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Design and Fabrication of Components for Automation of Flame Thermal Spray Process

A. Barba-Pingarrón, E. Garduño, J. M. Dorador-Gonzalez, C.A. Barba-Ostria

***Abstract*— This article shows the design sequence for the automation of combustion powder thermal spray process. With this process is possible obtain coatings of many different compositions with capabilities to achieve excellent corrosion and wear resistance. The elements obtained were validated using CAD modeling and 3D animation before their construction. A working prototype was produced using rapid prototyping techniques. Mechanical and electronic components were assembled together and adapted to a thermal spray gun attached to a robot arm that provided the necessary movements to generate combustion thermal spray coating process. Results produced with this automatic coating process are discussed.**

***Index Terms*— Automation, coatings properties, components design, thermal spray coatings.**

I. INTRODUCTION

Thermal Spray technology is one of the deposition techniques used in Surface Engineering. This technique produce surface coating with different compositions, that could be metallic, ceramic or a combination of them. This kind of coatings can improve wear and corrosion resistance of parts and components. [1]- [6]

Thermal spray process begins with the fusion of the materials that will be used for coating. This fusion is obtained with a diversity of energy sources, being one of them the combustion of gas mixtures of oxygen and acetylene in the inner part of a specially designed gun. The melted material is projected using an air or gas current that carry the melted particles and produces an impact with the target surface of the part. [1] [2]. The gun, usually is manipulated by a person that moves it continuously following a path.

The obtained coating with this conventional process can be porous and discontinuous in its thickness, with porosity and low adherence. These imperfections produce a low-quality coating, but can be reduced using an automatic deposition system that could produce better adherence and uniformity and reduce porosity.

In order to obtain the integration of the automated combustion powder thermal spray process is important to consider the characteristics of this process, namely: The aperture of the valves for gases of the process, the activation of the ignition system of the gun, the movement of the trigger that allows the flow of the powder used for spraying. It is important, additionally, to consider that the weight of the components of the system must be kept to a minimum in order to allow the use of a low capacity robot.

II. DESIGN PROPOSAL

The design of the components necessary for the proposed system was based on the methodology given by Pugh [7]. This method includes the following stages in the design process:

- Detection of the specifications
- Conceptual design
- Detailed design
- Manufacture

In order to achieve the automation of the combustion powder thermal spray system a conventional gun will be used, so that the first step in the design was to obtain its dimensional and volumetric characteristics together with its operational parameters. A CAD model of the gun is shown in Figure 1.

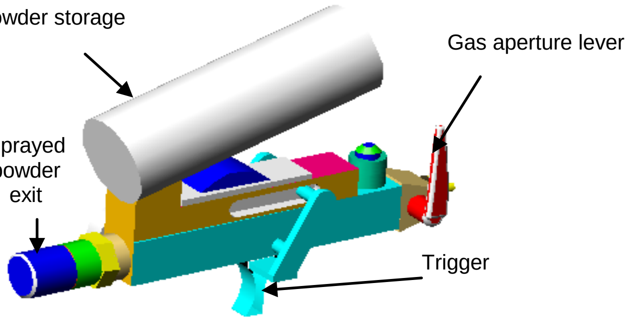

Fig 1: Spray gun, model 5PII, Sulzer Metco.

III. DESIGN OF MECHANICAL COMPONENTS

The final design for supporting the spray gun and its container is shown in Figure 2. The support was built using 10 mm sheet of Aluminum 1100 AA. The holes are for the assembly of the cover, the gun and for allowing its attachment to a robot arm. This part was manufactured using a NC machine.

Fig 2: Support

The shutter system for moving the trigger of the spray gun was designed as shown in Figure 3.

The following table compares the advantages and disadvantages of the use of one or other of the drives for the tigger.

TABLE I Selection of Drives for tigger

ADVANTAGES	DISADVANTAGES
Magnetic field is superior and with this you get one force majeure in the drive trigger	It increases its volume and therefore the structure becomes larger.

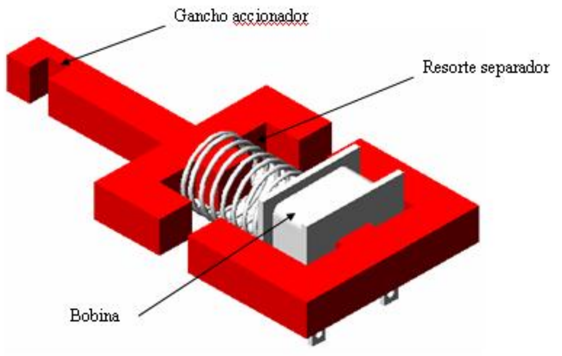

Fig 3: Shutter system for the trigger

In order to activate the trigger and protect its operation, housing is necessary. This housing is shown in Figure 4.

