INTERNATIONAL SCIENTIFIC CONFERENCE ON
ADVANCES IN MECHANICAL ENGINEERING

19 November 2015, Debrecen, Hungary

THE CONNECTIONS BETWEEN DIFFERENT TYPES OF COLD FLAME-SPRAYED DISTANCES ON MECHANICAL SURFACE

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Abstract
Nowadays one of the most important research areas of maintenance and surface treatment is the cold flame-spray technology. The research trend shows a lot of potential in cold flame-spray technology. This kind of technology is used by vehicle, aviation, and shipping industry and we can also find it in many other mechanical areas. Companies have spent (considerable) amounts of money on repair costs to find out which could be the best repairing method. Different powders, spraying guns, methods etc. are available from different firms. The study presents the influence of the spraying standoff distance on a normal and shear component of coating bond strength. The authors give guidance on the possibilities of cold flame-spray technology.

Keywords: *metal spraying, sprayed layers, cold-flame spray, normal and shear strength*

1. INTRODUCTION

The flame spraying technology is a member of the thermal spraying technology group. This technology is in fact a technique or method of surface engineering. This is quite a cheap technology and it is easy to use compared with any other spraying method. We call this technique cold flame spraying because it needs a relatively low thermal input. The preheating temperature is about 100 ^oC and the system temperature is not more than 250 ^oC.
The relatively mild conditions can have good bonding properties between substrate materials and different types of alloys especially if we use intermediate bonding films on the surfaces. Nowadays, cold flame spraying of surfaces can be the final step in the production process or we can consider it to be a new surface restoration technology. The cold flame spray technology is used by different engineering areas as we can read about it in the abstract.

2. METHODS

Cold spraying is the newest method of thermal spray processes. This technology is technically not a true thermal spray process because it does not use thermal energy as its primary energy source to melt materials, it only uses kinetic energy to project particles onto a mechanical surface. We can see the schematic figure of the cold spray process in Figure 1. [1]

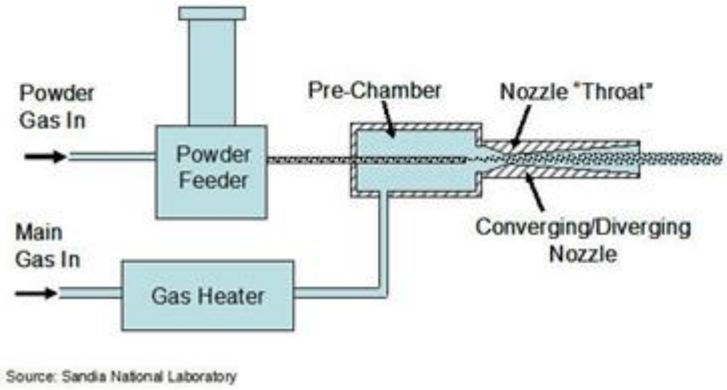

Figure 1 Schematic drawing of the cold spray process [1]

We used a RotoTec-80 equipment (Castolin Eutectic) during our research program. The main parameters of this equipment were the following:

- oxygen pressure: 4.0 bar
- acetylene pressure: 0.7 bar
- standoff distances: 100, 140, 180, 220, 260 [mm]
- spraying angle: 0^o

In the first step we preheated the experimental samples by an oxygen-rich flame. The temperature of the samples was about 50-100 ^oC. The thickness of the bonding layer was 0.2 mm. The coating was 1.5 mm on the samples which were prepared to tests of the normal component of coating bond strength.

3. MATERIALS OF THE EXPERIMENT

We selected 3 different powder alloys which have different characteristics for the extreme technological application of the cold flame-spraying metal powder spraying technology. These alloys are characteristically distinguished by their chemical compositions.

We used the following powders:

- HardTec 19400 – hard coating, protection against abrasive effects,
- LubroTec 19955 – excellent sliding requirements,
- DuroTec 19910 – tough and hard coating utilization of the dynamic loadability

Table 1 Results of the measurement

Alloy	C	Ni	Cr	Fe	Mn	Mo	Co	B	Si	S	Al
Xuper Ultra Bond 51000		89,5				5,4					5
DuroTec	0,1	84,6	9,4	2,1	0,02	0,3	0,05	1,1	4,8	0,015	
HardTec	0,1	1,1	15,8	78,1	0,08			1,0		0,018	
LubroTec	0,03	74,7	15,4	8,4	0,11	0,1	0,1			0,01	

