Training in Coating Evaluation Techniques - A Unique Approach for Discussion

J.P. Sauer
Metcut Research Inc., Cincinnati, Ohio

Abstract

The Central Coatings Laboratory (CCL) is a program that deals with training in coating evaluation techniques. The approach uses a combination of both theoretical and hands-on instruction to teach various concepts. The system is educational based, incorporating a philosophy of making the students problem solvers in lieu of following "cookbook" evaluation procedures. Examples of teaching techniques will be discussed and suggested course material reviewed to highlight this training philosophy.

MEETING CUSTOMER NEEDS AND expectations is an important goal and focus of thermal spray production facilities or any other business. To accomplish this task, training of employees is a major emphasis in many companies to develop an educated and productive work force. The thermal spray industry is moving toward training and certification of spray equipment operators to meet both internal/external requirements. This will allow better control of the process and reduce costly stripping and recoat. Testing and coating characterization is also a critical step in the manufacturing process. Incorrect test results can produce the same costly down time and reprocessing as faulty spray parameters. Training in coating evaluation techniques can produce educated and knowledgeable laboratory personnel who identify problems and prevent unnecessary rework.

The Central Coatings Laboratory CCL)

The Central Coating Laboratory (CCL) is a concept developed in 1993 to address the need for training in coating evaluation techniques. The program was developed because no formal training system was available and there was a lack of publications that specifically focused on testing of thermal spray materials. Textbooks and courses existed that covered the general evaluation methods but usually only covered thermal spray test applications in passing if at all. There is a general consensus in the industry that significant variation can exist for a given evaluation method on a coating system when comparing facility to facility. Coatings are generally more sensitive to testing methodology than the metals (substrate) which receive the spray application. The goal of the CCL and any other training system should be to promote understanding of testing and evaluation for thermal spray coatings and move towards technique standardization.

How Do We Get There?

The philosophy of training must be education based. Students who attend any course should be trained as problem solvers armed with the knowledge to meet day to day laboratory challenges. This program or any system should focus on analyzing the important parameters of the test methods in question and how these factors will either enhance or degrade specific coating properties. A combination of both theoretical (presentation) and hands-on training is suggested to accomplish this task. The hands-on emphasis is an important aspect of the instruction. The student to instructor ratio should be an average of 4:1 throughout the sessions with a 2:1 ratio during hands-on training. Both "good" and "bad" methods of testing should be illustrated to emphasize the critical items of training.

Table I summarizes a suggested training outline. The initial five (5) days of the program could cover both metallographic preparation and evaluation. The final two (2) days could review tensile bond testing, hardness, and erosion. Any combination of time frames and topics could be incorporated to cover the required testing techniques in a given situation. It is, however, critical to include sufficient opportunity for inclusion of hands-on examples that reinforce critical concepts which are emphasized in the presentation modules.

Table I - Generic Training Outline - Thermal Spray

Introduction	- 3 Hrs.
Metallography Presentation	- 4 Hrs.
Metallography Hands-On	- 12 Hrs.
Metallographic Evaluation Presentation	- 4 Hrs.
Metallographic Evaluation Hands-On	- 12 Hrs.
Tensile Module	- 8 Hrs.
Erosion /Hardness Module	- 4 Hrs.
Testing Module	- 4/8 Hrs.

Training Examples

Metallographic preparation and evaluation instruction must be an important part of any training program. Two examples are highlighted to illustrate how the sessions could be taught:

Metallographic Preparation. A critical issue in metallographic training is the important interaction that exists between materials produced by the spray process and the sample preparation procedure. Figure 1 and 2 might be used to highlight this emphasis. When developing or qualifying a new coating at a facility, great care is taken to produce a tightly bonded, dense coating. This could be characterized as the "good" or "immune" material in Figure 1. The important step of metallographic procedure development might occur at this point with the only input being this "good" coating. The technique could fall into the "aggressive" classification and be designated for use on a day to day production basis.

When ongoing/daily spray production begins, normal process variation occurs and the quality level of the coating will change. The coating might now be characterized as the "bad or ugly" designation in Figure 1. The aggressive metallographic procedure would then indicate that the coating is indeed unacceptable or "bad". At this point the question is: does the coating really fail the specification or is the aggressive metallographic procedure causing the failure? The logic in Figure 2 could address this issue. Unless the preparation technique is developed using numerous samples produced with a wide range of spray process parameters, it is difficult to answer the question. When formulating and standardizing the testing procedure using varied material quality levels, the metallographic technique can then actually identify changes in the spray process when trends exist.