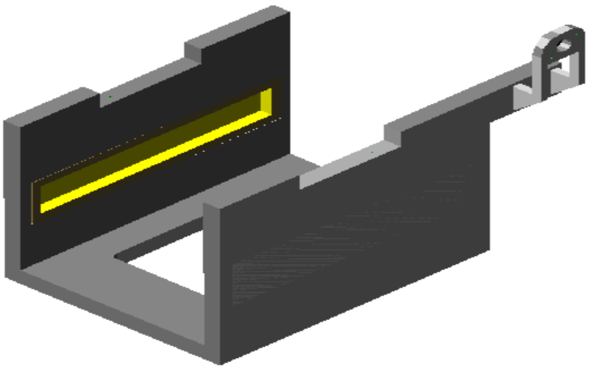

Fig.4: Housing for protection of the trigger.

The following table compares the advantages and disadvantages that we have to make one or other of the drives for the housing.

Table II.- Selection of drives for Housing

ADVANTAGES	DISADVANTAGES
Jse of less quantiy of material to manufacture.	Structure becomes more fragile
ove the clamping assembly of the flange, that shows an excess weight and disassembly of the clamping muff for manual labor.	To use the gun sprayer in a craft it is necessary to invest in time for the placement of the aperture system of the gas valves

Position switch-type sensors, were selected to carry out the ignition and shutdown process was necessary to have an element that one could choose at different points: the first for the opening of the gas, which serves for the lighting of the team, the second for the full implementation of the gas and the melt of the particles to be projected, and the third for the closure of the passage of the gas and shutdown of the computer.

Such a design in conjunction with the sensors were selected because of its ease of positioning and easy control for operation when performing the work, supporting the force applied there on effective to actuate the valve opening of gas.

A critical section of the equipment is the aperture system of the gas valves. In order to obtain this movement, a part was designed to apply the necessary force to the valve using a CD motor with sensors, for obtaining the positions of maximum and minimum apertures. This system is shown in Figure 5.

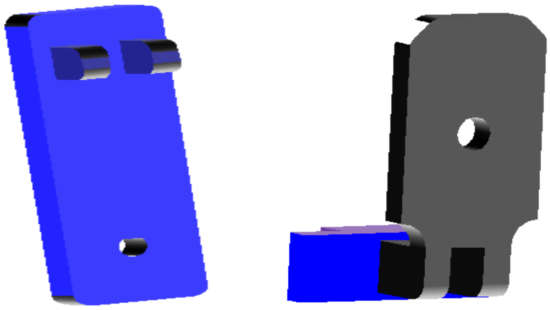

Fig 5: Parts for opening system of the gas valves.

The above mentioned parts were manufactured using a rapid prototyping system that allowed obtaining complex parts in ABS polymer, which is light and functional. The complete assembly of the system is shown in Figure 6.

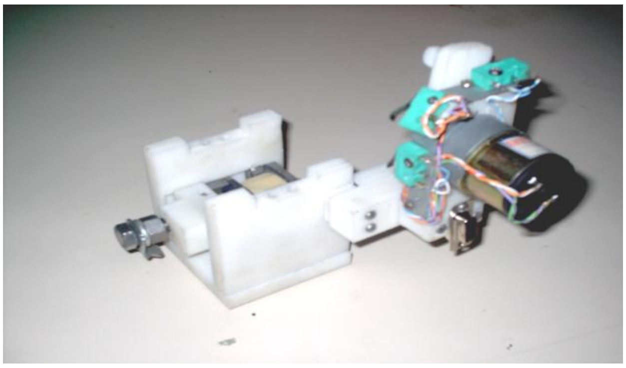

Fig 6: Assembly of the automation system for thermal spray gun.

The assembly of the automation system, the support and the spray gun is shown in Figure 7. Figures 8 and 9 show the system mounted in the robot arm.

