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# THE INFLUENCE OF THE SPRAY PARAMETERS ON THE MATRIX DURABILITY BY SPRAYING METAL MOLTEN

**Ioan FODOREAN, Petru BERCE, Dinu POP, Sorina MURESAN**

***Abstract:*** *This paper presents research on influence of process parameters on the sustainability of the spray coating spraying. We made experiments with the purpose to find out optimal parameters of layer in which to have a better sustainability of mold gain by metal spraying molten. Uniform grain microstructure well sudden between them and high density without oxides lead to better resistance of layer pulverized. The conclusion of good results is the temperature and the speed of particulars at impact moment and cooling condition of layer pulverized as well influence the layer's microstructure and all the mechanic proprieties of the mold gain by pulverized.*

***Key words:*** *injection molding, metal spraying, rapid tooling.*

## 1 INTRODUCTION

The manufactories' preoccupation is focus on shorting the cycle of manufacturing, time of assimilation of a new product, manufacturing costs, technology and tools device measuring appropriate form and precision product batch. When it comes to small series these problems are more difficult to solve, as in parts of the same hundreds of thousands. A proven solution for production of active molds elements for small and medium series and submissions is sprayed (Metal Spraying) on a model in order to obtain negative master's, then used as molds for molding or injection. [1] Series production can be achieved with a set of spray metal molds can be covered by very diverse. For polypropylene can be reduced to 25-250, and for ABS can be raised at 1800-2500[2].

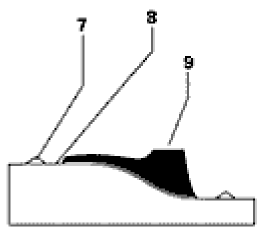
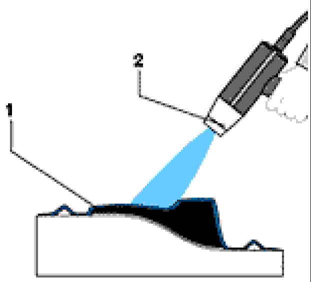
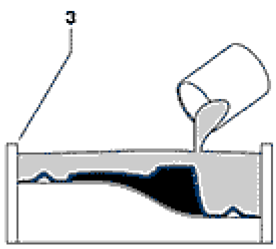
### 1.1 The metal spray tooling technology

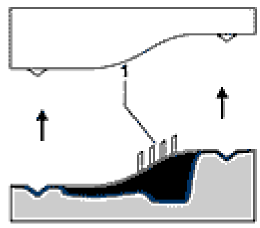
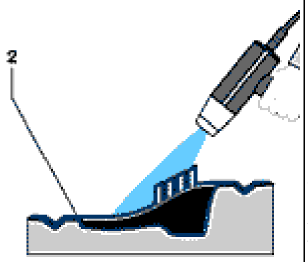
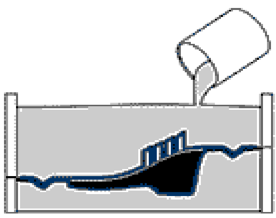
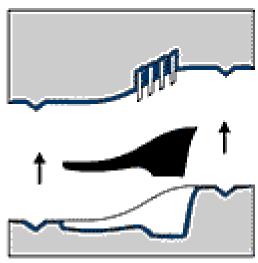
In the next lines will be described rapid prototyping manufacturing technology called Metal Spraying can be achieved by active elements of the mold.

Manufacturing process is relative simple spray and used in other areas. The table 1 illustrates the main steps of the metal spraying technology and presents some hints to make the metal sprayed molds.

*Table 1*

**Rapid tooling by metal spraying**

| | |
|---|---|
|   | -Prepare the master model;<br>-Set up the splitting line and fix the RP model, so that the metal could be sprayed onto the first half of the mould, only. |
|   | -Spray the metal onto the master model, until a metal layer about 0.5 - 2 mm thickness is obtained;<br>-Do it in one working session, if the master model's melting point is high enough. If there are pauses to cool down the model, the oxidation could decrease the bounding between layers. |
|   | -Back-up the first half of the mould with enforced resins;<br>-The epoxy resins are mixed with aluminum pellets and the mixture is poured over the metal layer, into the wood box (3). |

| | |
|---|---|
|  | -After solidification (by curing the resin into the oven), the back of the first mould is machined by milling, in order to get a good planar surface;<br>- The first half of the mould is ready. |
|  | -Rotate the package by 180 °;<br>-Repeat the metal spraying procedure onto the second part of the master model, which has been covered (e.g. with plaster) up to the splitting line. |
|  | -Back up the second half of the mould with enforced resins;<br>-The aluminum pellets added to the resin, increase the thermal conductivity of the mould; |
|  | -After curing and milling the second mould, the master model could be removed;<br>-The two moulds could be assembled together and prepared for injection molding |

