COAXIAL LASER CLADDING OF STELLITE: ANYLYSIS OF PROCESS PARAMETERS

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Abstract

The paper summarizes the results of first series of laser cladding experiments. New system combining the solid state disc laser with power up to 5.3 kW and cladding head with coaxial powder feeding was used. The powder used in experiments was Stellite 6. The experiment was design to observe the influence of main processing parameters including laser power, processing speed and powder feeding rate on the basics single clad characteristics. The main goal of the work was to discover possibilities and limitation of the new cladding system, verify the expected dependencies between of process parameters and the single clad geometry and to indentify the optimal process parameters for following experiments.

Keywords: Laser cladding, Co alloys, Stellite 6, Clad geometry

1. INTRODUCTION

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]. And so the goal of this work is the analysis of influence of main processing parameters on single pass clad bead.

Stellite 6 alloy is one of the most commonly used protective and wear resistant coatings. The mechanical properties and microstructure of laser clad stellite 6 coating were studied by many researchers [4, 5, 7, 8]. For this reason the stellite 6 powder was chosen for experiments in this study.

2. EXPERIMENTAL PROCEDURE

The system for laser cladding consist 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. The powder feeder used here, 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**.

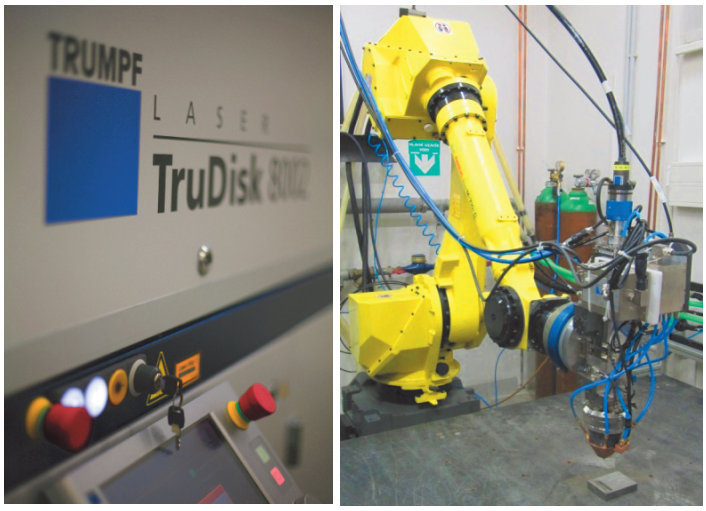

Fig. 1 The cladding system

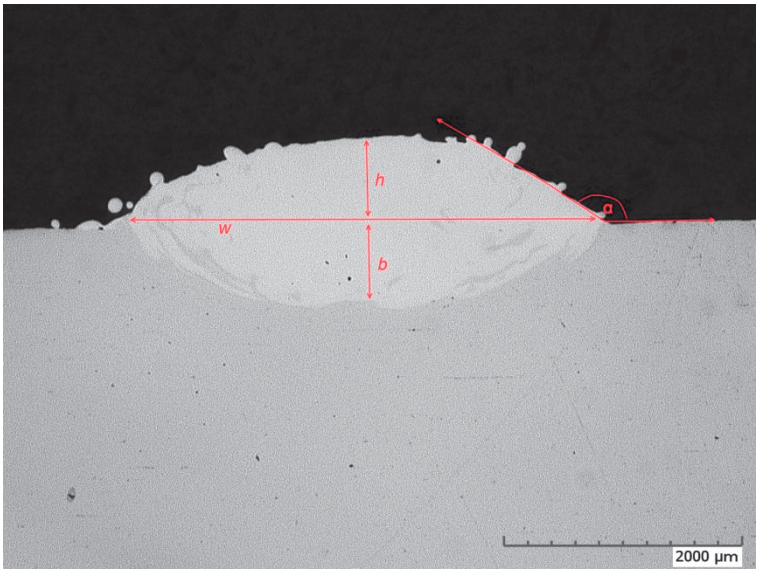

Fig. 2 Typical single clad cross section geometry. Evaluated characteristics clad width *w*, clad height *h*, molten depth *b* and clad angle *α*

