COAXIAL LASER CLADDING: INFLUENCE OF OVERLAP

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Abstract

The paper summarizes the result of laser cladding experiments design to observe the influence of single track overlap. The system combining solid state disc laser with power up to 5,3 kW and cladding head with coaxial powder feeding was used. Powders used in experiment were stainless steel 316 L and Stellite 6. In previous work the single track geometry was discussed, now the different values of single track overlap were tested. The goal of the work is to determine the influence of overlap to coating properties and choose suitable overlap for further experiment. The geometry and mechanical properties of final coatings is discussed.

Keywords: Laser cladding, stainless steel, Stellite 6, overlap, Clad geometry

1. INTORUCTION

Laser cladding is a modern technology capable of producing quality, metallurgically bonded coatings on 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 pre-placed material on the substrate. This is usually time consuming process, it has small processing window and it can be applied on limited shapes of substrate [1, 2, 3]. Secondly the clad material can be delivered in the form of a wire, the advantage is 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 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 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 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 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 overlapping ratio is defined:

$$OR = (w - D)/w \tag{1}$$

where *w* is the width of single clad bead and *D* is the distance between the centers of neighboring tracks. The *OR* quantifies the fraction of the track that overlaps with its forerunner.

The overlap influences the final thickness of the coating, the dilution and thus the final functional properties of the coating. If the overlap is insufficient, the dilution is too high and excessive mixing of coating material with substrate occurs. This may lead to decreasing of functional properties of the coating such as wear and corrosion resistance [7]. Based on geometrical properties of single clad bead, the final coating thickness and other properties can be estimated for different values of clad overlaps [8]. The influence of process parameters on single clad bead geometry have been reported in previous work [9]. The goal of the work is to continue in research and observe the influence of overlap to geometry and mechanical properties of final coating.

2. EXPERIMENTAL PROCEDURE

The system for laser cladding consists of solid state disc laser Trumpf TruDisk 8002, which emits on wavelength 1030 nm and 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 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 on the **Fig. 1**.

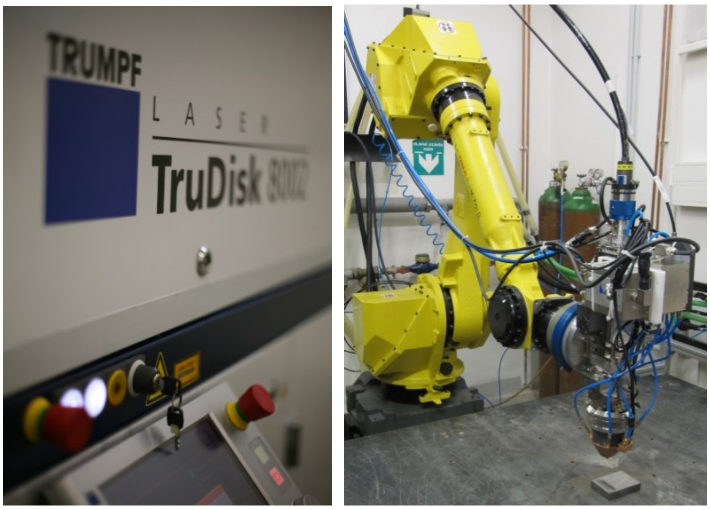

Fig. 1 The cladding system.

The powders used for experiments were stainless steel 316L (MectoClad 316-Si) and stellite 6 (MectoClad 6). 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. For the stainless steel coating, four different combinations of process parameters were chosen and the overlapping ratio from 20 – 50 % was tested for each combination. Next, for stellite powder, two combinations of process parameters were tested: the powder feed rate $f = 12\ g/m$ and laser power $P = 1000\ W$ (process parameters 1); $f = 16\ g/m$ and $P = 2000\ W$ (process parameters 2). The overlapping ratio was 40 and 50 %.

The clad geometry was evaluated on the cross sections by optical microscope Nicon Epiphot 200 and by digital optical 3D microscope Hirox KH7700. The geometrical characteristic of cladded coating were evaluated (clad width *w*, clad height *h*, molten depth *b*). The depth profile of hardness HV1 was measured on the coatings cross-sections using automatic hardness tester CETR - UMT3.

3. RESULTS AND DISCUSSION

3.1. The stainless steel

On the **Fig. 2** you can see cross section of stainless steel coatings created with different overlap ratio for one given combination of process parameters. It is clear that with increasing overlap, the height of clad coating is increasing and the molten depth is decreasing – this means that the dilution is decreasing. For the overlap ratio 20 % and 30 % the height of the coating is not significantly higher than for single pass and the dilution of the clad is still too high. Therefore, for the next experiments, the overlapping ratio higher than 30 % was chosen.