Tools and molds manufactured by spraying molten metal are used successfully in many applications, including cold plastic deformation, plastic injection, molding under pressure, etc. Such components can be manufactured from a wide variety of materials such as polypropylene, ABS, polyamide, and the materials considered difficult, such as composite materials.

## 1.2 Description of the spraying process

Spray forming, basically, is a metallurgical process whereby near-net shaped performs with outstanding material properties may be produced direct from a metal melt via atomization and consolidation of droplets.

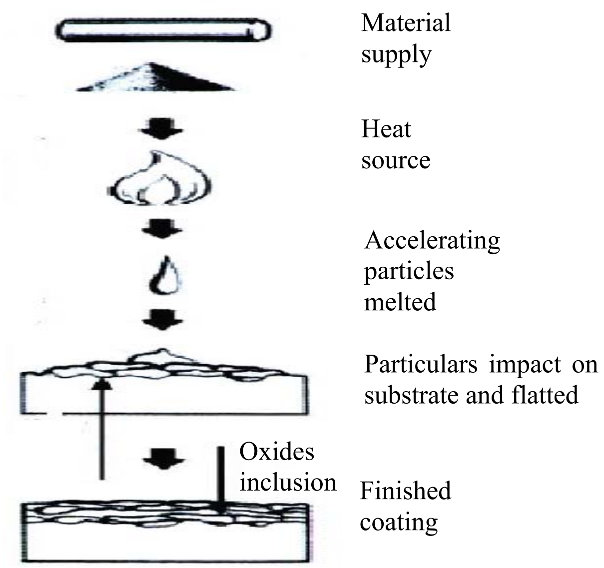



**Fig. 1.1.** The principle of metal sprays [6]

Spray formation is a metallurgical process that combines the main advantages of the two basic approaches to traditional manufacturing of semi finished materials and complex geometry, namely:

- Molding metals: production involving large volumes of complex geometry.
- Powder metallurgy: the small volume to obtain a homogeneous microstructure with fine grain

In the formation of spray, metal preparation and mixing of molten metal which is distributed through a melting crucible loaded into the spray. Here, in most applications, inert gas jets with a high kinetic energy causes the flow of metal melt disintegration (twin-fluid atomization) In the resulting spray drops are accelerated towards the substrate, thus beginning to cool and solidify partly due to intensive heat transfer of cold gas sprayed. Spray droplets and particles affect the substrate. At the impact with substrate molten drops flatting and weld between made the structure. Depends on the grade of melt and the speed at impact results microstructure with some porosity. In coating resulted by pulverized might appear oxides because the atmospheric condition were the pulverized is made it.

In the process of spraying intervene eight parameters independent that influence the process of spraying figure 1.2.

