Y-12

**OAK RIDGE
Y-12
PLANT**

MARTIN MARIETTA

Y/DX-2249

CONF-940859--30

Schilling Titan 7 Plasma Spray System

S. C. Robinson, L. R. Mooney,
R. E. Pollard, W. F. Thompson,
E. W. Walker, J. R. Younkin

Development Division

February 1994

Prepared by the
Oak Ridge Y-12 Plant
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.,
for the U.S. DEPARTMENT OF ENERGY
under Contract DE-AC05-84OR21400

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Schilling Titan 7 Plasma Spray System

S. C. Robinson, L. R. Mooney,
R. E. Pollard, W. F. Thompson,
E. W. Walker, J. R. Younkin
Y-12 Development Division Robotics and Automation Team
Oak Ridge Y-12 Plant[1], Oak Ridge, TN

ABSTRACT

An automated plasma spray facility was needed to apply refractory material to the inside of cylindrical graphite crucibles. A tilt-rotary table and a Schilling Titan 7 manipulator were available for developing a system to manipulate the plasma spray gun and crucible.

IGRIP simulation software was used to generate the workcell layout. Simulation also revealed that the Schilling joint motion was constrained by the small inside diameter of the crucible. Because of the motion constraints, the spray gun could not be properly reoriented during the transition from spraying crucible sides to bottom. This was solved with a custom end effector that reoriented the spray gun. Motive power for the reorientation was provided by wrist rotation.

A controller was developed to simplify generation of spray paths and coordinate the Schilling and tilt-rotary table. Software was generated by modification of existing Schilling teach/playback code. This software ran on a PC embedded in a VME system.

INTRODUCTION

Plasma spray is a technique for deposition of high temperature coatings. In the plasma spray gun, inert gas flows through a charged orifice, creating plasma at temperatures of 20,000° F. Powdered coating material is injected into the plasma stream where it is melted. The molten particles are ejected from the spray gun at velocities approaching Mach 2. These coatings are often applied with hand-held guns, exposing the operator to high temperature, noise, and overspray dust.

A plasma spray facility was needed to spray the inside of graphite crucibles with a multi-layer protective coating approximately 0.5 mm thick. This coating was necessary to extend the life of the crucible and maintain purity of the melt. The crucibles were 610 cm tall with an inside diameter of 457 cm. The confined space of the crucible and uniformity requirements on the coating dictated this be an automated system to enhance safety and improve product quality.

---

[1] Managed by Martin Marietta Energy Systems, Inc. for the U. S. Department of Energy under contract DE-AC05-84OR21400.

FACILITY AND MECHANICAL DESIGN

A tilt-rotary table and a Schilling Titan 7 manipulator were available for developing an automated system to manipulate the plasma spray gun and crucible. The Schilling Titan 7 is a hydraulically powered remote manipulator designed for undersea operation. In normal use, an operator manipulates a small master arm. The motion of the master arm is duplicated by a larger slave arm. The slave arm has a 78 inch reach, 250 pound lifting capacity, and weighs 125 pounds. These specifications, along with ease of installation, make it attractive for factory and laboratory projects. In the spray facility, the tilt-rotary table would slowly rotate the crucible while the Schilling moved the spray gun down the inside wall, across the bottom, and back out. The IGRIP software package was used to lay out the workcell and determine the relative positions of the tilt-rotary table and Schilling. The completed workcell is shown in Figure 1.