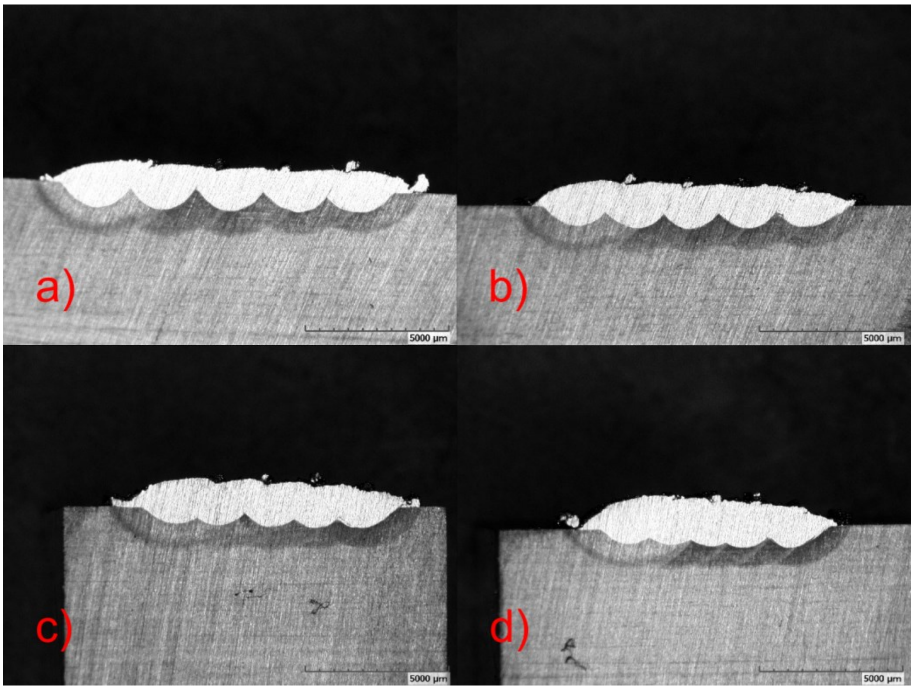

Fig. 2 Stainless steel coatings cladded with different overlapping ratio:
a) 20 % b) 30 % c) 40 % d) 50 %.

3.2. Stellite

The geometrical characteristics of stellite coating for two different sets of process parameters and for two values of overlapping ratio are in the **Table 1**. The **Fig. 3** shows the cross section of stellite coating (for the process parameters 2). It is clear that higher overlapping ratio leads to lover dilution values and higher thickness of the coating. The depth profile of HV1 hardness for stellite coating cladded by parameters 2 and for both overlapping ratio is presented on the **Fig. 4**. You can see the example of hardness measurement on cross section on the **Fig. 5**. The hardness is approximately 500 HV1 and it is nearly constant for whole thickness of the coating up to the boundary with the substrate.

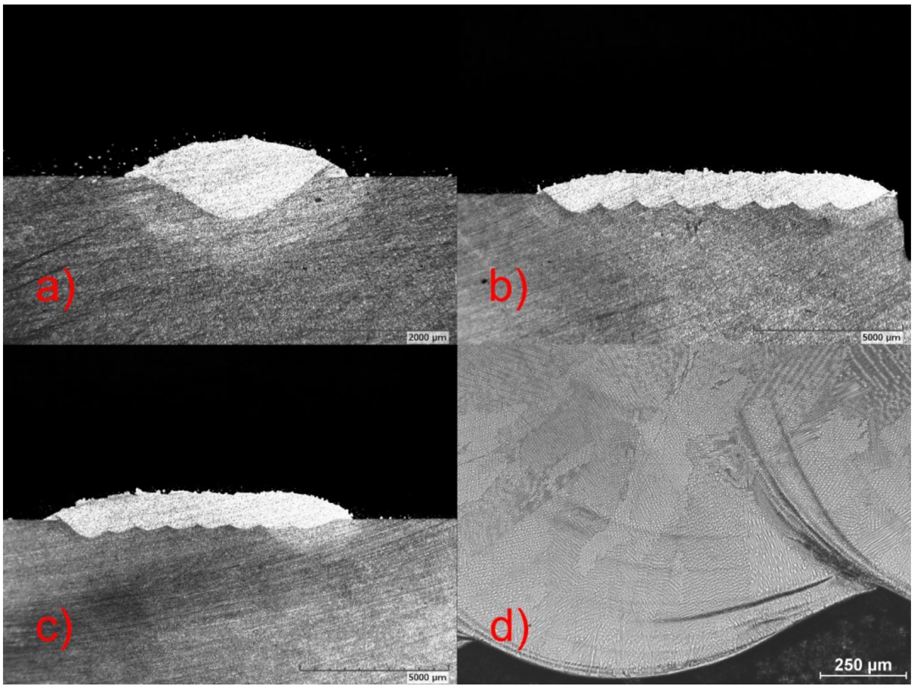

Fig. 3 Stellite 6 coatings cladded by process parameters 2 with different overlapping ratio: a) single clad bead, b) OR = 40 %, c) OR = 50 %, d) detail of OR = 50 %.

