COAXIAL LASER CLADDING OF INTERNAL DIAMETER

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Abstract

The paper summarizes the result of laser cladding experiments design to observe the influence of the mutual angle of the cladding head and treated sample. The system, combining solid state disc laser with power up to 5.3 kW and cladding head with coaxial powder feeding, was used. The clad geometry is evaluated for the different position of the sample and different incident angle of the cladding head. The goal of the work is to determine the maximal incident angle in which the cladded coating is unaffected and based on the result determine the minimal internal diameter which can be cladded with given equipment. Then, the half tubes with small internal diameter are cladded and the geometry of the coating is verified.

Keywords: Laser cladding, clad geometry, incident angle, internal diameter

1. INTRODUCTION

Laser cladding is a modern technology capable of producing quality, metallurgically bonded coatings on a variety of materials. The advantage of this method is minimal dilution, minimal distortion and low heat affecting of the substrate. There are many possibilities for applicability of this method: producing protective wear, resistant coatings, repair of worn out parts by adding the material or producing new structures for rapid prototyping [1].

Basically, there are three possible methods of clad material delivery. The first is using the pre-placed material on the substrate. This is usually a time-consuming process, it has small processing window and it can be applied to limited shapes of substrate [1, 2, 3]. Secondly, the clad material can be delivered in the form of a wire, the advantage is a lower cost of a wire than metal powders, but the drawback is lower surface quality, low bonding strength, etc. [1]. Finally, laser cladding by powder injection is promising method and it is the subject of this study.

In this method, the powder is delivered by the carrier gas and it is blown under the laser beam while it scans the processed surface generating a melt pool and thus creating the single clad bead. A complete dense coating is produced by overlapping the single clad tracks. The powder injection can be either off-axis, but it leads to more complicated cladding condition depending on the direction of processing and higher powder consumption [1, 2, 3]. Or more efficient way is coaxial powder injection by ring nozzle or multiple discrete nozzles.

Laser power suitable for cladding technology is usually in the range from hundreds of watts to several kilowatts. The suitable lasers for claddings are high power diode lasers [3], solid state lasers [2, 4, 6] or CO_2 lasers [5]. The continuous wave or pulse mode [4] can be used. There are many parameters which have an influence on laser cladding process. The main parameters are laser power and laser beam characteristic, powder feed rate and process speed. Usually, the first step in understanding the laser cladding process and influence of individual parameters is to produce single clad tracks and observe its geometry and mechanical properties [2, 3, 4, 6, 7]. In the process of creating the compact coating, the overlapping ratio (*OR*) plays the important role. The influence of process parameters on single clad bead geometry and the influence of overlapping ratio have been reported in previous work [8, 9].

Now the influence of the angle between cladding head and the sample on the single clad bead and coating geometry is tested. This is important to know in the case of cladding complex parts with hardly accessible areas, or in cladding the small internal diameter.

2. EXPERIMENTAL PROCEDURE

The system for laser cladding consists of solid state disc laser Trumpf TruDisk 8002, which emits at wavelength 1030 nm and its maximal available power is 5300 W. The laser radiation is coupled via 600 µm optical fiber to Precitec coaxial 4-way cladding head YC52. The cladding head is equipped with a motorized collimator which allows changing of laser spot diameter in the range from 1.26 to 3.37 mm. The cladding head is mounted on industrial robot Fanuc M-710iC. Used powder feeder is the GTV PF 2/2 MH, the argon was used as a driving gas and also as a shielding gas. The laser cladding system is in **Figure 1**.