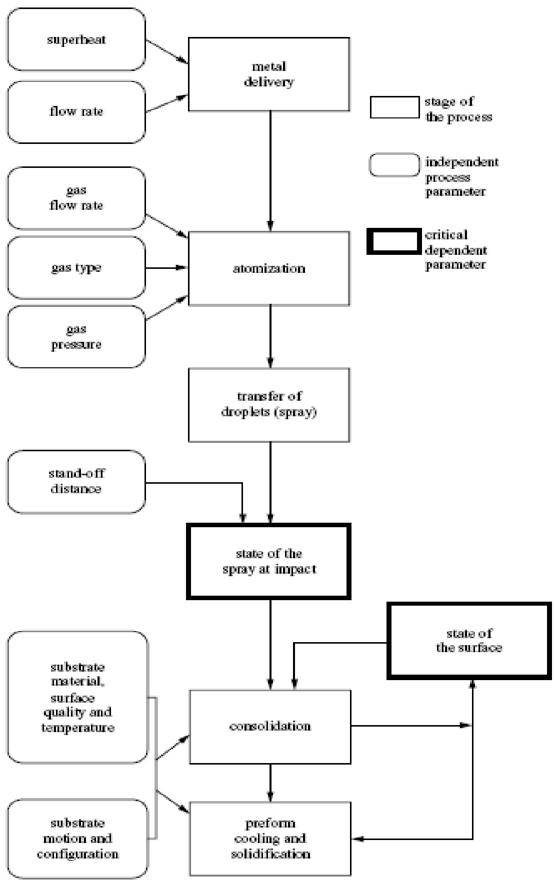



**Fig.1.2** Modelling of dependent and independent process parameters as a flow diagram[3]

The most imoprtant parameter of the process is the temperature of particle sprayed in each step of the process . Analysis begins with the thermal history of the crucible temperature, flow through the crucible, the spray nozzle, and further, the solidification behavior of molten metal droplet when the spray reaches the warehouse, the warehouse and the impact further consolidation and cooling in the spray drift The results from each previous step of the process is transferred to the next step of the process model as a limit condition. In order to determinat parameters of pulverized we will analize the temperature of particulars(coating) at impact moment .

## 2 DESCRIPTION OF EXPERIMENTS

In view of developing experiments to built a closed chamber, provided with a suction gas and particles with a vacuum inside the explosion, This provides protection against explosions and safety work. Spray gun and pyrometer are fixed to the top and the table is in the bottom and moves on three axes XYZ is fixed by a CNC table (table is able be conected by the robot arm). Linear table moving with a constant chosen speed and makes the race (200 mm) round trip away from pre-spray gun Spray pistol is fixed and is perpendicular to the table spraying continue.

Spraying shall be made on a card 150 mm x 300 mm which was covered with a layer of demulant (PVA), Which is not let to adhere to layer. The choice of parameters of the operation of the pistol: the temperature of the alloy, the rate of deposition, and the pressure of compressed air which makes spraying.

The introduction of motion parameters of the table in the CNC. Fixing pyrometers, introducing and focusing on reflection coefficient.

After the material from the crucible of gun reaches a temperature programmed it starts, it registers the data using pirometer and than moves with the spped of advance over a distance of 200 mm round trip

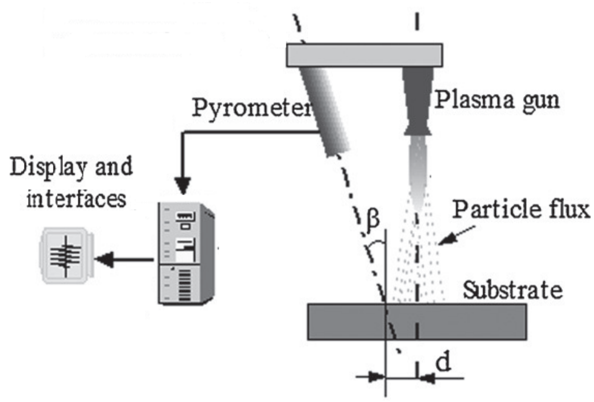



**Fig.2.1**. Temperature monitoring system [4]

Of the eight independent parameters of the process of spraying I chose three parameters which I have. Others were considered constants.

- Temperature input variables of the MCP 200 from the crucible of the spray gun was chosen between 280-307 $^{0}$ C *.
- Distance from the spraying 75-150 mm *.
- Adjust deposits 1-2,88 rotati* (*According to the "Technical Book on pistol MCP 8 k)

The results collected from the experiments are:

- spray coating temperature variation during spraying
- microstructure degradation (size grauntilor, their component)
- Density substrate by spraying

## 2.1 Temperature variation of powder layer

After achieving the 15 sprays and graphical representation of temperature during the process we see that the temperature in the layer 1 to be sprayed with 3-5 $^{0}$C will increase slightly as layer after layer 1 and 2 start to see a significant temperature jump to 11 - 44 $^{0}$C above the temperature of the layer 1 and layer 2 to the end temperature decreases slightly – Fig.2.2.