Table 1: Dimensions of cladded stellite 6 coatings

Process parameters 1	**Single clad**	**OR = 40 %**	**OR = 50 %**
Clad height [μm]	214	330	419
Molten depth [μm]	370	286	267
Clad width [μm]	1655		
Dilution [%]	63	46	39

Process parameters 2	**Single clad**	**OR = 40 %**	**OR = 50 %**
Clad height [μm]	520	905	1010
Molten depth [μm]	648	400	219
Clad width [μm]	2500		
Dilution [%]	55	31	18

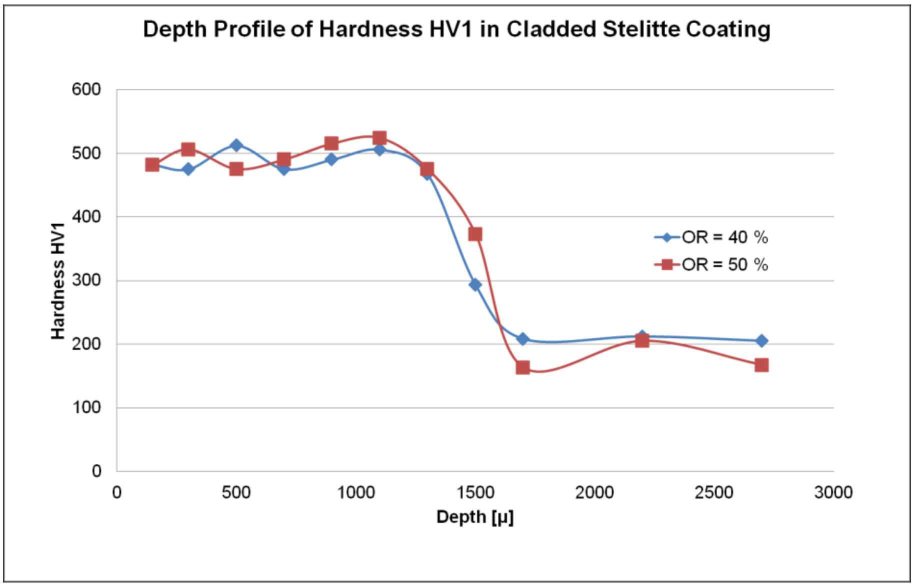

Fig. 4 Depth Profile of Hardness HV1 in stellite coating for different overlapping ratio.

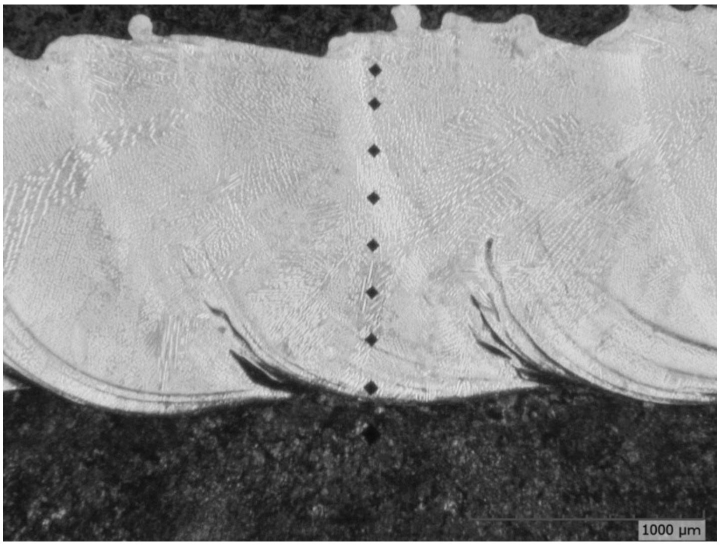

Fig. 5 Hardness measurement on cross section of cladded stellite coating.

CONCLUSUION

The series of laser cladding experiments for observing the influence of overlapping ratio was performed. First experiments with stainless steel powder showed, that lower overlapping ratio – 20 and 30 % is insufficient and leads to high dilution values and low values of the clad height. The OR 40 and 50 % lead to thick coating with acceptable dilution.

Next, the dimensions of stellite coating created with OR 40 and 50 % were presented. It showed that for higher overlapping ratio, the height of the coating is increasing and the dilution is decreasing. The depth profiles of the coating hardness were presented. The hardness for both values of OR reaches the 500 HV1 and it remains nearly constant with increasing depth up to the boundary with substrate material. This showed that there is not excessive mixing with the substrate material and the functional properties of the coating are not degraded.

The experiments showed, that for creating the coating with acceptable thickness and suitable dilution values, it is necessary to choose overlapping ratio at least 40 %. The OR 50 % appears to be more convenient, regarding the dilution values, and it will be used in further work.

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