Metal-Matrix Composites and Thermal Spray Coatings for Earth Moving Machines
Quarter 8 Report

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Abstract:

In the eighth quarter, investigations in both thrusts focused on abrasive wear characterization. For the steel matrix composites, various systems were tested at DOE Albany Research Center using wear tests which produced low stress scratching, high stress gouging, and gouging and impact wear. Based on the wear results, it is uncertain as to whether the composites created have sufficient wear resistance to provide a 2x life increase in a selectively reinforced component in all applications. High stress component abrasive wear tests were conducted at Caterpillar on arc lamp processed, thermal sprayed components. Testing showed that in many cases, arc lamp processing parameters and resulting fusion were insufficient to prevent coating spallation. Of those coatings which experienced only limited spallation, wear life improvements approached 2x and it is expected that project goals can be met with additional process modifications.

An overview of the progress during the 8th quarter of this project is given below. Additional research details are provided in the limited rights appendix to this report.

Experimental

Steel Matrix Composites

Abrasive wear testing of carbide reinforced and oxide reinforced composite systems was conducted at DOE Albany Research Center. Carbide cermet based composites tested included those with boride coated particles and performs containing boride particles to improve infiltration and limit particle dissolution (discussed in previous reports). Abrasive wear tests performed included (1) dry-sand, rubber wheel (DSRW, ASTM G65 Procedure B) which produces low stress scratching wear, (2) pin-abrasion, which produces higher stress gouging wear, and (3) impeller-abrasion, which produces high stress gouging and impact wear. Pin abrasion testing was conducted at three different test loads in order to identify how the composites react to increasing abrasive stress. Given the size limitation of the oxide reinforced castings produced at UC Santa Barbara, only pin-abrasion test coupons could be extracted and tested.

Thermal Spray Coatings

Full scale laboratory wear testing of seven coated and fused components was completed. This testing was conducted at Caterpillar in a test rig designed to duplicate motions and stresses of an actual service application, with an aggressive abrasive loading to accelerate testing.

Results and Discussion

Steel Matrix Composites

For low stress scratching, the carbide based composites demonstrated 6 – 8x improvement in wear life over current ground engaging tool (GET) steels. In contrast these same materials exhibited only around a 1.5x increase in wear resistance over GET steels for impact-abrasion in limited testing in the impeller-abrasion test. For gouging wear using the pin-abrasion test, the carbide based composites having boride particle additions to the perform performed similar to the oxide based composites. However at the highest test load the wear resistance of the carbide based composite dropped relative to the oxide based composites. The boride coated carbide particle based composites never performed as well as the oxide based composites and they also exhibited a decrease in wear resistance with increasing stress. In comparison to the GET steel at the highest test load, the oxide based composites exhibited a wear resistance of 10x that of the GET steel, while the composites containing boride coated carbide particles and carbide and boride particles mixtures, exhibited wear resistance improvements over the GET steel of 2x and 5x, respectively. Based on abrasive wear performance in impact and gouging for the boride coated carbide cermet based composite, it may be concluded that these composites in their current form, would not provide target component life increases in selectively reinforced components. The other composites systems could potentially be used to meet the component life goals, however the life goals may not be achieved in severe impact applications.

Thermal Spray Coatings

In contrast to baseline components, typical wear scars were not produced on the coated components. Instead the coating was merely "polished" during testing. During testing all but one of the coatings experienced some degree of spallation. This spallation occurred at the coating interface with the substrate and resulted from insufficient metallurgical bonding being imparted by the arc lamp treatment. Factors contributing to the lack of bonding include an arc length which was slightly short for the width of the coating, potentially excessive water cooling, and lower power density at the extremities of the arc. Those bushings which experienced only limited or no spalling exhibited life increases of 83-88%. Improvements in coating bonding through the use of a longer length arc lamp head will likely lead to component wear lives which will meet or exceed project goals.

Conclusions and Future Work

Steel Matrix Composites

Wear test coupons will be analyzed in order to understand the observed trends in abrasive wear resistance. It is expected that fracture data on these composite systems may also help explain some of the wear trends (awaiting report from UC Santa Barbara on fracture toughness tests). Based on the wear results for the WC-Co based composites and the difficulty in fabricating the oxide based composites, the ability to cost effectively achieve the project goals with these composite systems is uncertain. At this time no plans are being made to fabricate more composites. If wear and fracture studies provide favorable

insight, further development of these composites may be pursued outside the scope of this project.

Thermal Spray Coatings

Assuming the funding is allocated for the 2003 contract extension, fusing of coatings on both heat-treated and non-heat-treated bushings will be performed. Emphasis will be placed on optimizing the metallurgical bond, minimizing process time, and controlling coating cracking. Investigations into the ability of fused coatings to withstand heat treatments will also be arranged. Once the processing has been optimized, further wear testing of the nature described in this report will be done.