Metallographic Evaluation/ Interpretation. Analysis of the coating morphology begins with identification and definition of the basic microstructure characteristics. Table II is a listing of items which begin to highlight coating features. With the wide variety of companies/students that could attend the sessions, the initial thrust would be to ask the class what they believe the definitions of the varied characteristics should be. This method can be used in other areas of the course to assess the knowledge levels of the students and determine a baseline for instruction. It also creates some interesting interaction when varied answers are received from different members of the class.

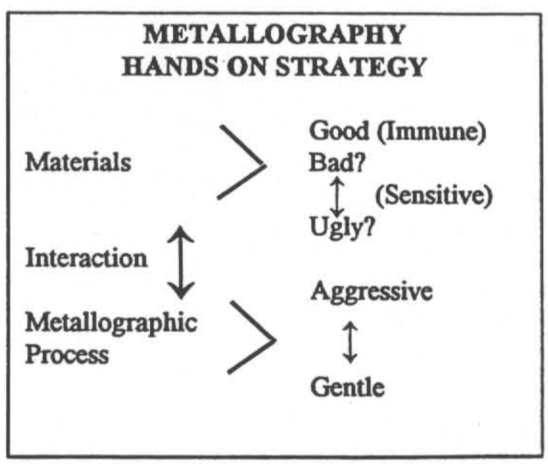

Fig. 1. Instructional Handout

METALLOGRAPHY
HANDS ON STRATEGY

* Procedures Developed For <u>Immune Material May Fail A Good Coating/Process</u>

* Procedures Must Be Developed For Sensitive Coatings - Can Then Identify Process Variations

Fig. 2. Instructional Handout

The variation in definition also addresses a very important philosophy of the training; comparison of procedures or student knowledge should be reviewed to understand why there might be differences in methodology and subsequently results. It is not to decide <u>right vs wrong or correct vs incorrect</u>. A definition of an unmelt may be different from company to company but identification of the particle is generally the same. This class-instructor interaction also allows the students to become aware of ideas from others and possibly apply those principles to the day to day operations of their laboratories.

When definitions are agreed upon and established, the students should move to the microscope for hands-on training and identification of the characteristics. This constitutes a building block approach moving from definitions to actually noting the characteristic in the microstructure. Subsequently, the hands-on training could be further refined by identification of the same characteristic in specific coatings such as Tungsten Carbide Cobalt (WC-Co), Nickel Chrome Aluminum (Metco 443) and others. The remainder of the training in tensile, hardness, and erosion could also be taught using this same basic philosophy of combining both presentation and hands on instruction.

Why Train?

Variation in the testing process is a given just as the differences that exist in day to day spraying of hardware. An educated laboratory technician can ascertain where the significant variation exists and help to solve production problems. Students from various industries/manufacturers can develop, via training, a better understanding of why subtle changes in test methodology can make a major difference in final results.

A substantial cost savings can also be realized via reduction in the amount of rework. In the metallographic process, flaws such as porosity, cracks, and delaminations can be introduced into the coating microstructures. An educated technician will develop procedures which produce consistent and reproducible structures which represent the true output of the production facility.

Summary

Training is an important aspect for many companies in the 1990's. An educated work force for a thermal spray production facility should include both trained spray operators and laboratory technicians. Knowledgeable laboratory personnel can make a major impact in day to day operations by developing procedures which provide consistent and reliable test results. This will reduce rework and give valuable input to the production floor with regard to the spray process parameters. The key to success is knowledge and understanding of how the process works.

Table II -Microstructure Characteristics Definitions

Porosity/Voids -	Holes or pores within a coating. A microstructure feature containing no matter.
Pull-out -	Artificially induced porosity resulting from unsatisfactory preparation.
Oxides -	Particles or linear striations which result from the metal powder combining with oxygen during the spray process.
Oxide Clusters -	Numerous oxide masses grouped closely together.
Oxide Stringers -	Continuous linear oxide striations running parallel to coating base metal interface.
Unmelted Particles -	Unreacted powder particle. Spherical, non-flattened or partially flattened with an aspect ratio (width to height) of less than 3:2 when viewed at 200X magnification.
Metallic Inclusion -	Presence of metal/intermetallic particles in the coating.
Delamination -	Horizontal cracking or separation within a coating or between the coating - base metal interface.
Spalling -	Detachment or flaking of particles/layers from a surface.
Transverse Cracks -	Cracks perpendicular to the base metal.
Interface Condition -	Embedded foreign particles, contamination, or voids observed at the interface between the base metal and the coating.