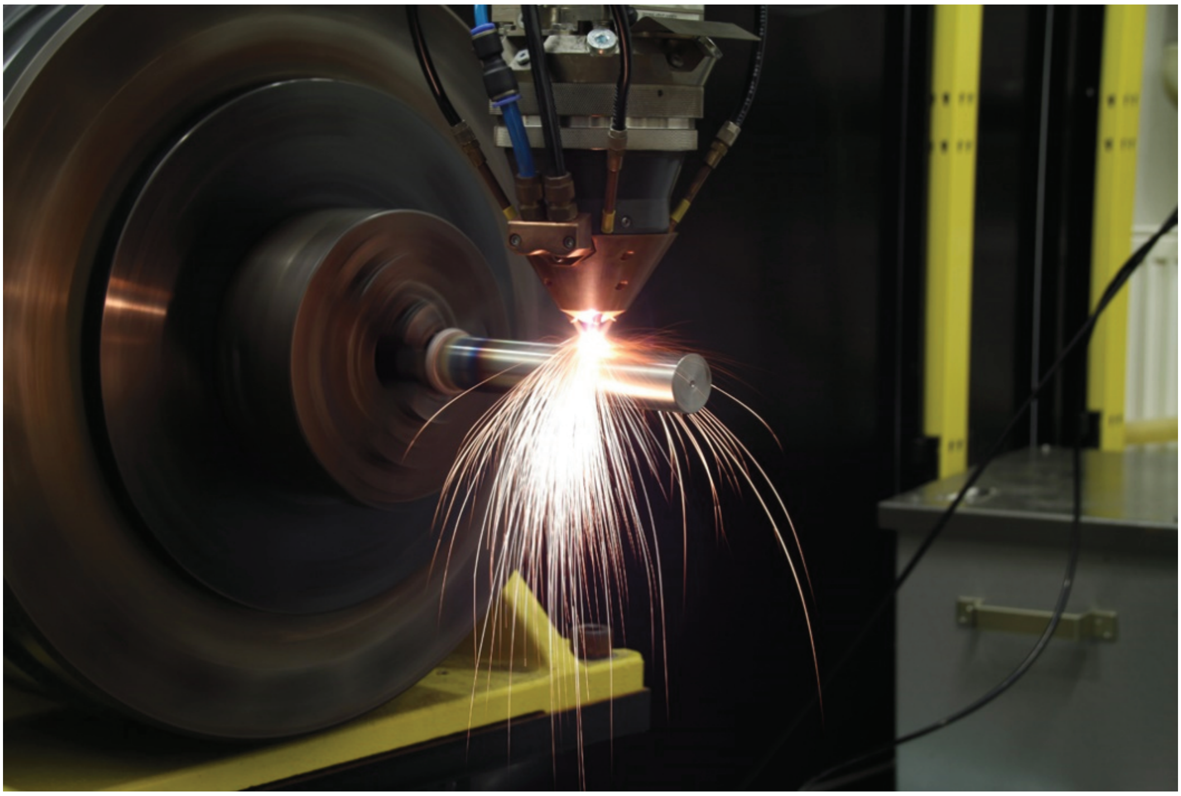

Figure 1 The cladding system

The powder used for experiments was stainless steel 316L (MectoClad 316-Si). The substrate was steel C45 (EN), the dimensions of the samples were 200 x 100 x 10 mm to ensure sufficient heat dissipation during cladding process. The process parameters were kept constant: laser power P = 2000 W; process speed 50 cm/min; powder feed rate F = 16 g/min. The cladding was performed for three position of the sample: A) horizontal, B) vertical, C) at the angle 45 ° (**Figure 2**). The change of incident angle α between the substrate and the cladding head was tested. The range of the angle α for the three positions is summarized in **Table 1**. In the first step, the individual beads were cladded and their geometry was evaluated. Then, the suitable cladding angle was narrowed for the following experiments. Next, in the same set-up, the five beads with overlapping ratio OR 50 % were cladded to verify the influence of the incident angle during the creation of complete coating. Finally, the inner surface of half tubes with different internal diameter was cladded. It basically combines the cladding in all three previously mentioned positions and the incident angle is fluently changing.

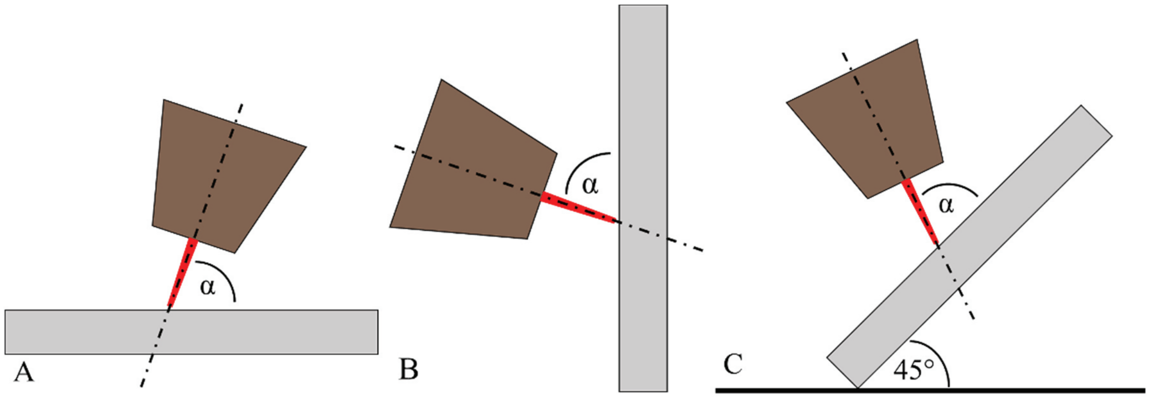

Figure 2 Three different position during the cladding: A) horizontal, B) vertical, C) at the angle 45 °

The clad geometry was evaluated on the cross sections by optical microscope Nikon Epiphot 200 and by digital optical 3D microscope Hirox KH7700. The geometrical characteristics of cladded coating were evaluated (clad width *w*, clad height *h*, molten depth *b*).

