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Electric Arc Thermal Spray Process using Zn Coating for Stainless Steel Thin Wires

Maftah H. Alkathafi* **and Alhammali A. Younis**

Department Mechanical Engineering, Sirte University, Sirte-Libya

Abstract

Coating of zinc was applied on stainless steel wire substrate using twin wire arc spray to change the surface properties of the substrate, such adhesion, wettability, and corrosion and wear resistance. In this work, there are three basic experimental activities. Firstly the coating parameter optimization, followed by wire coating and finally the fiber coats properties characterization. The properties of the coated wires have analyzed through metallographic analysis and bending test is a mechanical test was used in this work to study qualitatively the adhesion of the coated layer. The results showed that the optimal parameters to coat Zn-layer on the stainless steel wires are as following:

Voltage: 22 V
Current: 200 A
Air pressure: 2.4 bar
Stand-off distance: 150 mm
Wire clamping pressure: 1 bar
Gun speed: 18000 mm/min
Nozzle diameter: 2.2 mm
Blasting (pressure/distance): 6 bar/100 mm
Linear wire speed: 785.398 mm/min
Average coating thickness was varied between 100 μm and 220 μm.
The Zn-coating layer started to crack for the bending angles less than 120°C.

Keywords: Thermal spray • Electric arc • Zn coating • Twin wire • Stainless steel

Introduction

Thermal Spraying is a type of surface coating which uses combination of thermal and kinetic energy leads to coating particles flattening and spreading on the substrate surface and creating full cover coating [1]. Based on the energy sources the thermal spraying can be classified into: flame, electric arc and plasma method. These energy sources are used to heat the coating material (in powder, wire or rod form) to a molten or semi molten state. The resulted heated particles are accelerated and propelled toward a prepared surface by either process gases or atomization jets. Upon impact, a bond forms with the surface, with subsequent particles causing thickness buildup and forming a lamellar structure [2]. Surface preparation is the most critical step in a thermal spraying operation. Coating adhesion quality is directly related to the cleanliness and the roughness of the substrate surface. The substrate surface preparation is necessary to ensure successful application of the thermal spray coating. Inspection of the base metal prior to coating is necessary to detect flaws where the structural flaws will produce similar flaws in the coating. Cracks in the substrate cannot be repaired by thermal spraying. Therefore, the first step in the preparation of a substrate for thermal spraying is to remove all surface contaminants such as scale, oil, grease and paint. The heat of spraying cannot remove contaminants, and contamination will inhibit bonding. After cleaning, Abrasive grit blasting is used to produce a surface to which a sprayed coating will adhere. Abrasive grit blasting is the most commonly used surface roughening technique, the surface to be coated is disturbed by the impingement of abrasive particles. Care must be exercised in grit selection. The effects of grit blasting depend on the type and size of abrasive. Sharp, angular particles provide the best results. Spherical or rounded particles should not be used. All abrasives must be clean, dry and free of contaminants. The most commonly used types of abrasive grit are: Aluminum oxide, Silicon carbide, Chilled iron, and Garnet. In the two wire electric arc spray method which indirectly heat the particles using heated gas jets, use a direct current (DC) electric arc between two consumable electrode wires. An electric arc is formed in the gap between the wire tips as the two wires are continuously fed together, as shown in Figure 1. A high velocity air jet located behind the intersection of the wires shears away the molten metal, that continuously forms as the wires are fed into the arc and melted. As the molten metal shears from the wires, it atomizes, or breaks up, the material into finer particles, creating a fine distribution of molten metal droplets. The atomizing air is also used to accelerate the particles toward the substrate surface, where the molten particles impact, deform and solidify to build up a coating. The droplets are already molten when the material is picked up and entrained in the jet. In order to minimize oxidation in the electric arc spray process, the dwell time needs to be shortened by using short standoff distance and high atomizing air flows. Particle size and distribution are functions of the operating parameters used. Particle size increases with current

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***Address for Correspondence:** : Maftah H. Alkathafi, Department Mechanical Engineering, Sirte University, Sirte-Libya, Email: maftahok@ su.edu.ly*

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increases, voltage decreases, air pressure/flow decreases or wire size increases and vice versa. It has been observed that droplet (particle) size range from submicron (fume) to about 200 micrometer, depending on the process parameters the splat is the basic structural building block in thermal spray coatings. “Splat” is the term given to a single impacted droplet/ particle; many overlapping splats solidify and adhere to one another to form a continuous coating layer. The arriving molten droplets are generally spherical and on impact with the substrate surface they spread over and fill the underlying interstices (spaces). The droplets become flattened, disk like structures. Electric arc spray microstructures can be improved by using smaller diameter wires, deposited at lower feed rates (current), using high velocity air caps to reduce dwell time, using inert atomizing gases to reduce oxidation, reducing standoff distance to minimize oxidation and reducing the arc voltage to minimize overheating of the droplets [3]. The successful application of thermal sprayed coatings to engineering usage is greatly dependent on the adhesion between the coating and the substrate. Mechanical interlocking of the substrate surfaces and the coating increases with an increase in density, viscosity and velocity of the impinging droplet and the roughness of the substrate surface. Interlocking decreases with increasing surface tension at the substrate/droplet interface. Interlocking is at a maximum in the central part of the splat and decreases in the direction of its periphery. The formation of a solidified crust on the splat between the “teeth” of the roughness of the substrate surface contributes to the development of better interlocking between the coating and the substrate. The development of adhesion depends critically on the morphology of the substrate surface. In the case of rough surfaces melting and subsequent solidification in the substrate interfacial region are more pronounced and lead to much better substrate coating adhesion than is the case of a smooth surface [4,5].

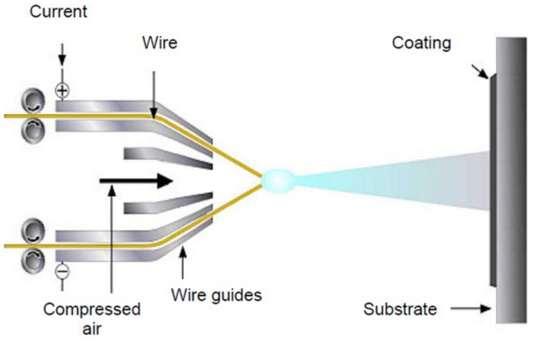


Figure 1. The electric arc wire spray process

Materials and Methods

Equipment

The electric arc spray system employed in this research work is a Sulzer Metco Smart Arc Device (350RU), which is illustrated in Figures 2A and 2B.