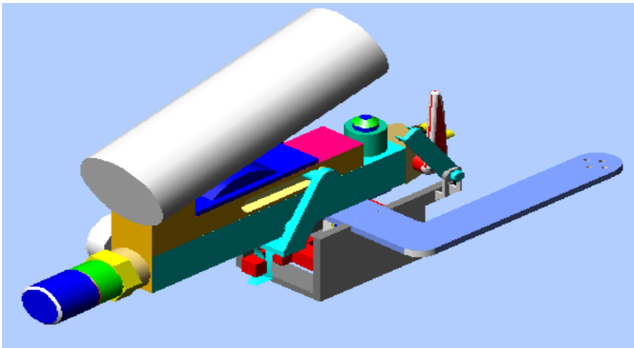

Fig 7: Spray gun with the automation system assembled.

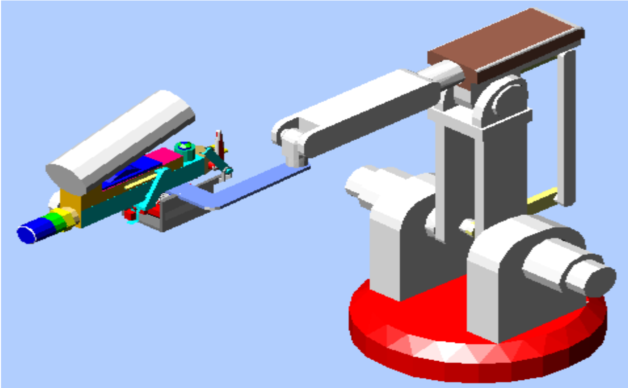

Fig 8: Robot arm with the automated combustion powder thermal spray gun attached.

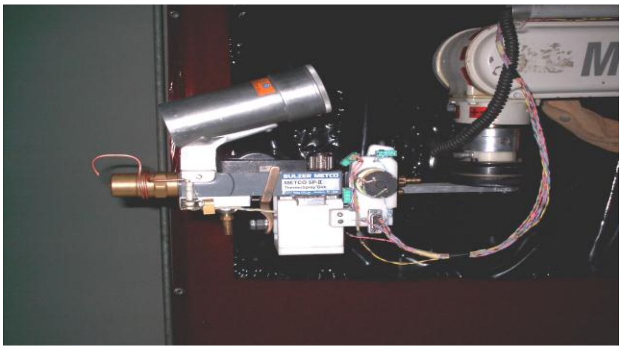

Fig 9: Prototype attached to the robot

IV. DESIGN OF THE ELECTRONIC SYSTEM

It is important to understand that to drive the switches were used curved plates, avoiding obstacles on way to or from the actuator arm with the gas valve to prevent malfunction of the automation.

The selection of the system actuators was made simultaneously with the design of the mechanical components, in order to ensure an adequate mechatronics system.

For the aperture of the gas valves a geared CD motor was selected and mounted as shown in Figure 10.

For the activation of the trigger of the gun a solenoid was selected.

For obtaining the spark for starting the flame a commercial system used in stoves was selected.

In the system of control of the team had with outputs of 24 volts of direct current, insufficient to generate a necessary spark for ignition.

We selected a transformer formed by a solenoid which enables us to obtain 110 volts alternating current sufficient to generate a spark by means of a resistor coated on one end of the ceramic material to control current flow and prevent melting. The system can be used both in automatic or manual mode. This idea was decided to allow testing and maintenance of the individual systems.

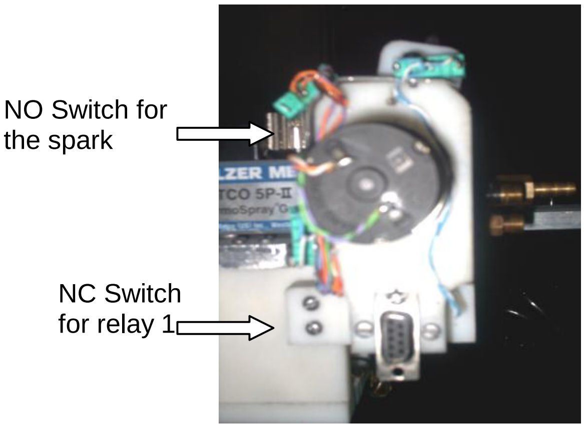

Fig 10: Geared motor coupling to the housing of the automation system.

The circuit was placed inside a box that will be used for controlling all the components of the system. Figure 11 shows the position of the buttons and switches

The recommendation is that this box should be placed to one side of the control of the MOTOMAN system.

