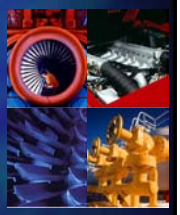
Rolling Contact Fatigue of Hot Isostatic Pressed WC-NiCrBSi Thermal Spray Coatings

S. Stewart

Supervisor : Dr R. Ahmed

Introduction

Thermal Spray Coatings are used in a number of industrial applications ranging from the automotive and aerospace industries to biomedical applications. However, in many types of industrial machinery such as gears, camshafts and rolling element bearings, surface damage generated by rolling / sliding contact limits the life of the component and hence reduces durability and product reliability. This drives the development and implementation of state of the art surface coatings which enable improved life reliability and load bearing capacity in more hostile environments.



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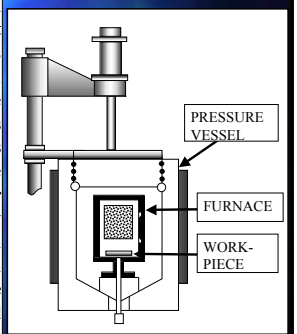
AIMS AND OBJECTIVES

Subjecting Thermal Sprayed coatings to the post treatment, Hot Isostatic Pressing (HIPing), leads to significant densification within the microstructure. The combination of high temperatures and equi-axial pressure reduces porosity and leads to the formation of a more lamellar microstructure. This preliminary study marks the first investigation in published literature in which the rolling contact fatigue performance of HIPed functional graded WC-NiCrBSi coatings are studied.

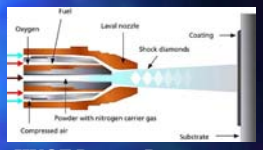
HIP Unit



Coating fabrication process

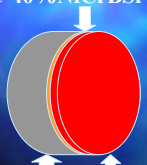
WC
+
Ni-7.56%Cr-3.69%Si-2.57%Fe-1.55%B-0.25%
(sintered and agglomerated)

WC-40%NiCrBSi (100µm)



HVOF Process Parameters

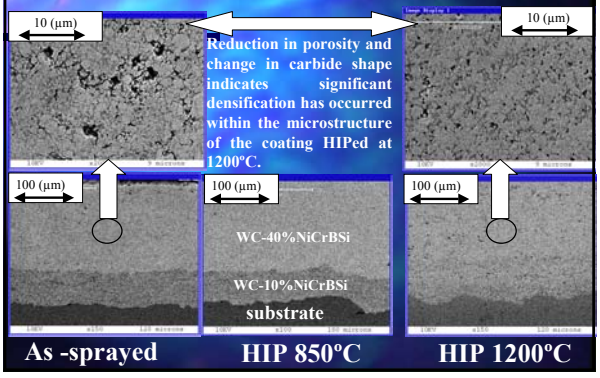
Gun type : JP5000
Spray distance : 380 mm
Barrel length : 4”
Fuel gas : Kerosene
Powder Carrier gas : Oxygen

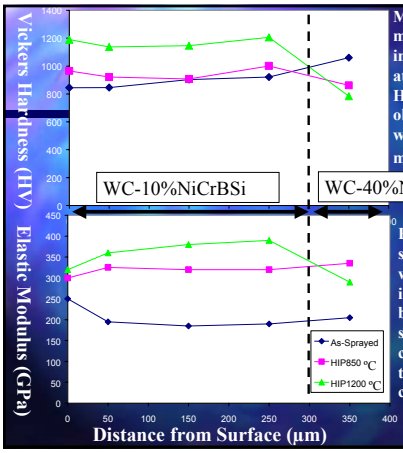


440-C Bearing Steel

WC-10%NiCrBSi (300µm)

Analysis of coating microstructure



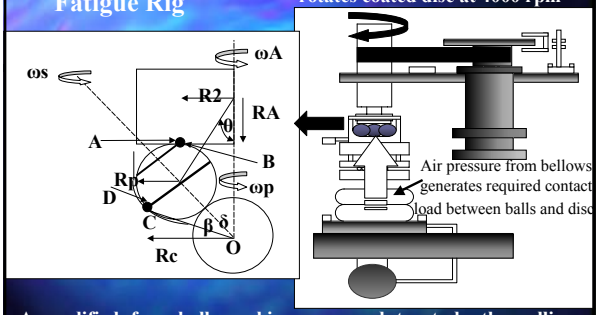


Micro-hardness measurements show increased hardness values at elevated temperatures of HIPing verifying the observation of densification with the coating microstructure.