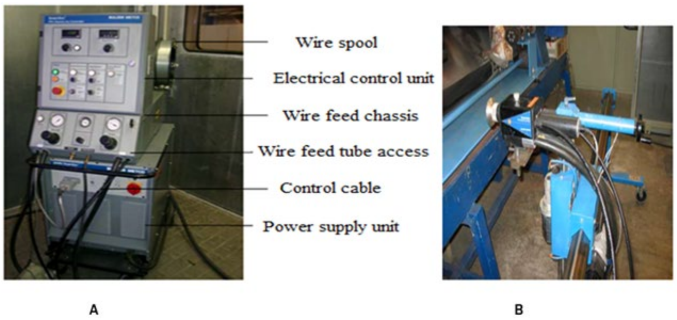


Figure 2. (A) Electric arc thermal spray system (Sulzer Metco Smart arc 350RU) (B) Spray gun (Smart Arc)

Technical data of electric arc spray system

- **Operating voltage:** 3 × 380 V/50 Hz
- **Power output:** 400 A at 38 V DC-current
- **Wire spools (mm):** 200, 300, 400
- **Spray gun type:** Smart Arc
- **Wire diameter (mm):** 1.6-3.2
- **Air cap:** **“**Fine spray “air cap, Blower air cap, High speed air cap.
- **Gun moving mechanism type:** ENGELHARDT for 2-axies, with maximum speed 12000 mm/min

Coating parameters optimization

To optimize the coating parameters, the Austenitic chromium nickel stainless steel 1.4310 (AISI 301) have been used. Table 1 shows the chemical composition, mechanical and physical properties for this kind of steel.

Table 1. Chemical composition, mechanical and physical properties of 1.4310 [5]

Chemical Composition							
Element	C max	Si max	Mn max	Pmax	S max	Ni	Cr
Wt%	0.15	1.00	2.00	0.045	0.030	6.0-8.0	16-18
Mechanical Properties							
Yield Strength (Annealed)				205 MPa			
Tensile Strength (Annealed)				515 MPa			
Elongation (2%)				40 %			
Physical Properties							
Density				8.03 g/cm3			
Young's Modulus				193 GPa			
Specific Heat (0-100°C)				500 j/kg.°K			

Samples preparation and coating

Substrate surface roughening and cleaning: To get a high adhesion between layer and substrate an abrasive blasting associated with an ultrasonic cleaning has been applied. Conventional abrasive blast cleaning is accomplished through the high velocity propulsion of a blast media in a compressed air stream against the substrate. Alumina (Al2O3, grain size 250 – 354 µm) has been used as a blasting material. The blasting process has been carried out at a pressure of 6 bars and stand-off distance of 100 mm. The samples after abrasive blasting have been cleaned in an ultrasonic bath.

Coating set up

After the sample surfaces have been roughened and cleaned, the coating process has been carried out to optimize the parameters. The optimized parameters are used to coat the stainless steel wire (1.4310, Ø 1.2 mm). Voltage, current, atomizing air pressure and distance between pistol and sample (stand-off distance) have been varied to find out the optimized parameters. The density of the coated layers has been used as criteria in the optimization process. Zinc wires with a diameter of 2 mm (GTV mbH, Germany), as a coating material and rectangular stainless steel 1.4310 samples (30 × 20 × 5 mm) have been used to optimize the coating parameters. The following parameters have been remained constant during Zn-coating process:

- **Wire clamping pressure:** 1 bar
- **Gun speed:** 10000 mm/min
- **Nozzle diameter:** 2.2 mm
- **Blasting (pressure/distance):** 6 bar/100 mm

Table 2 presents the experimental set up.

Table 2. Experimental set-up to optimize the parameters with Zn coating

Arc voltage optimization					
Samples number	Y47	Y46	Y48	Y79	Y95
Voltage [V]	18	20	22	24	26
Current [A]	200	200	200	200	200
Air pressure [bar]	2.4	2.4	2.4	2.4	2.4
Stand-off distance [mm]	150	150	150	150	150
Current optimization					
Samples number	Y96	Y97	Y48	Y98	Y99
Voltage [V]	22	22	22	22	22
Current [A]	160	180	200	220	240
Air pressure [bar]	2.4	2.4	2.4	2.4	2.4
Stand-off distance [mm]	150	150	150	150	150
Pressure (blasting gas) optimization					
Samples number	Y100	Y101	Y48	Y102	Y103
Voltage [V]	22	22	22	22	22
Current [A]	200	200	200	200	200
Air pressure [bar]	2.0	2.2	2.4	2.6	2.8
Stand-off distance [mm]	150	150	150	150	150
Stand-off distance optimization					
Samples number	Y104	Y105	Y48	Y106	Y107
Voltage [V]	22	22	22	22	22
Current [A]	200	200	200	200	200
Air pressure [bar]	2.4	2.4	2.4	2.4	2.4
Stand-off distance [mm]	130	140	150	160	170

To enhance the coating adhesion two ways have been used, pre-blasting and preheating of samples. Table 3 represents the coating with optimal parameters obtained by preheated samples at different temperatures.

Table 3. Experimental set-up to optimize the adhesion by preheating the samples

Samples number	**Y69**	**Y70**	**Y71**
Substrate temperature [°C]	435	420	335
Voltage [V]	22	22	22
Current [A]	200	200	200
Air pressure [bar]	2.4	2.4	2.4
Stand-off distance [mm]	150	150	150

Wire coating

The process of stainless steel wires coating is illustrated in the Figure 3. Wire speed is one of the factors which affecting the uniformity of the wire coating. Linear speed of the wire depends on the rotation speed and the diameter of the driving wheel. The linear speed is optimized in this work. The rotating speed of driving wheel is transmitted from rotating speed of motor shaft by applying:

Where:

$$N_2 = \frac{Z_1}{Z_2} \text{ x } N_1$$

N2: Rotation speed of driving wheel shaft (rpm)

N1: Rotation speed of motor shaft (rpm)