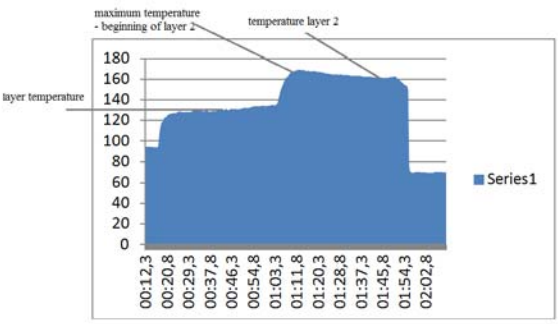



**Fig.2.2.** Temperature variation during the spraying

## 2.2 Microstructure.

Microstructure power is influenced by**:**

- The temperature of impact time
- The speed of particulers in the impact time
- Cooling spray coating (heat extraction through the substrate)
- The percentage of oxidation of the particles

Particle size, shape, welding and porosity depend on these variables. A low temperature, a small and a sudden cooling of the spray lead to a structure of small density, with the resulting porous. A relatively high temperature accumulated a higher impact speed and a slow cooling of the substrate results in a large grain structure with tight seams between them and a low porosity[5].

In order to study the structure of the layer sprayed metallographic samples collected were polished and attacked with a mixture of hydrochloric acid and water for 10 minutes.

Optical microscope help we took pictures of the structure on a scale of 1:1000. The first 4 samples have larger grains and higher porosity, samples 5, 7, 13 and 15 have a structure of homogeneous and low porosity.

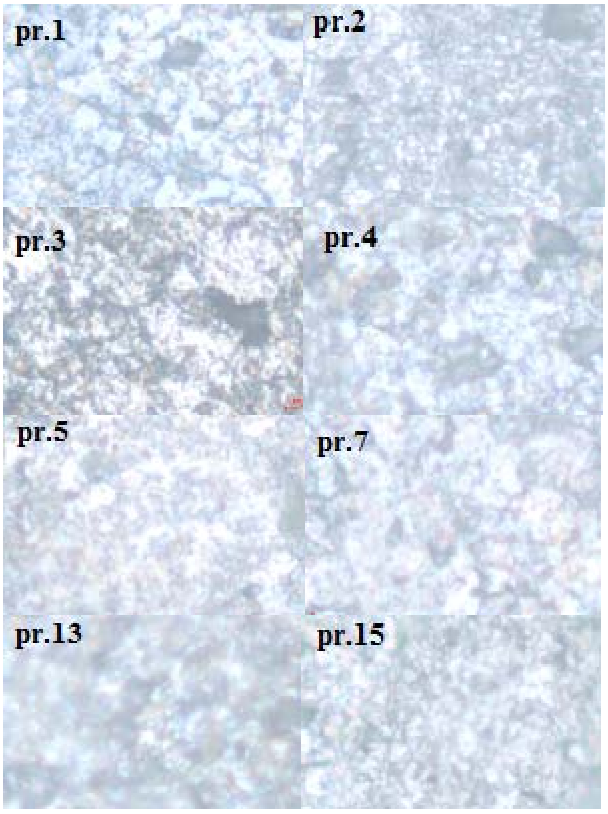



**Fig.2.3**The microstructure of layer pulvirized

## 2.3 Density determination

Density The experiment was performed using electronic balance Shimadzu- (Fig.2.4) . This balance allows experimental determination of the density of a body based on its weight in air and weighed in a liquid whose density knows.

Relationship for calculating the density of sprayed parts is

$$\rho_p = \frac{m_{p\_aer}}{m_{p\_aer} - m_{p\_apa}} \cdot \rho_{apa} \qquad (1)$$

Looks like:

ρp – analyzed piece density [g/cm3];

mp_air - piece weighed in air mass [g];

mp water - weighed in water play table[g];

$P_{water}$ – water density [g/cm$^3$].

Water density was measured using Anton Paar digital densimeter thermo-DMA 35n. Measured density value is 0.9976 g/cm3 at 22.8 0C.

**Fig .2.4** Density determination tools

After weighing each piece and calculating the volume density was determined.As you can see in the table 2 the proofs that were form by pulvirized at low temperature of molten and a bigger space between the head pulvirized and the layer have a strucutre porosy with neuniform grain.

