ADMINISTRATIVE INFORMATION

1. **Project Name:** Development and Implementation of Advanced Wear and Corrosion Resistant Systems through Laser Surface Alloying and Materials Simulation

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

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

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** The program involves the development of processing and material simulation techniques for identifying and creating advanced coatings through the laser surface alloying (LSA) process. This will be accomplished through theoretical analyses, augmented by laboratory experimentation, to develop and verify advanced composite coating systems and laser processing technology that may be transferable to industry.

8. **Technical Barrier(s) Being Addressed:** Technical barriers that are being addressed under this program include:

   (1) availability of precise thermodynamic data for the many material components that are of interest,
   (2) accurate depiction of microstructural data via an integrated process and materials model, and
   (3) ability to control heat input to prevent dissolution of hard particles, which is one of the most common unwanted microstructural modifications that may occur during production of composite coating systems.

9. **Project Pathway:** Accurate thermophysical properties are being acquired for the material systems of interest. This includes accumulation of specific reference thermophysical data, as well as acquiring thermophysical data bases that have been generated for computation thermodynamic calculations. The present simulation techniques rely on manual passing of thermal history to the thermodynamic and kinetic models to predict microstructural evolution. To support virtual-based development of the material and process requirements, process and materials models are being developed and integrated to allow numerical heat transfer with computational thermodynamic and kinetic models to predict the microstructural evolution in laser surface modified regions. The coupled models are also being utilized to identify processing conditions and material systems that minimize heat input while maximizing deposition, such as the use of distributed heat sources of direct diode lasers, to ensure survivability of coating having hard, second phase particles.

10. **Critical Technical Metrics:** Success of the first year of this program will be measured against four metrics. These are:

    (1) refining the simulation techniques and integration of the components into a single system capable of predicting composite coating microstructures for two broad material systems,
    (2) identifying and collecting thermodynamic data on these two material systems that is capable of depicting a wide range of processing conditions,
    (3) conducting detailed analysis sessions, with direct input of the industrial partners, using the integrated simulation system that are directed at specific coating applications, and
    (4) conducting initial tests for validation of the coatings for these specific applications.

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:** The heat transfer model for the laser surface alloying process was completed. The model utilizes a three-dimensional explicit finite differencing scheme, and utilizes variable grid spacing in two dimensions (the thickness and width) and a fixed spacing in the third dimension (length) to reduce computational time. It is capable of time-dependent analysis, as well as quasi-steady state calculations. The model is capable of varying substrate size, powder layer thickness, and position of clad scan. The model also incorporates two sets of properties that are used to define the porous powder and the substrate. Because of the importance in energy transfer efficiency in the heat transfer model, numerous calorimetric experiments were conducted to determine the effective absorption coefficient for a Nd:YAG laser beam irradiating and iron and nickel-based powders.

A survey was conducted to identify composite coating systems of interest. This was used to guide detailed materials simulations, and primarily involved the analysis of carbides in Fe-Cr matrix alloys. This particular system would be anticipated to show good corrosion resistance and significant improvements in wear resistance associated with the hard, martensitic matrix and the hard carbide particles.

Process and materials simulation was used determine specific carbide and nitride particles that have potential as composite coatings, based the on Fe-Cr matrix alloys identified above. This resulted in a matrix of experimental conditions that included laser surface alloying of a mild steel substrate with a martensitic grade of stainless steel, A431, and the addition of hard particles, TiN, TiC, and WC. The thermodynamic analysis also indicated the potential for shielding gas to influence the retained microstructure of the coating. Therefore, the experimental matrix was designed to evaluate the effect of hard particles, peak temperatures and cooling rates through changes in processing speed, and shielding gas on stability and retention of the composite coating microstructures.

The results of these experiments indicated that the laser deposits representing TiC and alloy 431 powder and produced in argon resulted in microstructures retaining some TiC particles and a modest increase in hardness when compared to deposits produced using only the 431 powder. Laser deposits representing TiC and alloy 431 powder and produced with various levels of active nitrogen shielding gas argon resulted in microstructures retaining some TiC particles, as well as fine precipitates of Ti(CN) formed during cooling. The laser deposits representing TiN and alloy 431 powder and produced with various levels of active nitrogen shielding gas argon resulted in microstructures retaining some TiN particles, as well as fine precipitates of Ti(CN) formed during cooling. It was also found that the laser deposits of TiC and alloy 431 powder produced using active nitrogen shielding gas resulted in hardness values significantly higher than those achievable with current hardfacing powders.

12. **Future Plans:** Key milestones and deliverables for this program are shown below.

Phase I (Year 1) Milestones and Deliverables:

(1) Refinement and integration of simulation techniques that provides predictive capabilities for describing the resultant composite structures. Deliverable is an integrated simulation system.

(2) Verification of theoretical analyses by designing advanced coating systems applicable to industry. This will include an experimental verification.

Phase II (Year 2) Milestones and Deliverables:

(1) Industrial demonstration of processes and materials for three applications that utilize advanced laser-based coating technology.
(2) Confirmation of enhanced performance of the technology and industrial implementation for improving efficiency and extended life of wear and corrosion critical components. This will also include a final report specifying improvements.

13. **Project Changes:**

The program start has been delayed due to fulfilling program contacting requirements. This has been addressed, and the program will begin June 1, 2004.

14. **Commercialization Potential, Plans, and Activities:** The program team has been selected to provide efficient transitioning of the technology to commercialization. Considerations of the potential applications of advanced composite coating technologies, having the greatest impact on reducing energy and improving component life, have been integrated into the project plan at the earliest possible stage. The approach of direct industry input for identifying applications of interest, continued collaboration with industry during development, followed by industrial site demonstrations, ensures a direct path to commercialization. The participants chosen for this team provide the expertise in their respective areas to successfully accomplish technical development and commercial implementation of advanced composite coatings technologies. Implementation will be performed by selecting several specific applications for advanced coating technology, conducting processing demonstrations, and testing to measure and verify improvements in performance.

15. **Patents, Publications, Presentations:** (Please list number and reference, if applicable. If more than 10, please list only 10 most recent.)

None during this contracting period. Program to begin June 1, 2004.