Z1: teeth number of fixed pulley=25

Z2: teeth number of rotatable pulley=40

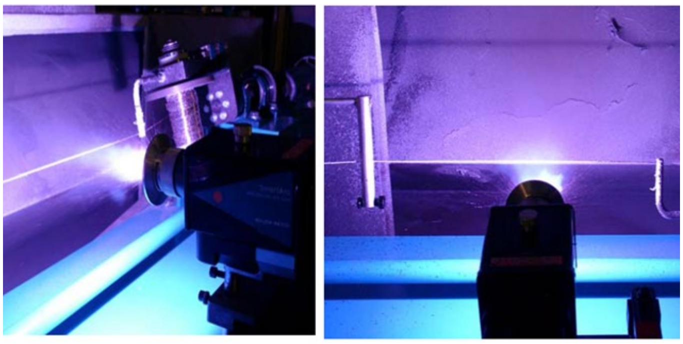


Figure 3. Coating process of stainless steel wires by Zn

The wire linear speed is obtained from: $V=\pi\ x\ D\ xN_2$

Where: V: Linear speed of the wire (mm/min) and D: driving wheel diameter (mm)

The stainless steel wires (1.4310, Ø 1.2 mm) have been coated with the above defined optimal parameter of Zn-coating. To guarantee a homogenous coating the wire speed is needed to optimize. Table 4 presents the experimental set up. The following parameters have been remained constant during Zn coating process:

- Coating material: Zn wires with a diameter of 2 mm
- Base material: Stainless steel wire with a diameter of 1.2 mm
- Blasting Pressure/Distance: 6 bars/100 mm
- Wire clamping pressure: 1 bar
- Support wheel diameter: 50 m

Table 4. Optimization of the parameters of wire Zn-coating

Linear speed of the wire optimization where driving wheel diameter 50mm			
Samples number	LD-9	LD-10	LD-11
Voltage [V]	22	22	22
Current [A]	200	200	200
Air pressure [bar]	2.4	2.4	2.4
Stand-off distance [mm]	150	150	150
Driving wheel diameter [mm]	50	50	50
Rotation speed [rpm]	2.344	2.969	3.438
Wire linear speed [mm/min]	368.195	466.369	540.040
Linear speed of the wire optimization where driving wheel diameter 20mm			
Samples number	LD-13	LD-14	LD-15
Voltage [V]	22	22	22
Current [A]	200	200	200
Air pressure [bar]	2.4	2.4	2.4
Stand-off distance [mm]	150	150	150
Driving wheel diameter [mm]	20	20	20
Rotation speed [rpm]	2.344	3.438	5
Wire linear speed [mm/min]	147.278	216.016	314.159
Linear speed of the wire optimization where driving wheel diameter 20mm the samples were preheated			
Samples number	LD-16	LD-17	LD-18
Temperature [°C]	50	50	50
Voltage [V]	22	22	22
Current [A]	200	200	200
Air pressure [bar]	2.4	2.4	2.4
Stand-off distance [mm]	150	150	150
Driving wheel diameter [mm]	20	20	20
Rotation speed [rpm]	2.344	3.438	5
Wire linear speed [mm/min]	147.278	216.016	314.159
Wire Zn-coating optimization by moving spray gun			
Samples number	LD-19	LD-20	LD-21
Temperature [°C]	-	50	-
Blasting [bar/mm]	6/100	-	6/100
Voltage [V]	22	22	22
Current [A]	200	200	200
Air pressure [bar]	2.4	2.4	2.4

Stand-off distance [mm]	150	150	150
Driving wheel diameter [mm]	50	50	50
Gun speed [mm/min]	18000	18000	-
Rotation speed [rpm]	5	5	5
Wire linear speed [mm/min]	785.398	785.398	785.398

Sample characterization

The adhesion between layer and substrate has been characterized by employing the bending test. Metallographic investigation has been applied by using the light microscope to investigate the coating layer morphology and thickness.

Bending test

Bending test is a mechanical test used to study qualitatively the adhesion of the coated layer. The coated wires have been bending around a given radius. It has been applied on the stainless steel wires coated by electric thermal spray (wires coated with final optimal parameters) to determine the critical bending angle at which the coating layer is cracked. Figure 4 gives the procedure, by which the bending test is applied on the thermal spray coated wires.

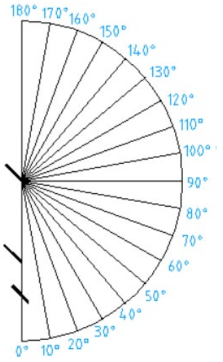


Figure 4. Illustration of the procedure by which the thermal spray coated wires were bended

Metallographic characterization

Mounting: The cold mounting process is used according this study. The cold mount material consists of polymeric resin and hardener. The mounts are typically cured and ready to sectioning, grind and polish within 30 min.

Cutting: Following proper mounting metallographic samples have been cutting. Cutting operation obtained by using abrasive cutting machine (Accutom-5, Struers). The abrasive wheel from silicon carbide is used to perform the cutting. Water was used as a coolant during the cutting process.

Grinding and polishing: After cutting process the samples have been grinding by using grinding/polishing machine RotoPol-22 from Struers. The machine parameters including: grinding/polishing pressure (30 N), relative velocity distribution (300 rpm) and the time (3 min.). Silicon carbide (SiC) abrasive paper was used. An abrasive grinding procedure would consist of 320 grit SiC paper followed by decreasing the size of the SiC paper (600,1200, 2400 and 4000 grit). According grinding process, water was the coolant. After each grinding step, sample has been washed by water and dried by compressed air. Polishing is the most important step in preparing a specimen for microstructural analysis. It is the step which is required to completely eliminate previous damage. Diamond spray from Struers has been used as an abrasive material in the polishing process. Polishing subdivided into rough and fine polishing. One rough polishing step was applied with diamond abrasives 3 micron and low nap cloths. Two fine polishing steps were applied by using higher napped polishing cloths, first with diamond abrasives 3 micron followed by 1 micron. DP-lubricant Blue from Struers was used as a cooling and lubricant throughout polishing process. Between the polishing steps and after the last step of grinding process the sample was cleaned through an ultrasonic.