We had to pay special attention during the standoff spraying because flame spraying is usually

performed by hand, during which it is impossible to keep the normal SOD, proposed by the manufacturer, precisely. The standoff spraying distance has a strong influence on the mechanical surfaces. This is the reason why we had to check our work with different SODs.
The research team checked the self-lubrication ability of the porous coating with oil uptake and release measurement and analyzed the change of surface energy components and the final chemical composition of the sprayed surface.
The main variables of our test are the following:

- spraying distance generally suggested by the producer (180 mm),
- increasing the spraying distance with 40% in extreme value,
- reducing the spraying distance with 40% in extreme value, and
- Using further spraying distances between extreme values.

4. NORMAL STRENGTH INVESTIGATION

We can define stress as a strength of a material per unit area in unit strength. It is in fact the force on a member divided by area, which carries the force or forces (N/mm^2; Mpa). [4]

$$R_{\perp} = \frac{F_{\perp}}{A} \qquad (1)$$

- $R_{\perp}$ = Normal bonding strength (MPa)
- $F_{\perp}$ = Normal force acting on the sprayed surface (N)
- A = the sprayed area subjected to the normal force (mm2).

We can see a figure about normal stress in Figure 2.

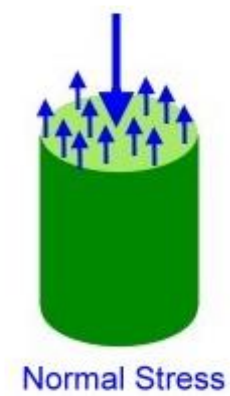

Figure 2 Normal stress [2]

We found a number of methods, techniques and literature for our research. We selected the Nádasdi – method from these activities. We can see a picture of it in Figure 3.

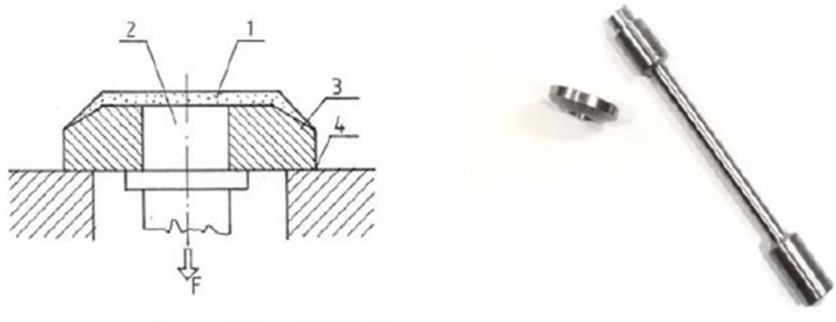

Figure 3 Test combination for normal strength tests

1 – Porous sprayed layer, 2 – tested substrate part, 3 – mating ring part, 4 – fixed base

5. SHEAR STRESS INVESTIGATION

Forces parallel to the area resisting the force cause shearing stress. It differs to tensile and compressive stresses, which are caused by forces perpendicular to the area on which they act. Shearing stress is also known as tangential stress. [5]

$$R_{\parallel} = \frac{F_{\parallel}}{A} \tag{2}$$

- $R_{\parallel}$ = shear strength (MPa)
- $F_{\parallel}$ = acting shear force (N)
- A = surface subjected to shear force (mm^2)

We can see an illustration of shear stress in Figure 4.

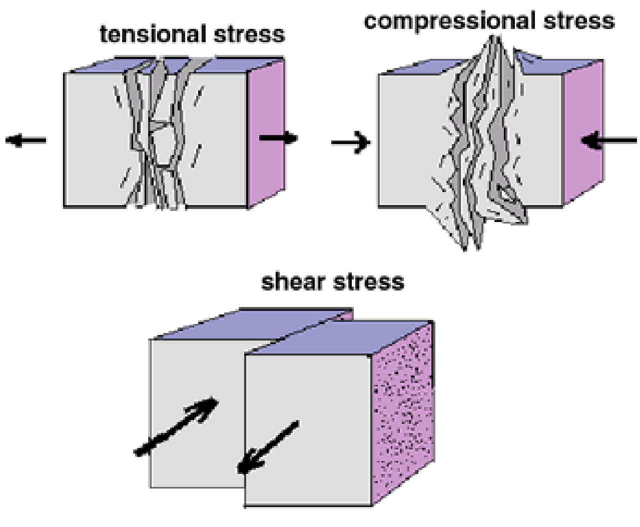

Figure 4 The difference between stresses [3]

During our research we chose the METCO method. This method is part of the DIN 50161. The applied test sample can be seen in Figure 5.