Table 1 The range of the incident angle α during tests

	First test: single clad beads	Second test: overlapping
A) horizontal	90 ° - 50 °	90 ° - 60 °
B) Vertical	90 ° - 50 °	90 ° - 60 °
C) At the angle 45 °	50 ° - 110 °	70 ° - 110 °

3. RESULTS AND DISCUSSION

The influence of the incident angle on the geometry of the single clad bead is best presented on the cross section. The cross sections are presented in **Figure 3** for the sample in a horizontal position, in **Figure 4** for a sample in a vertical position and in **Figure 5** for the inclined sample. The clad bead on the horizontal sample at α = 90 ° is taken as a paradigm and the rest is compared with it.

The sample in a horizontal position: the geometry of the clad beads for the angles 80 ° and 70 ° do not significantly differ from the one at α = 90 °. For the angle α = 60 °, the part of the clad is shifted from the main interaction zone and does not create a metallurgical bond with the substrate material. The shift of the material is even more significant for the angle α = 50 °. The part of the clad bead which do not create metallurgical bonding with the substrate material can cause problems later during cladding of complete coating. The shifting of the material is caused by the flow of the carrier and protection gas.

The sample in vertical position: The clad bead for α = 80 ° is not significantly shifted compared to the one for the same angle in a horizontal position. The influence of the gravity is small compared to the influence of the flow of the carrier and protect gas. Again, the clad beads for angles α = 80 ° and α = 70 ° do not differ significantly, the clad bead for angles α = 60 ° and α = 50 °are already shifted.

The inclined sample at 45 °: The clad beads for the incident angle α = 70 - 110 ° are not significantly altered. For the angle α = 50 ° and 60 ° there is a significant drop in the clad bead volume (the drop in cladding efficiency), rather than shifting from the interaction zone.

Based on the geometry of single clad bead, the incident angle α = 50 ° was assessed as not suitable for cladding of complete coating.