Metallographic Investigation

Metallographic investigation of coating layer was done by using a light microscope ZEISS (Axiophot, 1987) equipped with digital video camera ZEISS (AxioCam HRC) and software Axiovision 3.1. With this system the coating thickness and porosity can be also measured. The coating morphology and the adhesion between the coating and substrate can be analyzed

Results and Discussion

Results of coating parameters optimization

Metallographic investigations have been carried out to select the optimal coating parameters. The parameter corresponding to the densest layer was selected as the optimal parameters. The Figures 5-9 represents the morphology of the coated samples, in which the arc voltage has been varied. It has been observed that the densest coating was obtained for a medium arc voltage value. Above and below this arc voltage the coating density decreases. This observation is in accordance with the work of L. J. Grant [6]. In this case the densest layer was obtained for a voltage value of 22 V, refer to Figure 7

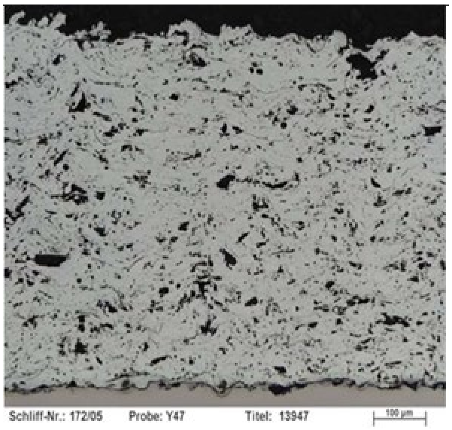


Figure 5. Optical micrograph of sample Y47 (Voltage=18 V)

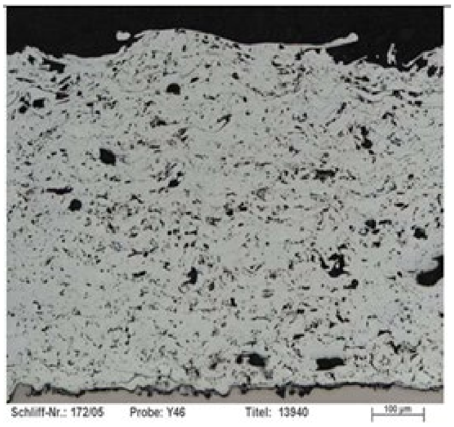


Figure 6. Optical micrograph of sample Y46 (Voltage=20 V)

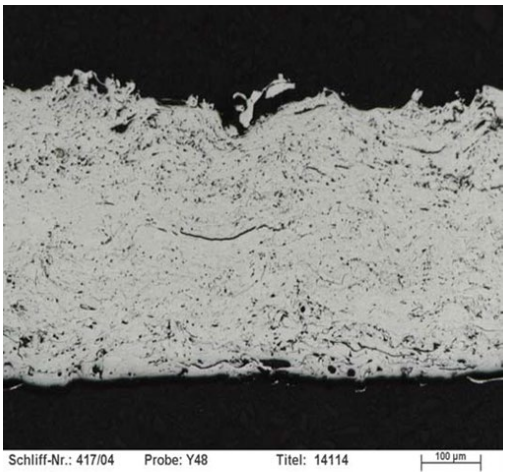


Figure 7. Optical micrograph of sample Y48, Voltage=22 V, Current=200 A Air pressure=2.4 bar, Stand-off distance=150 mm

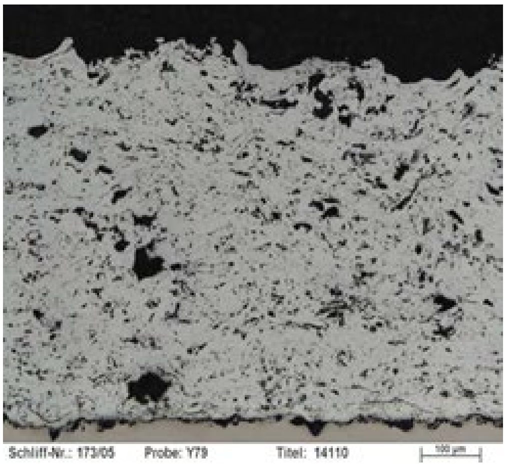


Figure 8. Optical micrograph of sample Y79 (Voltage=24 V)

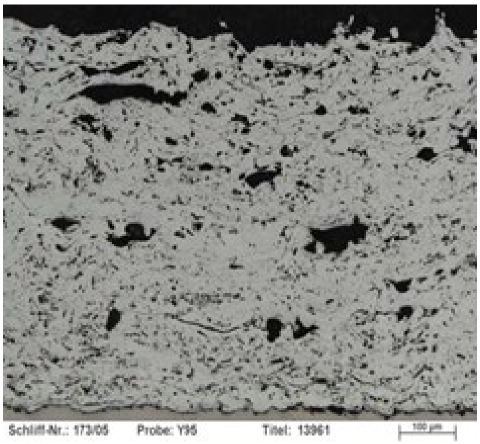


Figure 9. Optical micrograph of sample Y95 (Voltage=26 V)

The current optimization has been done using the optimized arc voltage value. The variation of the coating morphology with current has been presented in th

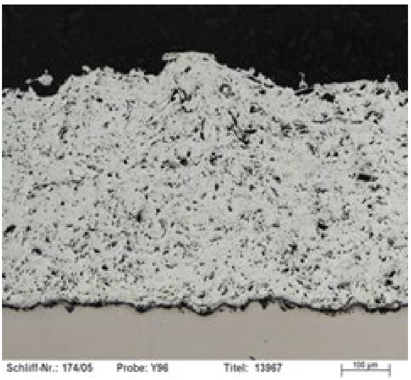


Figure 10. Optical micrograph of sample Y96 (Current=160 A)

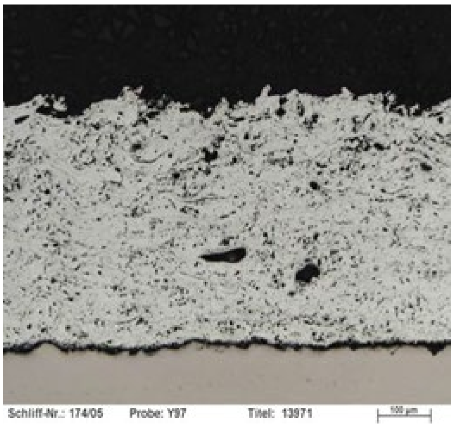


Figure 11. Optical micrograph of sample Y97 (Current=180 A)