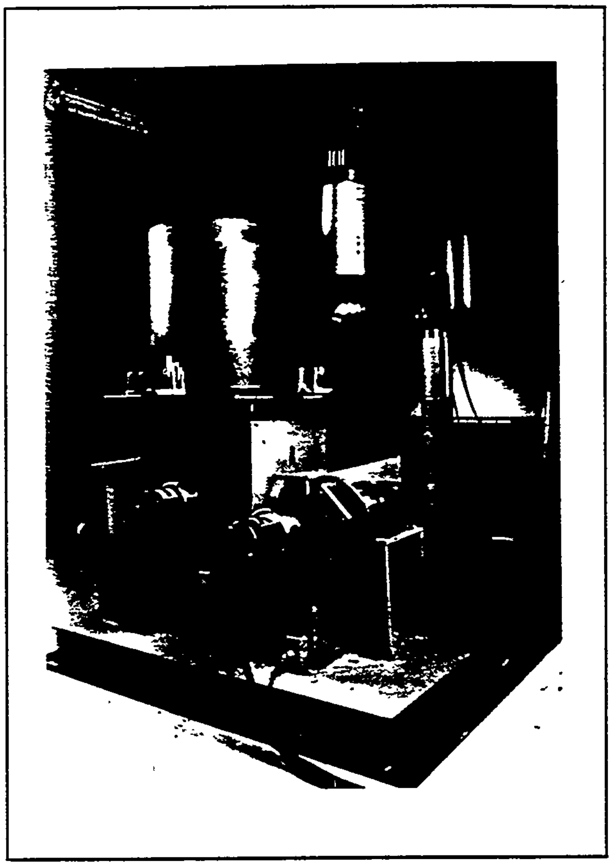

Figure 1. Plasma Spray System

To achieve the highest quality, the plasma spray gun must remain perpendicular to the surface being coated. As a result of IGRIP simulation, it was found that if the gun was mounted directly on the arm, perpendicularity could be obtained for spraying either the sides or the bottom of the crucible, but not both. This was because the small diameter of the crucible prevented the Schilling joint motion needed to reorient the gun. A custom end effector was developed to solve this problem. The end effector was equipped with a small rotary table connected to a paddle through chains and sprockets. The paddle was held by the Schilling gripper when the end effector was mounted on the arm. The gun, mounted on the rotary table, would rotate through a 180° angle as the wrist was rotated through 180°. By controlling the position of the wrist, the gun could be pointed at the spray surface, maintaining perpendicularity.

During operation, the arm occasionally had a tendency to dither when at rest. Dither was greatly reduced by removing silt and other impurities in the hydraulic oil with a high efficiency filter in the oil line.

CONTROLLER

Plasma spraying the crucibles requires a slow, uniform surface speed and constant gun standoff distance. This must be accomplished inside a confined space that is not readily visible to an operator. These constraints would place impractical demands on an operator to use the Schilling master to manipulate the slave arm. To be used effectively, it was necessary to upgrade the Schilling from a remote manipulator to a system with full robotic capability and a means for designing spray paths. This was accomplished through the limited teach/playback capability available through Schilling's robotic option. This option allowed a PC to be inserted in the link between the master and slave controllers as shown in Figure 2. When teaching, the PC would sample position commands going from the master to the slave as an operator manually manipulated the system through a task. These position commands were stored on disk. Positions were retrieved from the disk during playback and transmitted to the slave controller. This software required an operator to use the master controller to manually perform the task during teaching and no means was provided to interface with the rotary table or the plasma spray controllers. Therefore, a controller was needed to provide the capability to simplify the design of spray paths and coordinate the manipulator and rotary table.

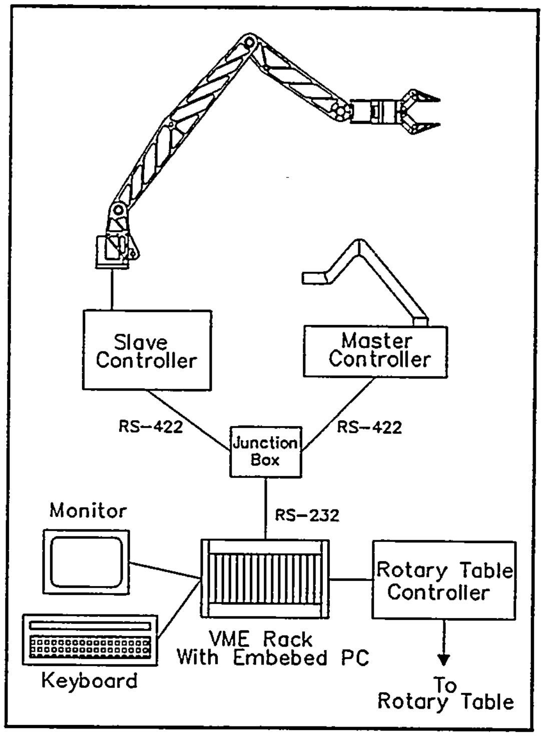

Figure 2. System Diagram

To maintain flexibility for future expansion, VME architecture was selected for the controller. A Radisys Corporation embedded PC system was plugged directly into the VME buss to run the Schilling software.

