS EROSION RESULTS (cont'd)

EROSION RESISTANCE OF SINTERED ULTRAFINE WC-Co COMPOSITES (cont'd)

RESULTS

Erosion resistance (at 75° impact angle) increased with

- **decreasing WC grain size (~ 3x for ultrafine over coarse)**
- **decreasing binder content**
- **decreasing binder mean free path – especially below 0.3 µm**
- **increasing hardness (~ 25% increase with ultrafine)**

Erosion crater diameter (at 90° impact angle) increased with

- **decreasing WC grain size – especially below 1 µm**

SEM of single impact sites reveals

- **very little penetration of the surface and a smear-like scar in fine and ultrafine materials (typical of ductile failure - preferential failure at low angles)**
- **cracking, deformation, and displacement of WC grains in addition to preferential removal of the cobalt binder in coarse materials (typical of mainly brittle failure – preferential failure at high angles)**

FEEDBACK FROM F.W. GARTNER

- **Impressed with multimodal coating toughness without compromising abrasion wear resistance**
- **Deposition efficiency was as good as or better than their commercial powder**
- **Evaluating the potential reduction in surface finishing time and effort**
- **Currently qualifying multimodal coatings for existing applications**
- **Will introduce the coating for new applications that can benefit from the superior toughness**

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca

POTENTIAL NAVY APPLICATIONS

Ref: NAVAIR Lakehurst website

Aircraft hookpoints used for arrested landings

- **subjected to heavy wear, impact, and thermal stress**
- **hookpoints made of 3340V alloy steel are limited to three to ten landings**

Slat and flap track areas of the airplane wing

- **subjected to high load and rolling fatigue wear**
- **requires coatings with high Young's modulus and fracture toughness**

Tel: (514) 240-7932; Fax: (514) 762-9022; email: info@perpetualtech.ca; www.perpetualtech.ca