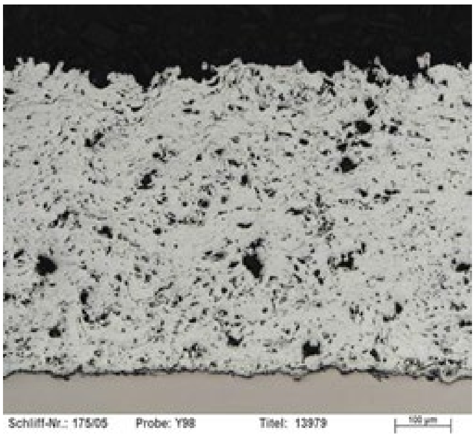


Figure 12. Optical micrograph of sample Y98 (Current=220 A)

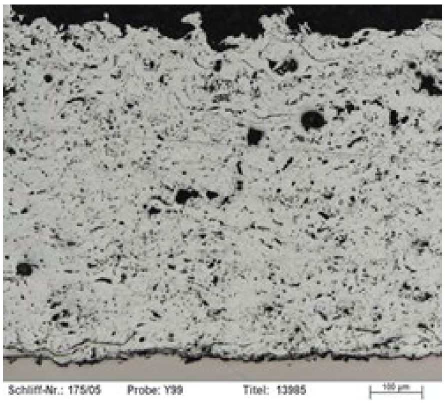


Figure 13. Optical micrograph of sample Y99 (Current=240 A)

It has been observed that the densest coating has obtained for a medium current value. Above and below this current the coating density decreases. The densest layer has been attained for a current value of 200 A, refer to Figure 7. The blasting gas pressure optimization was done using the optimized arc voltage and current values. The variation of the coating morphology related to the pressure is presented in the Figures 14-17

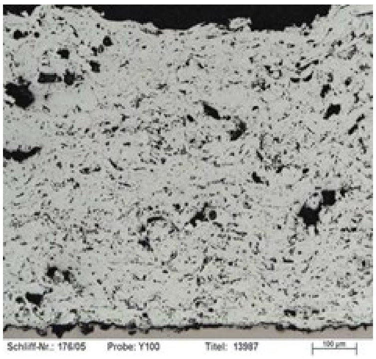


Figure 14. Optical micrograph of sample Y100 (Pressure=2.0 bar)

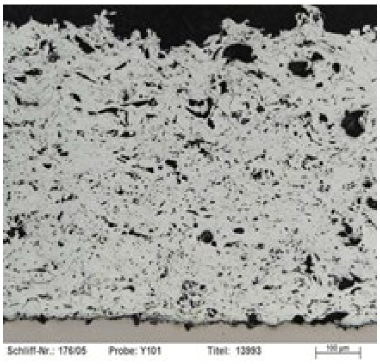


Figure 15. Optical micrograph of sample Y101 (Pressure=2.2 bar)

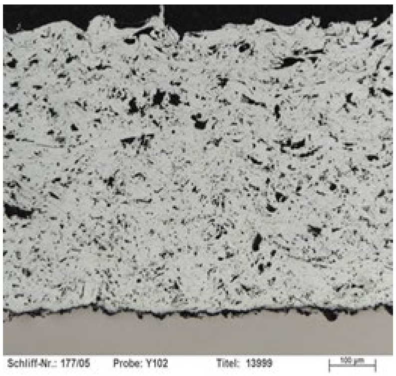


Figure 16. Optical micrograph of sample Y102 (Pressure=2.6 bar)

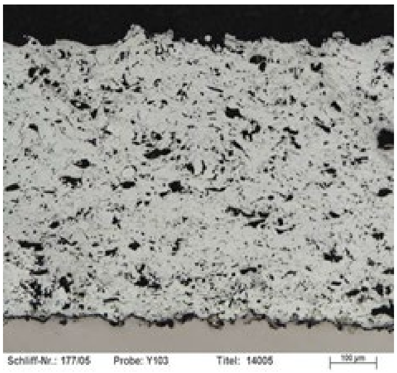


Figure 17. Optical micrograph of sample Y103 (Pressure=2.8 bar)

For a medium pressure value a densest morphology has been obtained. Above and below this blasting gas pressure the coating density decreases. The densest layer has been attained for a blasting gas pressure value of 2.4 bar, refer to Figure 7. To optimize the stand-off distance the optimized arc voltage, current and pressure values have been applied. The variation of the coating morphology with stand-off distance is presented in the Figures 18-21.

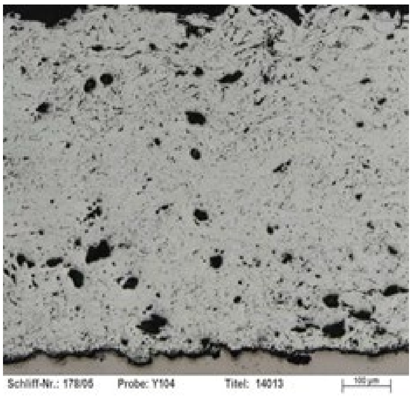


Figure 18. Optical micrograph of sample Y104 (Stand-off distance=130mm)

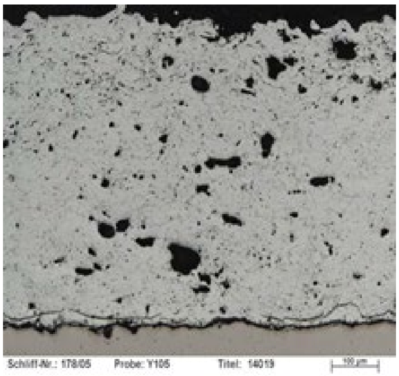


Figure 19. Optical micrograph of sample Y105 (Stand-off distance=140mm)

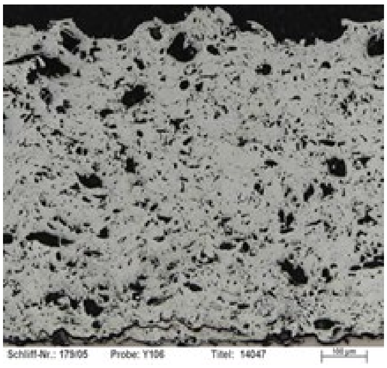


Figure 20. Optical micrograph of sample Y106 (Stand-off distance=160mm)

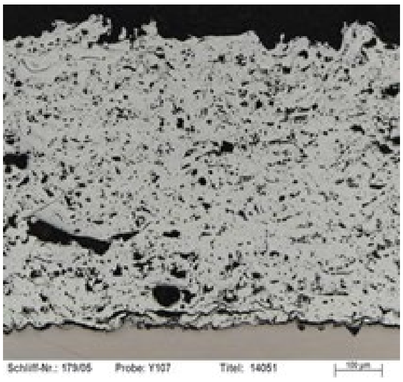


Figure 21. Optical micrograph of sample Y107 (Stand-off distance=170mm)