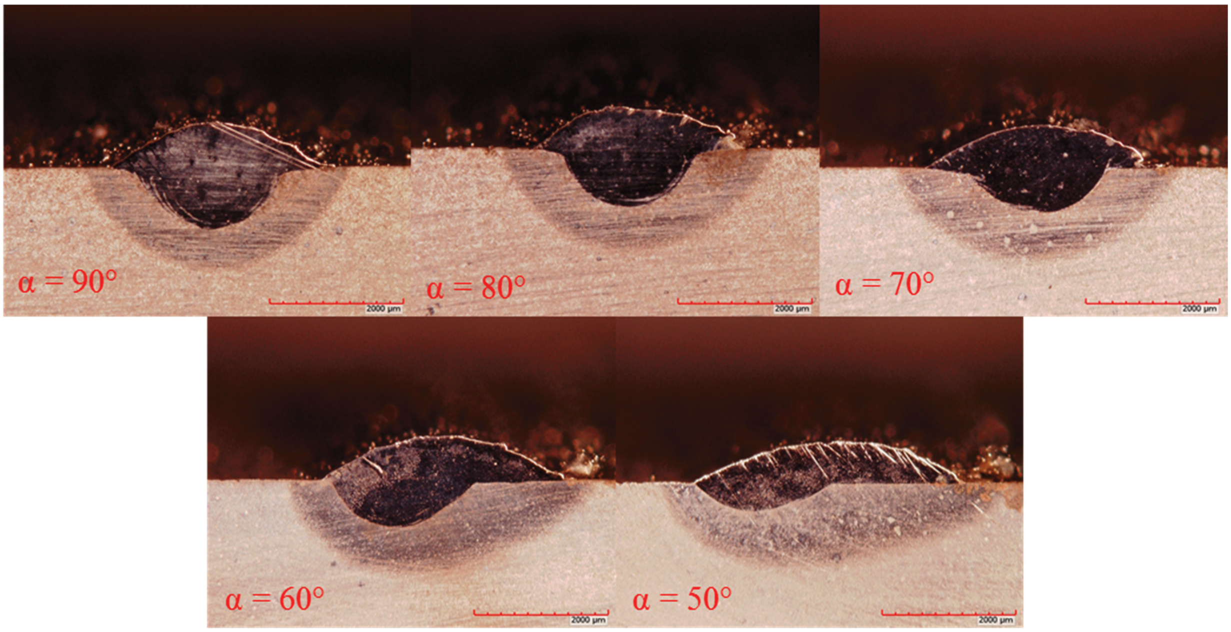

Figure 3 The single clad bead geometry for the sample in horizontal position

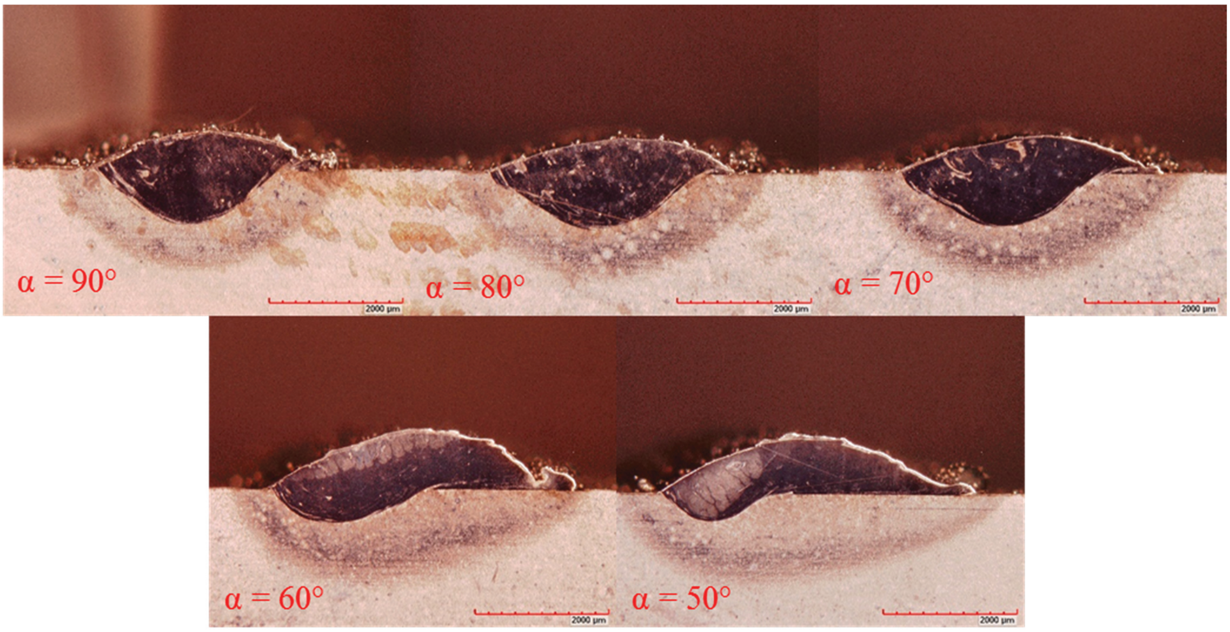

Figure 4 The single clad bead geometry for the sample in vertical position

Overlapping of the clad beads: In this case, the results for all three positions of the sample are quite similar. The cross sections of clads for different incident angle α for the sample in the vertical position are presented in **Figure 6**. For all sample positions and incident angles, there was not discovered any pores or another fault in bonding with the substrate material.

The cladded coating on internal surface of a half tube with diameter 70 mm is presented. In **Figure 7**. It is the smallest diameter accessible with cladding head YC52 with maximal incident angle 50 °. No imperfections were discovered in the cladded coating.