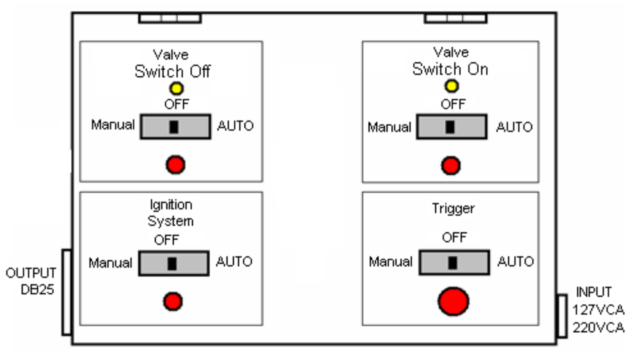

Fig 11: Control Box distribution

The control box was designed as an element of support for the operation of the equipment. This distribution allows a thermal projection process totally automated, semiautomated or manual, depending on the needs of the application or complexity of the pieces.

The wiring diagram for the circuit and its connections is shown in Figure 11.

V. EXPERIMENTAL EVALUATION OF COATINGS

The automatic system was tested using a powder named as 12C . [8] whose main characteristics are: (a) hardness 30-35 Rc, recommended for high wear and corrosion resistance. Its melting point is between 1010 and 1065 °C. Composition of the powder include a combination of Ni-Cr-Fe-B-Si

Parts to be coated of an AISI 1018 plain steel were prepared using a cleaning step using a trichlorethylene solution and after were preheated for ten minutes using the flame of the gun at a distance of 10 cm.

For thermal spraying at a rate of 150 cm / min were measured layer thickness at different points using Philips XL20 SEM. As can be observed in Figure 12, the thickness at a peak of the layer is 1.19 mm.

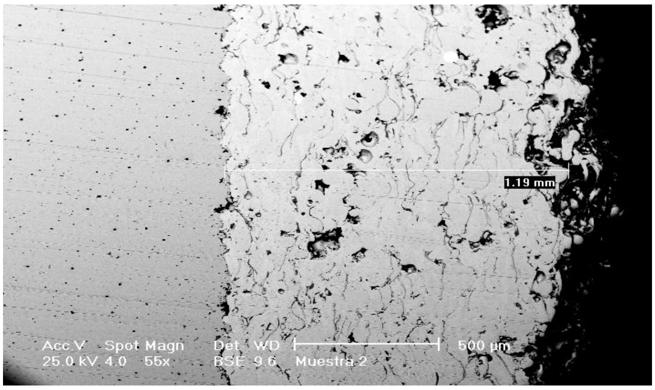

Figure 12. Image of coating of NiCrFeBSi obtained by flame thermal spray on AISI 1018 carbon steel. Thickness of 1.19 mm height of the layer. SEM. BSE

They were sprayed thermal with different times of projection, with the parameters of the previous test for a speed of 150 cm/min. The thickness of the layer obtained was measured and the results are shown in Table III and Figure 8.

Table III. Ratio of coating thickness vs flame thermal spray projection time

Layer thickness mm	Projection time sec
0	0
0.8	60
1.3	120
2.2	180
3.2 (Rise of the layer)	280

Tests were carried out for determining the better path for the spraying of the surface. The desired coating thickness was between 1.0 and 1.2 mm.

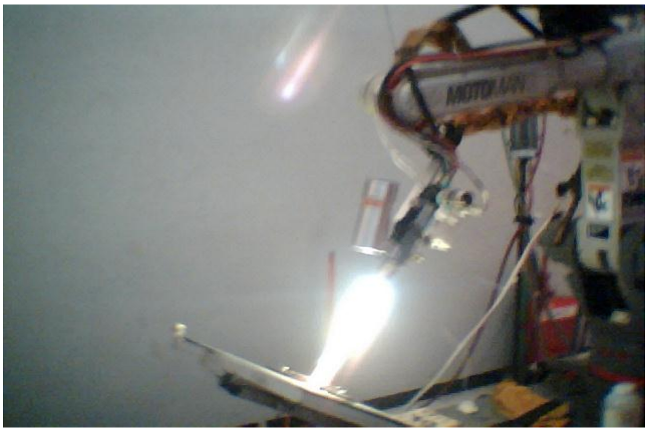

Fig 13: Image of the automated combustion powder thermal spraying process.(ACPTSP) operating.

Figures 14 shows a micrograph of a Ni-Cr-Fe-B-Si coating obtained with a manual combustion powder thermal spray and figures 15 and 16 show photos obtained with automated system and observed with a Philips XL20 scanning electron microscope (SEM) of the coated surfaces. Its clear that the use of the automated system increase the adherence and reduce the porosity of the coating.