It was observed that the densest coating has been reached at a medium stand-off distance value. Above and below this stand-off distance the coating density decreases. The densest layer has been obtained for a stand-off distance value of 150 mm, refer to Figure 7. Based on the former experiments the optimal parameters to coat Zn-layer through arc spraying are as following:

- Voltage: 22 V
- Current: 200 A
- Air pressure: 2.4 bar
- Stand-off distance: 150 mm
- Wire clamping pressure: 1 bar
- Gun speed: 18000 mm/min
- Nozzle diameter: 2.2 mm
- Blasting (pressure/distance): 6 bar/100 mm

These optimized parameters were used to deposit Zn on the steel wires

In order to improve the coating adhesion, preheated samples were then coated using optimized parameters. Figures 22-24 represent the coating morphology of these samples at different preheating temperatures

From Figures 22-24, it was found that the preheating substrate leads to increase in the coating density. This is in according to the observation by [7]., which states that preheating substrate surface before coating improves its wettability, slows solidification and promoting penetration into surface cavities

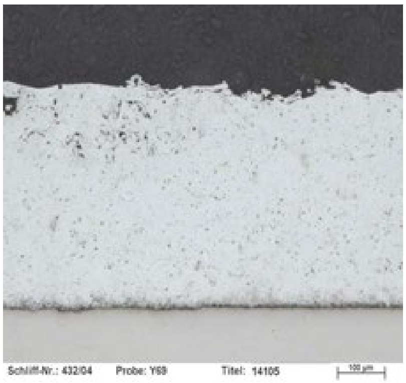


Figure 22. Optical micrograph of sample Y69 (Preheating temperature=435°C)

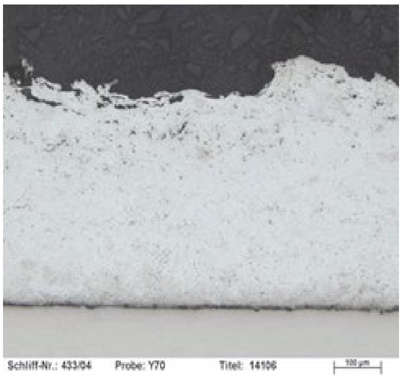


Figure 23. Optical micrograph of sample Y70 (Preheating temperature=420°C)

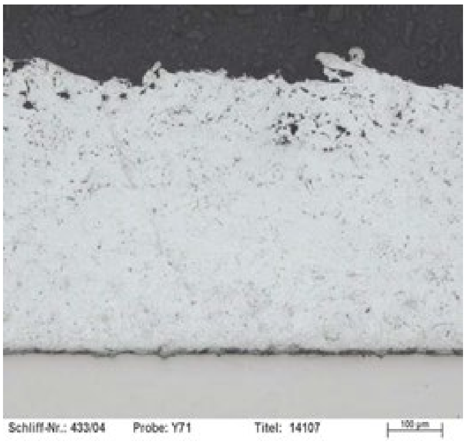


Figure 24. Optical micrograph of sample Y71(Preheating temperature=335°C)

Results of wires coating

Stainless steel (1.4310) wires of diameter 1.2 mm were coated with Zn using the respective optimal parameters obtained in this study. These optimal parameters were kept constant during the coating process and the linear speed of the wire feeding was optimized to get a uniform coating. The linear speed of the wire feeding depends on the rotation speed of driving wheel shaft and the diameter of the driving wheel. The Figures 25-27 represents the variation of the coating uniformity with the linear speed of the wire feeding using a driving wheel diameter 50 mm.

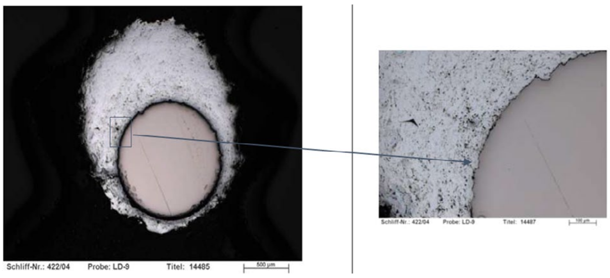


Figure 25. Sample LD-9, Rotation speed: 2.344 rpm, Linear speed: 368.195 mm/min Average thickness: 100 -850 µm

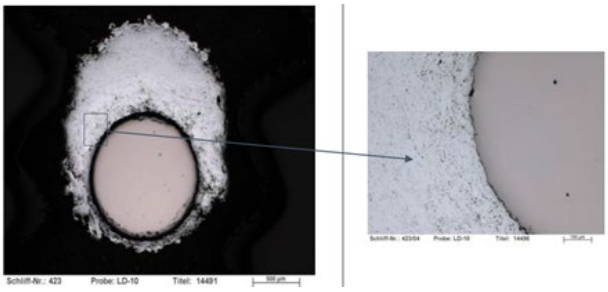


Figure 26. Sample LD-10, Rotation speed: 2.969 rpm, Linear speed: 466.369 mm/min Average thickness: 100 -730 µm.

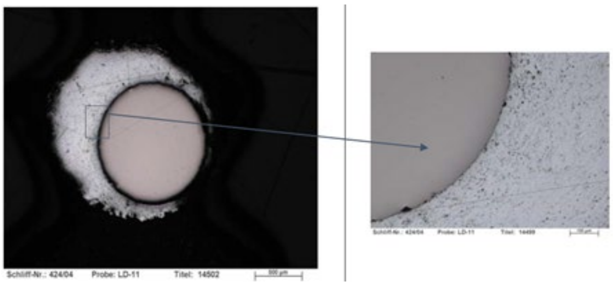


Figure 27. Sample LD-11, Rotation speed: 3.438 rpm, Linear speed: 540.040 mm/min Average thickness: 85 -530 µm

Figure 27 Sample LD-11, Rotation speed: 3.438 rpm, Linear speed: 540.040 mm/min Average thickness: 85 -530 µm From Figures 25-27, it can be observed that the deposited coating was not uniform. Coating thickness decreases with increasing linear speed of the wire. The coating adhesion was good. To enhance the coating uniformity the linear speed was decreased by reducing the driving wheel diameter. The Figures 28-30 represents the variation of the coating uniformity with the linear speed of the wire feeding using a driving wheel diameter of 20 mm