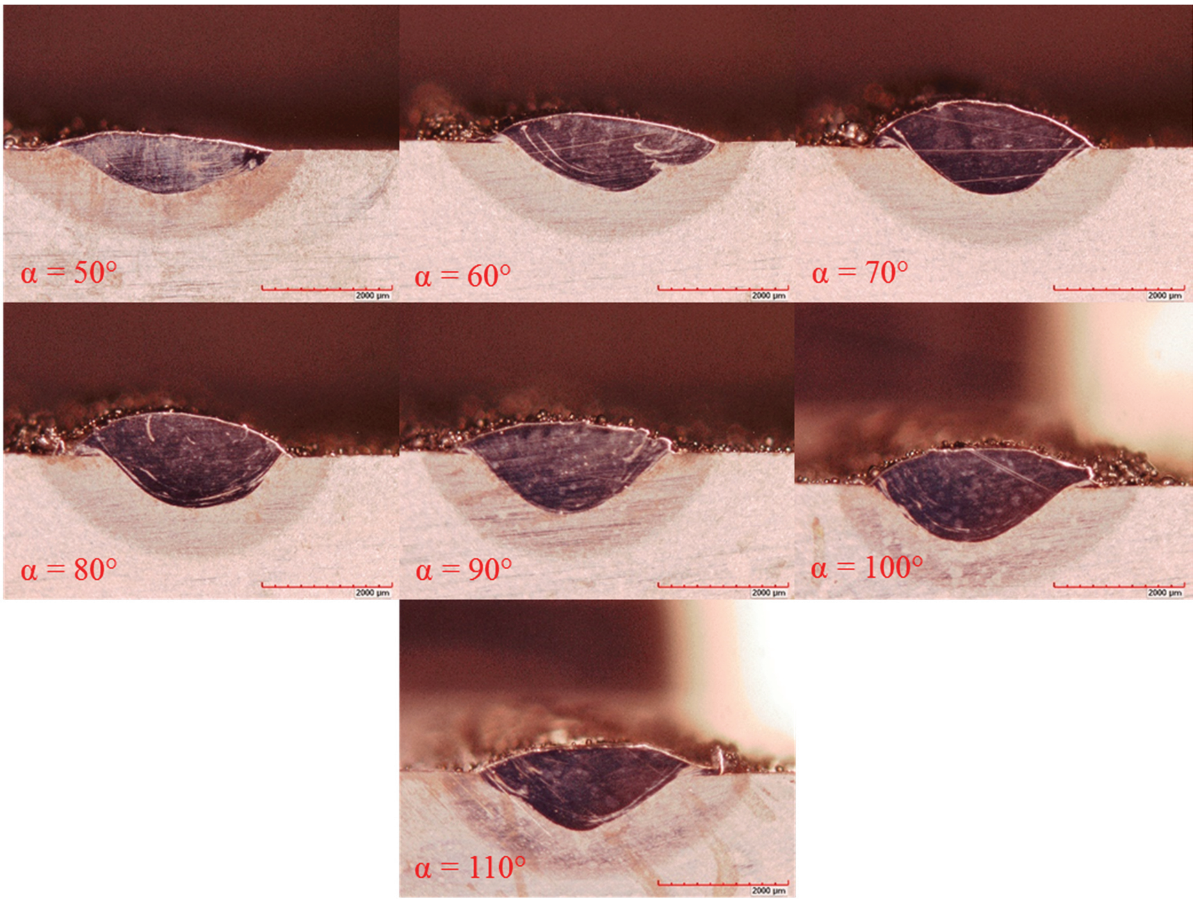

Figure 5 The single clad bead geometry for the sample at the angle 45 °

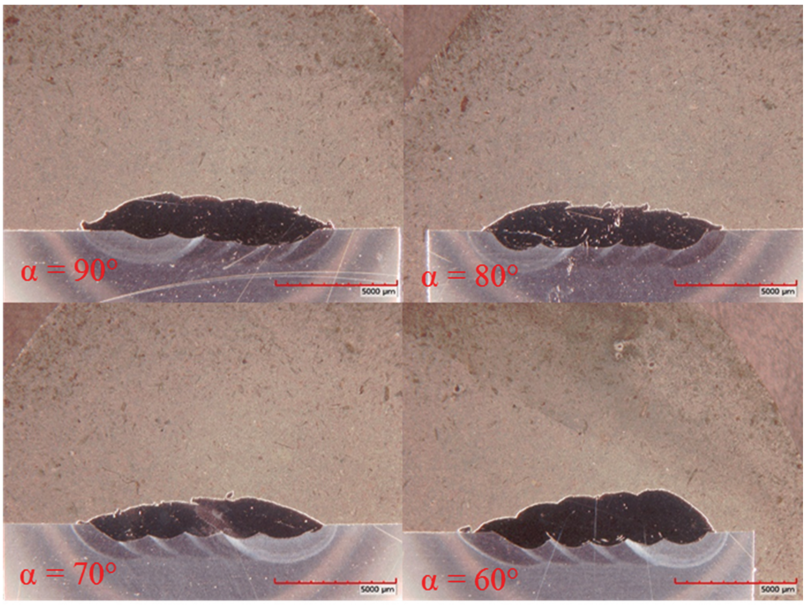

Figure 6 The cross sections of cladded coatings at different incident angle for the sample in horizontal position

Figure 7 The cross section of claded coating on inner surface of a half tube with internal diameter 70 mm

4. CONCLUSION

The influence of the change of incident angle and sample position on laser clad geometry was presented. It was discovered, that the change of sample position does not play an important role. The change of the incident angle by 20 ° does not significantly affect the clad geometry. The greater change in incident angle causes shifting of clad bead and drop of clad efficiency.

The information, which incident angle can be used without affecting the final clad, is important for cladding the shape-complicated parts. The cladding with different incident angle was verified by successful cladding of inner surface of a half tube with internal diameter 70 mm.

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