*Table 2*

**Data input parameters and results**

| number | Temp.melting $^0$C | Pulverized distance mm | The speed of moving mm/s | Flow rate metal | Temp. layer1 $^0$C | Temp. layer 2 $^0$C | Temp difference $^0$C | Density |
|---|---|---|---|---|---|---|---|---|
| **1** | 280 | 100 | 200 | 2,25 | 113,5 | 132,6 | 19,1 | 6,17 |
| **2** | 293,75 | 75 | 150 | 2,63 | 136,8 | 163,2 | 33,9 | 6,44 |
| **3** | 293,75 | 125 | 150 | 1,88 | 132,9 | 157,2 | 24,3 | 6,41 |
| **4** | 293,75 | 125 | 250 | 1,88 | 131,2 | 155,9 | 24,7 | 6,75 |
| **5** | 293,75 | 125 | 150 | 2,63 | 133,9 | 154,4 | 20,5 | 7,04 |
| **6** | 293,75 | 75 | 250 | 2,63 | 132,1 | 167,7 | 35,6 | 6,89 |
| **7** | 293,75 | 125 | 250 | 2,63 | 143,1 | 157,3 | 14,2 | 7,15 |
| **8** | 293,75 | 75 | 250 | 1,88 | 136,8 | 169,3 | 32,5 | 7,14 |
| **9** | 293,75 | 75 | 150 | 1,88 | 137,2 | 181,3 | 44,1 | 7,09 |
| **10** | 307,5 | 100 | 100 | 1,25 | 137,8 | 156,2 | 18,4 | 6,44 |
| **11** | 307,5 | 100 | 200 | 1,25 | 136,5 | 155,4 | 18,9 | 6,66 |
| **12** | 307,5 | 100 | 200 | 1,25 | 135,9 | 155,1 | 19,2 | 6,56 |
| **13** | 307,5 | 100 | 200 | 2 | 136,3 | 153,7 | 17,4 | 7,12 |
| **14** | 307,5 | 100 | 200 | 1,25 | 135,4 | 149,2 | 13,8 | 6,61 |
| **15** | 307,5 | 100 | 200 | 1,5 | 131,2 | 142,3 | 11,1 | 7,02 |

## 3 CONCLUSIONS

First investigations have shown the complexity and particularities the process that keeps the relatively low durability of the mold and the ratio of the 3D model accuracy - the accuracy of the prototype (master model) and precision mold obtained by Metal Spraying. On the other hand are considered issues of material required to be deposited, deposition technology, shell thickness, hardening them, cooling the mold during the injection process takes place environment where they are in close contact with the durability of the mold.[1]

Of the eight independent parameters of the process of spraying five of them are considered constant (gas flow, gas pressure, gas type, which is sprayed substrate, substrate configuration) and we varied three parameters of the process, the temperature of the alloy, spray distance and filing rate. With these three parameters plus speed were performed 15 experiments to determine optimum spray parameters to provide a high durability molds obtained by spraying the molten metal. A uniform grain microstructure with tight seams between them and with a high density without oxides lead to a good resistance of the layer sprayed. This microstructure is especially influenced the layer temperature, particle speed at the time impact and cooling time. As you can see in the table 2 the proofs that were form by pulvirized at low temperature of molten and a bigger space between the head pulvirized and the layer have a strucutre porosy with neuniform grain.

In the pulverized case of metal as models for to gain molds the temperature of particulars at impact moment has to be lower than softening temperature of models which is made the pulverized and also has to be enough higher to results a strongly coating pulverized

Sustainability depends on the distribution layer sprayed powder particles in the layer is not uniform it is distributed as a con After experiments the influence of process parameters was observed on both temperature and spray coating layer metallographic structure.

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INFLUENTA PARAMETRILOR DE PULVERIZARE ASUPRA DURABILITATII MATRITELOR OBTINUTE PRIN PULVERIZARE DE METAL TOPIT

***Abstract:*** *Aceasta lucrare prezinta cercetari privind influenta parametrilor procesului de pulverizare asupra durabilitatii stratului pulverizat. Din cei opt parametrii independenti ai procesului de pulverizare s-au variat trei parametrii importanti, temperatura, distanta de pulverizat si rata de alimentare. Am efectuat experimentele cu scopul de a determina parametrii optimi de pulverizare care sa ofere o durabilitate ridicata a matritelor obtinute prin pulverizare de metal topit.O microstructura cu graunti uniformi bine sudati intre ei si o densitate ridicata fara oxizi duc la o rezistenta buna a stratului pulverizat. Concluzia rezultateor obtinute este ca temperatura si viteza particulelor in momentul impactului,precum si conditiile de racire a stratului pulverizat influenteaza microstructura depozitului pulveriza si totodata proprietatile mecanice ale matritelor obtinute prin pulverizare.*

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