Elastic Modulus results show increased values with HIPing . This indicates improved bonding between the splats after HIPing which can improve resistance of the coating to rolling contact fatigue.

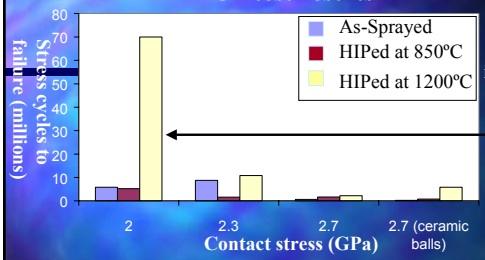
Rolling Contact Fatigue Rig

Drive shaft connected via belt to motor rotates coated disc at 4000 rpm



A modified four ball machine was used to study the rolling contact fatigue performance of the HIPed thermal spray coatings. A ceramic ball was placed below the three planetary balls to obtain the correct rolling / sliding contact kinematics.

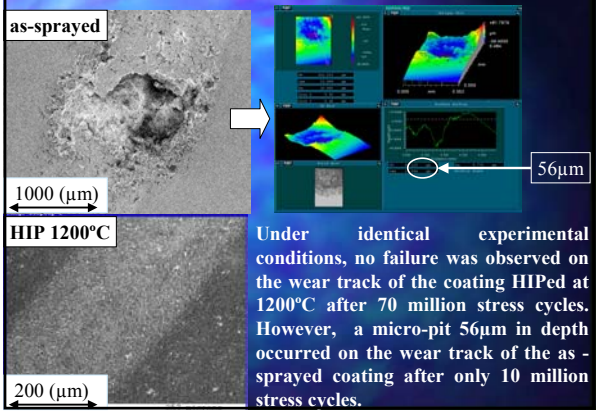
RCF test results



Significant improvement in RCF performance over as-sprayed coating

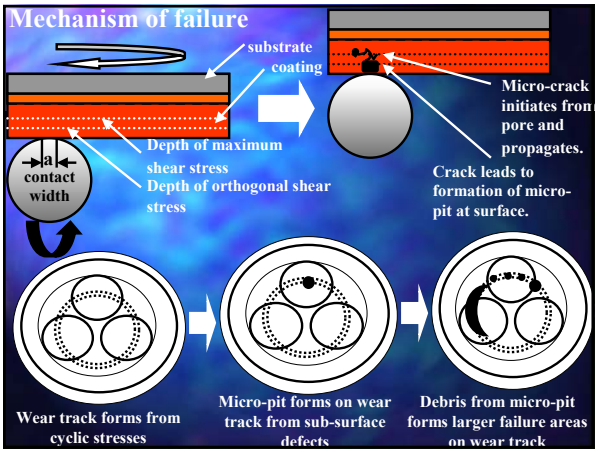
- A high viscosity lubricant was used to prevent asperity contact between the coating surface and the planetary balls during testing and hence maintain full film elasto-hydrodynamic lubrication.
- Tests were performed using either 440-C Bearing Steel or HIPed Silicon Nitride Ceramic planetary balls.

Post test Analysis



Under identical experimental conditions, no failure was observed on the wear track of the coating HIPed at 1200ºC after 70 million stress cycles. However, a micro-pit 56µm in depth occurred on the wear track of the as - sprayed coating after only 10 million stress cycles.

Mechanism of failure



Conclusions

- HIPing at elevated temperatures of 1200 ºC lead to significant improvement in rcf performance at low levels of contact stress. No failure occurred at 2GPa, and improvement was attributed to increased densification within the upper layer of the coating.
- The post treatment HIPing was shown to increase elastic modulus and micro-hardness. At elevated temperatures of HIPing, densification occurred which was verified by an increase in micro-hardness within the upper layer of the coating.
- Mechanism of failure in as-sprayed coatings was identified as delamination which initiated from sub surface defects.

Acknowledgments

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