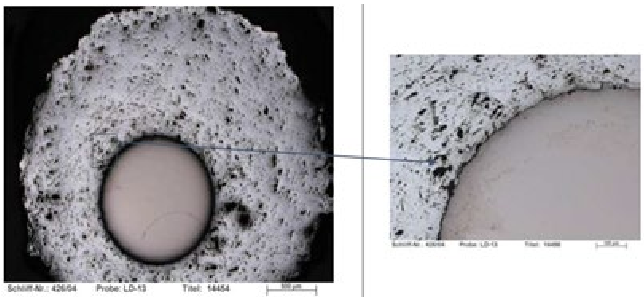


Figure 28. Sample LD-13, Rotation speed: 2.344 rpm, Linear speed: 147.278 mm/min Average thickness: 1050 µm

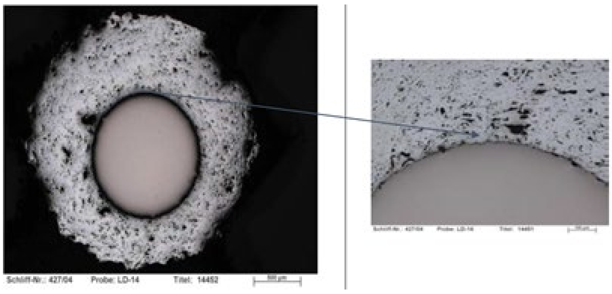


Figure 29. Sample LD-14, Rotation speed: 3.438 rpm, Linear speed: 216.016 mm/min Average thickness: 610 µm

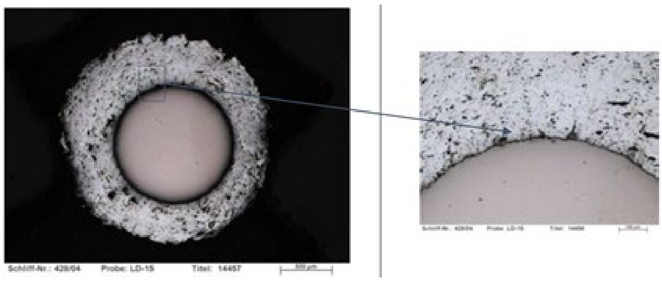


Figure 30. Sample LD-15, Rotation speed: 5 rpm, Linear speed: 314.159 mm/min Average thickness: 440 µm

It can be established that the coating was uniform. The linear speed was responsible for the rotation of the wire in an adequate time in the spray stream. Coating thickness decreases with increasing linear speed of the wire. It can be observed that the coating adhesion was good. To study the influence of the substrate preheating on the adhesion, the wire samples were preheated up to 50°C before coating. Figures 31-33 represent the variation of the coating morphology of the preheated samples with different linear speed.

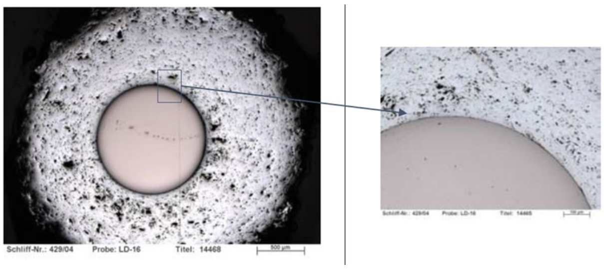


Figure 31. Sample LD-16, Rotation speed: 2.344 rpm, Linear speed: 147.278 mm/min Average thickness: 985 µm

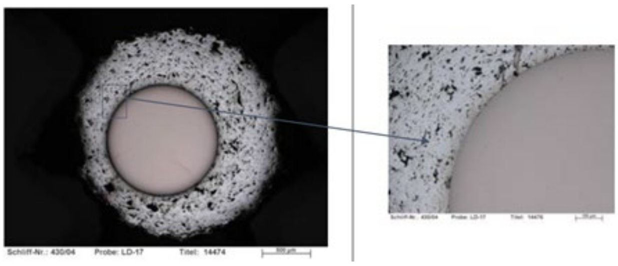


Figure 32. Sample LD-17, Rotation speed: 3.438 rpm, Linear speed: 216.016 mm/min Average thickness: 530 µm

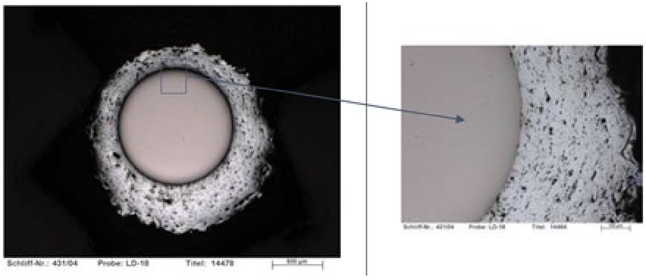


Figure 33. Sample LD-18, Rotation speed: 5 rpm, Linear speed: 314.159 mm/min Average thickness: 320 µm

The preheating substrate surface before coating improves the wettability, slows down solidification and promotes penetration into surface cavities. Figures 31-33 shows that the coating thickness was lower compared to the wires coated without preheating, while the coating adhesion was good. Continuous wire coating with preheating cannot be obtained in this process due to the variable hand heating system. But the system can be made continuous by providing an automated heat source just before the spray gun. In both cases of substrate pretreatments (with blasting and/or with preheating), coating cracked during rolling up of wire. This was due to high thickness of coating (320 µm-1050 µm) and the small diameter of driving wheel (20 mm). To reduce the coating layer thickness, the linear speed of the wire was increased and the driving wheel diameter was changed to 50 mm for the further wire coatings. In next experiment, two samples of the stainless steel wires were coated with Zn. First sample (LD-19) was pre-blasted (6 bar/100 mm) and the second sample (LD-20) was preheated to 50°C. In this experiment the spray gun was moved with constant speed 18000 mm/min. The linear speed of the wire was same for both samples and the driving wheel diameter was 50 mm. Figures 34 and 35 represented the metallographic examination of samples (LD-19) and (LD-20), respectively.