The series of experiments was performed. The initial parameters were based on the recommended values from producer of cladding head. Later the experimental matrix was designed to test the influence of main process parameters. The tested parameters were: laser power *P* in the range 1000-3500 W; spot size dimension (the final power density level were 160, 193, 289 and 338 W.mm^{-2}); the process speed *S*

(40-60 cm/min); the powder feed rate *F* (7-25 g/min). Rest of the process parameters, including stand-off distance, flow rate of driver and shielding gas, was kept on constant values.

The samples for laser cladding experiments were made from steel ČSN 12050, the surface of the samples was polished. The dimensions of the samples were 200 x 100 x 10 mm to ensure sufficient heat dissipation during cladding process. The powder chosen for experiments was Zander PTA Kobastell 6 with particle size 53-150 μm.

The clad geometry was evaluated on the cross sections (grinded and polished using automatic Leco grinding and polishing equipment) by optical microscope Nicon Epiphot 200 and by digital optical 3D microscope Hirox KH7700 using magnification 50x and 100x. Typical single clad geometry together with basic evaluated parameters is shown of **Fig. 2**. The evaluated characteristic were clad width *w*, clad height *h*, molten depth *b* and clad angle *α*. Another important characteristic of laser clad is the dilution *D*, calculated using formula: $D = b/(h+b)$ [1].

3. RESULTS AND DISCUSSION

The **Fig. 3** shows the single track beads clad by given laser power *P* with different combination of *S* and *F*. Surface of the clad beads is very good, especially for *P* = 1000 W and 2000 W. For higher laser power and higher powder feed rate, small part of un-melted powder particles remains on surface. This may show, that the powder feed rate is too high for given power (see **Fig. 4**). Usually, the clad surface undergo some form of after treatment and so the low present of un-melted particles on the surface is not defect as long as the clad layer is well melted and there is no pores in its structure.

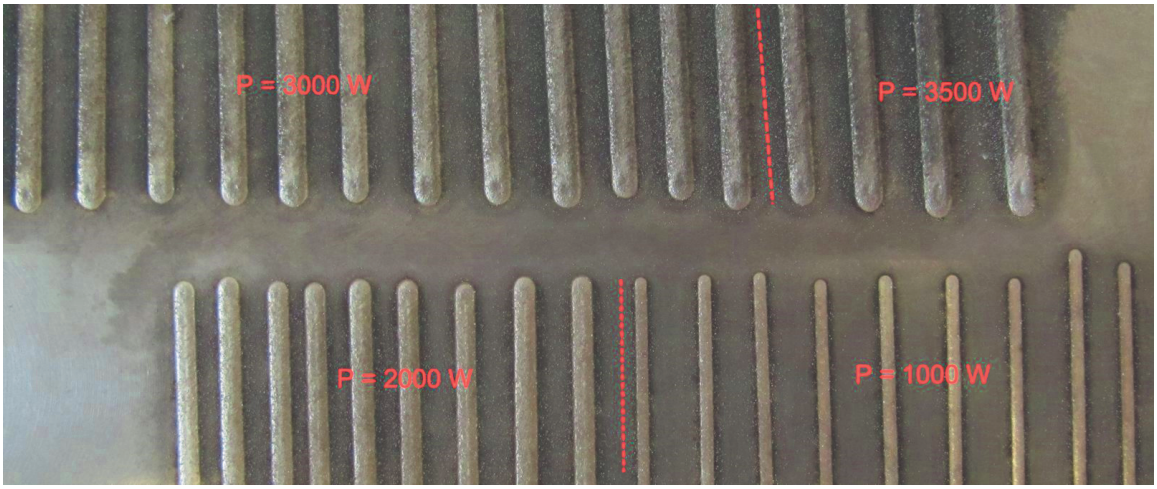

Fig. 3 Single tracks clad by given *P* and different combination of *S* and *F*

Regarding the clad dimensions, from the first view (**Fig. 3**) it is clearly visible that width of laser clad grows with laser power. The clad characteristics are not usually dependant on only one process parameters but on their combination. For example: a strong dependence of clad height *h* on ratio *F/S (*the amount of powder per unit length) can be found (**Fig. 5**). The dependence is linear with relatively high correlation coefficient (except for constant laser power P = 2000 W). It can be seen from the graph, that the increase of clad height in dependence on *F/S* ratio is more pronounced for higher laser power.