Figure 5 Shear test samples

1 – substrate part having sprayed and notched layer, 2 – shearing ring

6. RESULTS

The dependence of normal component of coating bond strength (R⊥) on the standoff distance for the various coatings is shown in Fig. 6.

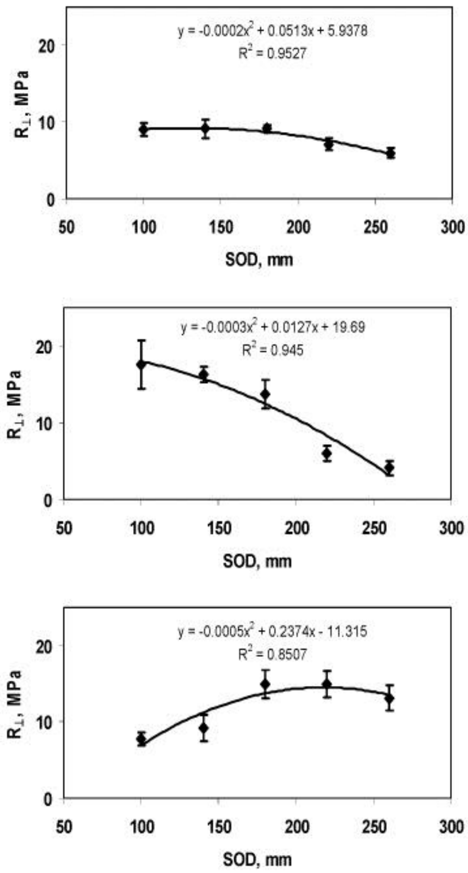

Figure 6. Normal component of coating bond strength, R⊥
From top to bottom: DuroTec, HardTec, LubroTec

If the normal and shear components of coating bond strength are compared, the normal component was always much smaller than the shear one which is the effect of the standoff distance on mechanical strength of cold flame-sprayed porous metallic coating 100 HardTec and LubroTec, respectively. As we can read in the previous chapter, flame spraying is usually made by hand, this is the reason why the normal SOD cannot be kept precisely on the surfaces. Figures 6 and 7 present the measuring results.

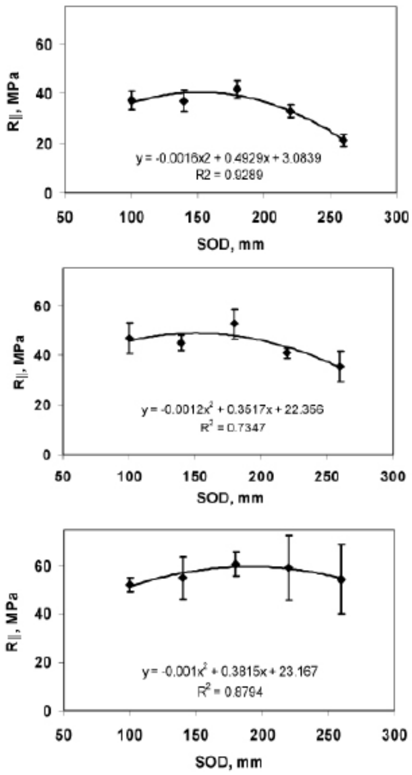

Figure 7. Shear component of coating bond strength, R⊥
From top to bottom: DuroTec, HardTec, LubroTec

The maximum available values of R‖:

- 40 MPa
- 50 MPa
- 60 MPa

for DuroTec, HardTec and LubroTec. This trend is positive, which can be explained by the hindered diffusion of B in HardTec and B and Si in DuroTec upon cold flame spraying. Comparing the normal and shear components of coating bond strength, the normal component was always much smaller than the shear one.

CONCLUSIONS

The development of flame-sprayed technologies continues nowadays. This kind of method can be used in a lot of different areas, like renewing, or repairing parts. Nowadays the cold flame spraying technology gets a high priority in modern maintenance life. The main advantage of the technology is that it can be used in low heat range (200-3000^{o}C). This is the reason why we can avoid the texture change on mechanical surfaces.

The paper describes the results of the laboratory test in connection with the analysis of interlaminar strength, which is of great assistance when choosing the most suitable thermal spraying technology. The author tries to give some information about the advantages of the cold-flame spray technology.

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