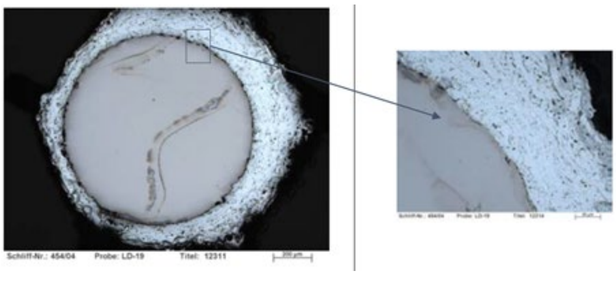


Figure 34. Sample LD-19, Rotation speed: 5 rpm, Linear speed: 785.398 mm/min Average thickness:100-220 µm

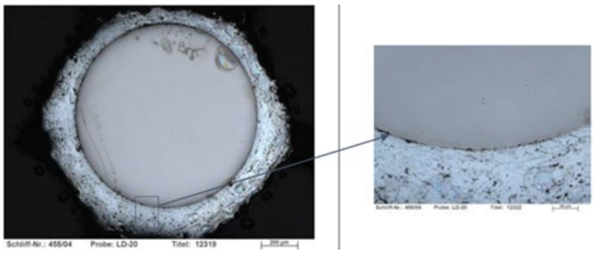


Figure 35. Sample LD-20, Rotation speed: 5 rpm, Linear speed: 785.398 mm/min Average thickness:93-175 µm

The metallographic analysis let to establish that the coating was uniformly deposited around the wire diameter. Sample (LD-19), which was coated after a preblasting, showed a coating layer thickness between 100 µm and 220 µm. The sample (LD-20) coated after a preheating showed a coating layer thickness between 93 µm and 175 µm. In both samples a good adhesion was achieved. The continuous wire coating; sample (LD-21), was made by using the same parameters applied on sample (LD-19) except in this case the spray gun was fixed. Figure 36 (LD-21) represents the variation of the coating uniformity with the linear speed of the wire

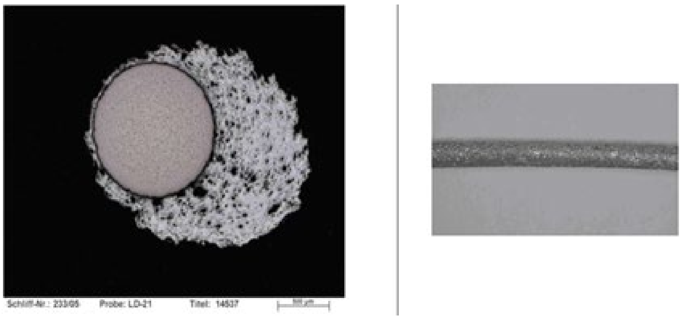


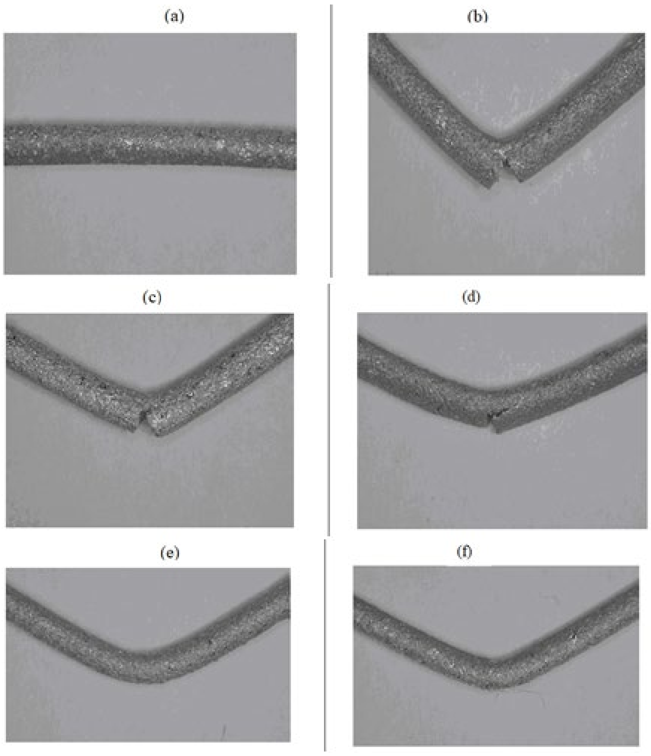
Figure 36. Sample LD-21, Rotation speed: 5 [rpm], Linear speed: 785.398 [mm/min] Average thickness:65 µm-940 µm

It can be observed that the coating was not uniformly deposited. Coating thickness varied between 65 µm and 940 µm

Bending test of coated wires

Bending test was performed to investigate the adhesion of the coated wires made by electric arc thermal spraying. Bending was carried out on the continuous coated wire sample (LD-21) to determine the critical bending angle, in which the layers cracked. Figure 37 represents the result of the bending test of wire zinc coated.

From Figure 37 it can be established that the critical bending angle was 120°. The Zn-coating layer started to crack for the bending angles less than 120°. The coating layer cracked due to its high thickness and non-uniformity. The thickness of the coated layers varied between 65 µm and 940 µm



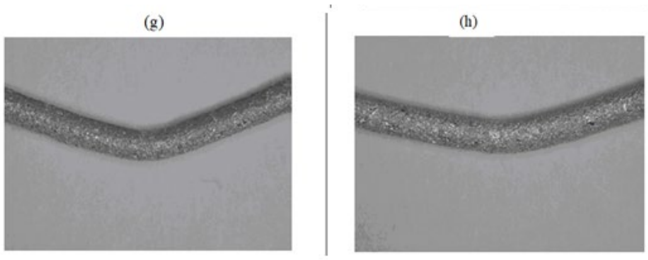


Figure 37. (a) Bending angle: 0°, (b) Bending angle: 90° (c) Bending angle: 100°, (d) Bending angle: 110°, (e) Bending angle: 120°, (f) Bending angle: 130° (g) Bending angle: 140°, (h) Bending angle: 150°.

Conclusion

The coating parameters with which the uniform Zn coating was obtained are:

- **Voltage:** 22 V
- **Current:** 200 A
- **Air pressure:** 2.4 bar
- **Stand-off distance:** 150 mm
- **Wire clamping pressure:** 1 bar
- **Gun speed:** 18000 mm/min
- **Nozzle diameter:** 2.2 mm
- **Blasting (pressure/distance):** 6 bar/100 mm
- **Linear wire speed:** 785.398 mm/min
- Average coating thickness was varied between 100 µm and 220 µm.

The Zn-coating layer started to crack for the bending angles less than 120°.

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