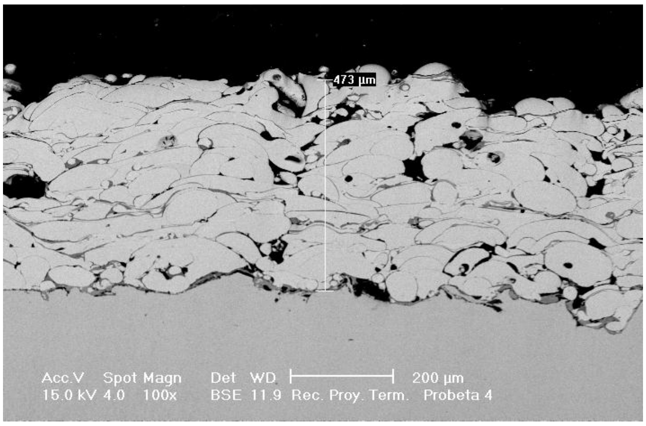

Figure 14.- SEM Micrograph of a Ni-Cr-Fe-B-Si coating obtained by a conventional manual combustion powder thermal spray process. Its possible to see limited adherence and high porosity.

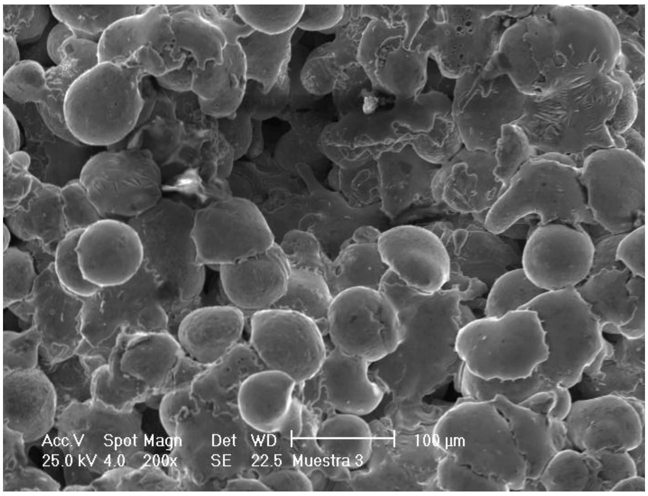

Fig15: SE Micrograph showing the structure of the coated surface obtained with ACPTSP.SEM. 200 X.

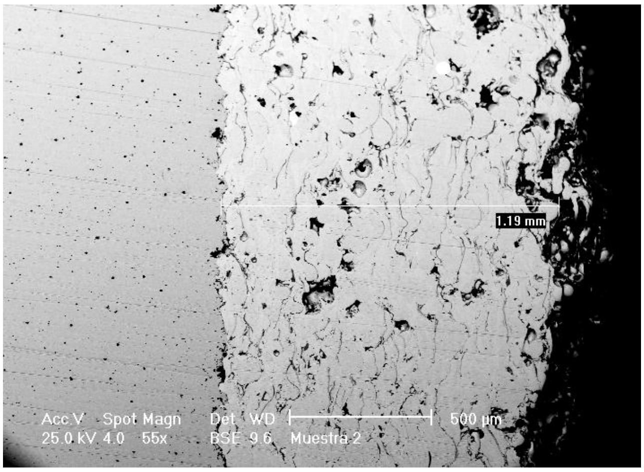

Fig 16: BSE Micrograph of the Ni-Cr-Fe-B-Si coating showing better uniformity of thickness and reduced porosity of the coated surface obtained with ACPTSP. SEM 55X

VI. CONCLUSIONS

Results obtained with the automatic system were compared with coatings obtained in a conventional way. The continuity and adherence of the coated surfaces was better than the obtained with the manual process and the porosity was reduced. All the material was perfectly coated to the parts, fulfilling the objectives stated at the beginning of the research.

Thanks to the automation of the systems of the combustion powder thermal spray process can now be considered as a real alternative for high quality coating systems. This automatic process represents a real alternative for industrial products that have a short life in use. Besides, coating is a process that can be used for rehabilitation of components allowing their reutilization.

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Arturo Barba Pingarrón. PhD (Metallic Materials). Barcelona University, 1997. Center for Surface Engineering Coordinator. Facultad de Ingeniería. UNAM. México. 145 publications in Surface Technologies

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Jesús Manuel Dorador González. PhD (Mechanical Engineering), Loughborough University, England, 2000, 50 publications in Mechatronics and Automation, Head of Mechatronic Engineering Department. Facultad de Ingeniería UNAM

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