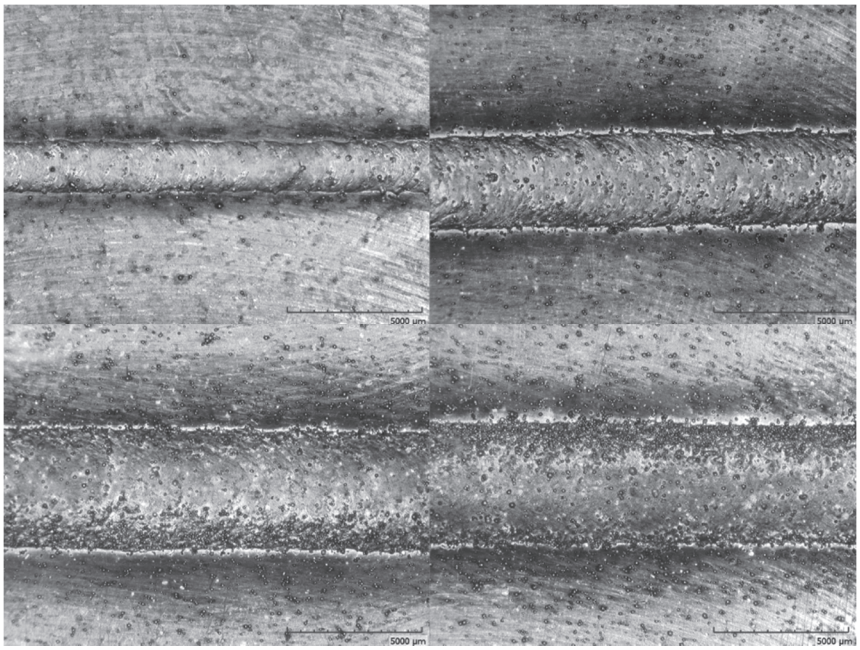

Fig. 4 Detail of the clad surface. a) P = 1000 W (top left), b) P = 2000W (top right), c) P = 3000 W (down left), D) P = 3500 W (down right)

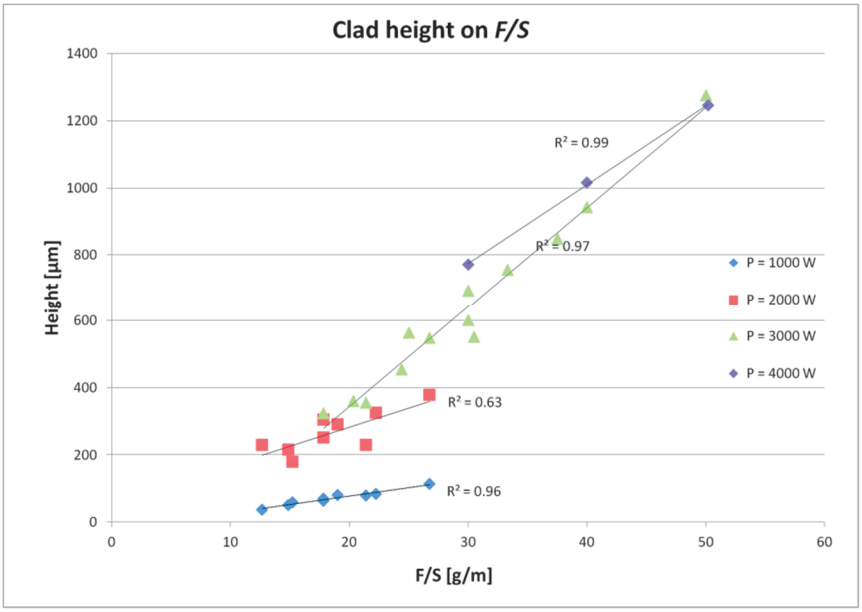

Fig. 5 Dependence of clad height *h* on combined parameter *F/S* for constant laser power

