ADMINISTRATIVE INFORMATION

1. **Project Name:** Structurally Integrated Coatings for Wear and Corrosion

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5. **Date Project Initiated:** January 1, 2004

6. **Expected Completion Date:** December 31, 2006

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** The proposed work effort will develop improved, cost effective surfacing materials and processes for wear and corrosion resistance in both sliding and abrasive wear applications. Materials with wear and corrosion performance improvements that are 4 to 8 times greater than heat treated steels are to be developed. Affordability will be assessed against other competing hard surfacing or coating techniques, balanced with overall materials performance. Where practical, state-of-the-art design and simulation capabilities will be incorporated to guide materials and process refinement.

8. **Technical Barrier(s) Being Addressed:** Materials degradation by simultaneous wear and corrosion is responsible for failure and life reduction of many components such as track undercarriage, ground engaging tools, piston rings and liners, engine valves, pumps, or other mobile systems. Because of the complexity of high wear resistant and corrosion resistant surface modified structures, an empirical approach is not only extremely time consuming and labor extensive, but also limited in the number of potential parameters that can be evaluated. The primary hurdle to the development of coatings to meet the goal of 4-8 times life improvement over current carburized steels is the balancing of the following: choice of substrates, processing contraints, and alloy systems to produce high hardness, corrosion resistant coatings with high toughness. The proposed economic analysis,

materials development, and processing design efforts will combine to address this issue. Coating cracking is perhaps the most difficult technical obstacle to overcome with the usage of extremely hard materials. To overcome this hurdle, efforts will be made to engineer crack free coatings and FGM designs that provide corrosion resistant and compliant base layer(s). Residual stress profiles of coatings will yield additional insights for input into materials and process design. Finally, it is recognized that necessary thermodynamics or kinetic data will be lacking with some of the materials systems utilized for surfacing and this will impact on the accuracy that can be achieved with the materials and processing simulation.

9. **Project Pathway:** Four deposition processes will be investigated for applying the surfacing materials: arc lamp fusing of thermal spray coatings, laser-aided thermal spraying, and plasma transferred arc (PTA). Material design and process simulation capabilities to guide materials and process refinement will be used to aid the development of the cost effective solutions. Systematic process simulation will be performed to augment experiments via numerical modeling based on a combination of transport phenomena, material science, and engineering mechanics. This approach will be effective in optimizing processing parameters to achieve the desired deposited material properties and performance. Potential hard facing materials and deposition processes will be categorized as individual concepts and evaluated for their potential to meet the requirements of the application. For concepts that meet the initial application criteria, more detailed modeling will be developed. These concepts will then be evaluated and a design analysis completed. The most promising candidates will be prototyped and evaluated experimentally. Design of experiments techniques will be used to evaluate each concept to determine the robustness of the design and validate the design assumptions and models. This methodology will streamline the development activity and enable a comprehensive solution to be accomplished.

10. Critical Technical Metrics:

- Develop two or more materials systems that provide a 4-8 times wear and corrosion resistance increase over current carburized steels.
- Develop two economically attractive processes for depositing coatings
- Determine intrinsic and extrinsic properties required for modeling of promising materials systems/coatings
- Modify existing and develop new testing methods as needed for quantitatively ranking the toughness of high performance, metallurgically-bonded coatings
- Model the microstructural evolution of high performance coatings during processing
- Analyze the feasibility of each coating process in terms of both economic viability and likelihood of industrialization resulting in “go” or “no go” decisions

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:**
    a. Initial material and processing costs have been developed for targeted alloys. Processing using PTA and Vortek arc lamp has been initiated at Caterpillar for verification of the processing costs. Hybrid laser arc welding has been dropped from the evaluation matrix due to the cost of the process and expected lower hardness achieved with this process.
    b. Detailed analysis of the microstructure of selected alloys has been performed and used to verify initial modeling results for microstructural modeling. The modeling will now be extended to predict microstructures expected in the PTA and Vortek arc lamp processing.
    c. Abrasive wear testing of selected alloys has been completed and will be used to direct the microstructural modeling to provide alloy and processing routes.

d. Vortek arc lamp equipment has been procured and installed at Caterpillar and initial samples have been processed.
e. Laser capability has been added to Caterpillar's thermal spray laboratory to provide laser assisted thermal spray processing.

12. Future Plans:
    a. Microstructural modeling will be extended to the coatings produced by PTA , arc lamp fusing and laser assisted thermal spray. One model alloy will be processed by all three processes and the resulting microstructures compared to the model. Complete by 3rd quarter 2005.
    b. Laboratory wear and corrosion screening of two coating processed by each process (arc lamp, PTA, laser assisted thermal spray). Completion date end of 4th quarter, 2005
    c. Simulated component wear testing will be done on two arc lamp and two PTA processed materials with goal to select material/process for field testing. Microstructural modeling will be used to guide the processing of the materials selected for test. Complete by end 1st quarter 2006.
    d. Mechanical/toughness screening of promising coating systems. Completion date end of 2nd quarter, 2006
    e. Produce field test parts using alloy and process selected from simulated component wear test. Complete by end of 3rd quarter 2006.

13. **Project Changes:** Dr. David Van Aken at University of Missouri-Rolla has been added as a subcontractor to help in the investigation of the interfacial toughness of the structurally integrated coatings. Dr. Van Aken's efforts will supplement the effort of Dr. Socie's at University of Illinois.

14. **Commercialization Potential, Plans, and Activities:** The technologies to be developed in this work effort are applicable to many industries. The integration of laser technology with thermal spray processes and arc welding would not be difficult for others to acquire and the material systems to be developed have shown promise to be cost effective for industry. Both the laser assisted thermal spray and hybrid laser-arc processes are patented by the Fraunhofer Institute of Germany and are available for licensing. Commercialization of arc lamp fusing will require purchase of an arc lamp by Caterpillar and is part of the program cost share if the process is selected as a prime path. This will allow for commercialization of the developed technologies by Caterpillar. Materials developed as part of this program will be made available through the program participants for use by others. It is the intent of Caterpillar to protect via patents the processes and materials to be developed. The processes and materials would then be available for licensing to third parties that are not in direct competition with Caterpillar. This will allow for implementation of the technology by a wide range of industries.

15. **Patents, Publications, Presentations: None to date.**