Two approaches were developed for programming the spray paths for the Schilling arm. Both use modified Schilling robotic software running on the embedded PC to communicate with the slave controller. The first approach was to program on-line, with the arm actually moving through the spray path during programming. The second approach was off-line programming where a computer model of the arm was used to generate the spray path. The actual arm did not move until the path has been created and evaluated in the model.

On-Line Programming

The Schilling program, "DEMO", provided the foundation for the control software. This software was written in C and ran on the embedded Radisys PC. The desired path is stored in a data file in the form of values for the joint potentiometers. The master/slave controllers and the PC communicate by exchanging information packets over serial links. The first packet to be exchanged is one from the PC to the master requesting control. The master replies with the second packet, granting control to the PC. A playback packet is sent from the PC to the slave controller to notify the slave that the PC is going to send position information. The PC then sends a position packet that contains the joint command values. The slave moves the arm into the commanded position, and returns an acknowledge packet to the PC, notifying the PC that the motion has been completed. The PC then sends the next position packet. This procedure continues until the path is complete. The PC then sends a playback off packet to the slave.

Code was added to DEMO to allow individual arm joints to be moved using keys on the PC. Although manual path teaching was still required, it was much easier to move the arm in a controlled manner with the PC keys than was possible with the master arm. Code was also added to interface with the tilt-rotary table by sending commands over an RS-232 line to the tilt-rotary table controller.

Off-Line Programming

Another approach to controlling the Schilling was accomplished using the Cimetrix off-line programming software package, Robline. Using this package, robot and equipment models can be constructed and moved. It has the capability to output robot joint angles as the modeled robot follows a modeled path.

Robline ran on a Hewlett-Packard workstation. A Force30 board running VxWorks was added to the Schilling controller VME buss. The workstation and the Force30 board communicated via Ethernet. In operation, joint angles generated by Robline on the workstation were sent over the Ethernet to the Force30 which put the data in the embedded PC's mailbox. Software running on the embedded PC converted the Robline joint angles to Schilling joint command values and passed these values to the slave controller. Motion acknowledgements were also passed from the slave controller back to the Robline system. The conversion factors for joint angle to joint command had been determined experimentally by physically measuring joint angles and noting the corresponding joint values returned from the slave controller. These measurements were fitted to a curve for use in the conversion software.

CONCLUSIONS

The Schilling Titan 7 can be used in robotics applications where high precision is not needed. A low end controller using a PC and Schilling's robotic option can be used for simple applications. For more complex jobs involving higher risk of collision or the need to synchronize auxiliary equipment, Schilling software can be modified to control the auxiliary equipment and accept PC keyboard input to move the Schilling joints. By adding additional hardware, software, and workstation with a simulation program, off-line programming can be developed for the Schilling.

Distribution

J. T. Fisher, MMES, Y-12 9998,MS-8204
J. T. Greer, MMES, Y-12 9203,MS-8084
R. E. Igou, MMES, Y-12 9998,MS-8205
√A. K. Lee, DOE-OSTI, 9731, MS-8175 (2)
L. R. Mooney, MMES, Y-12 9203,MS-8084
R. E. Pollard, MMES, Y-12 9998,MS-8204
S. C. Robinson, MMES, Y-12 9998, MS-8204
W. F. Thompson, MMES, Y-12 9998,MS-8204
E. W. Walker, MMES, Y-12 9203,MS-8084
J. R. Younkin, MMES, Y-12 9203,MS-8084
Y-12 Central Files, 9711-5, MS-8169