The dilution of clad beads depends on combination of all main process parameters $(P.S/F)^{1/2}$ (**Fig. 6**). Again the correlation coefficient for constant power P = 2000 W is not as high as for other values of laser power. The dilution is lower for higher *P*. According to literature the ideal dilution is approximately in range from 5 to 45 % [2, 6]. The higher values of dilution may lead to excessive mixing of clad material with substrate. It can result to lower hardness of clad layer. The hardness measurement of produced clad beads will be subject of future research. The clad angle should not be too small (less than 100°); otherwise it can lead to producing pores during track overlapping. In our case, the clad angle was in range from 103 to 173°.

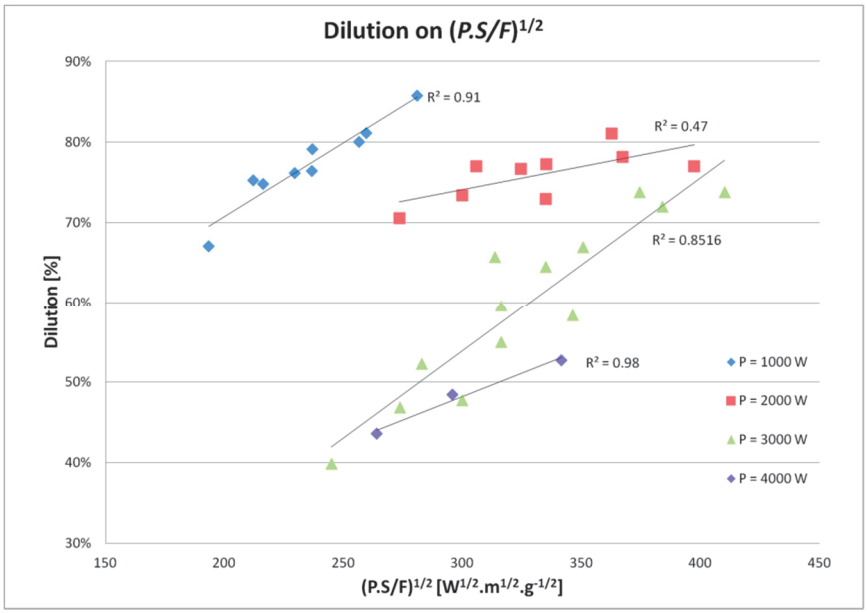

Fig. 6 Dependence of clad dilution on combined parameter $(P.S/F)^{1/2}$ for constant laser power

CONCLUSION

The first experiments with new cladding system were performed. The material chosen for cladding was Stellite 6. The single tracks beads were clad using different combination of main process parameters including laser power *P*, process speed *S* and powder feed rate *F*. The goal of the work was to discover possibilities of laser cladding and influence of individual parameters on clad geometry. The characteristics of individual clad beads including clad height *h*, clad width *w*, melting depth *b*, clad angle α and dilution *D*, were evaluated on cross sections.

The good surface quality of clad beads was achieved. Usually the clad characteristics show dependence on combined process parameters. The clad height exhibits strong dependence with high correlation coefficient on ratio *F/S* (the amount of powder per unit length). The dilution depends on combined parameter $(P.S/F)^{1/2}$. These findings are with agreement with conclusions of other researchers [2, 6]. The dilution of the produced clad beads is higher, which can influence the final characteristics of clad layer. The goal of future work will be producing clads with lower dilution and simultaneously the influence of dilution on clad hardness will be inspected.

The new cladding system was successfully tested and the influence of process parameters was verified. The findings will be used in further work in producing complete clad layers and 3D shapes.

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