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THE EVALUATION OF THE PROCESS OF SURFACE REGENERATION AFTER LASER CLADDING AND FACE MILLING

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Abstract: *This elaboration presents the results of experiments concerning milling of surfaces exposed to laser cladding. The aim of this elaboration has been to conduct the quality evaluation concerning the process of regenerating a flat surface of sheet metal made of steel C 45 through laser cladding and face milling. The assessment of the results of the regeneration process has been conducted on the basis of selected parameters of the geometric structure of the regenerated surface and the identification of surface defects.*

Keywords: regeneration of surface, laser cladding, face milling, geometric structure of surface.

1. Introduction

The connection of laser cladding with machining may be used to regenerate the surfaces of worn machine and device parts, i.e. the non-contact flat seals, pneumatic valves (Takosoglu et al., 2012, Takosoglu et al. 2014) and parts of gyroscopes (Koruba et al. 2011). Wear of precise parts may cause incorrect functioning of the device e.g. by generating vibration (Miko & Nowakowski, 2012, Błasiak & Kotowski 2009) . Laser cladding is one of the most modern, yet expensive, methods for coating of layers with special properties (Klimpel, 2000). It is about melting the additional material in form of powder or a wire, with energy from laser beam cladding, in a proper gas shield and, at the same time, melting the material of the surface. Mixing and melting together both materials causes formation of a surface layer of the clad surface that is called clad overlay (Klimpel, 2012). Consequently, a high-quality metallurgical connection is formed with the surface (Klimpel, 2000). After cooling, the metal layer should be machined in order to provide the regenerated surface with a particular dimension and form accuracy and required geometric structure of surface (SGP) (Miko & Nowakowski, 2012).

2. Methods

The procedure of quality assessment of the process of laser cladding was divided into several stages related to laser cladding, measurements and evaluation of SGP of the surface after laser cladding, as well as related to machining. The first stage included using a sample of steel C45 (non-alloy quality steel for tempering, easy to machine) for a simulated defect of the material in form of a 20x20 mm pocket with a corner radius of 5 mm and depth of 0.75 mm fig. 1.

Fig. 1. View of material defect

The second stage of research included filling the material defect of the sample through laser cladding by using LASERCELL 1005 manufactured by Trumph (fig. 2) facilitated with a powder conveyor produced by GTV (Sęk & Tofil 2014, Harnicarova et al. 2012). During the process of laser cladding, the powder used was metal powder PMNi of hardness of 57 HRC and granulation of 100–160 µm. In order to replenish the defect of 0.75 depth, 5 layers of clad overlay were applied. After the test, it appeared that such a number of layers is insufficient. Thus, two more layers were applied (fig. 3).

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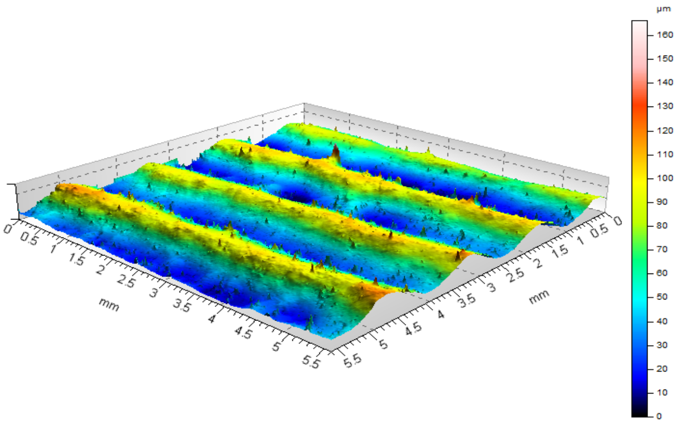
Fig. 2. Head used for cladding and the process of cladding (Wijas & Nowakowski, 2015)

PARAMETERS OF CLADDING:
Feed: 1000, mm/min
Width of the laser beam for deposition: 3 mm
Laser power: 35 % Pmax
Frequency: 20000, Hz
Gas flow Ar: 12, l/min
Rotations of the feeder: 3, 1/min
Gas flow of the feeder He: 3, l/min

Fig. 3. Sample after the cladding

After the process of laser cladding as a part of the third stage of the research, measurements of the surface were made with the profiler Talysurf CCI – Lite Non–contact 3D Profiler manufactured by Taylor Hobson.



Measurement conditions:

- lens x10
- measurement resolution 1.65x1.65 µm
- measured area 5.5x5.5 mm - assembly

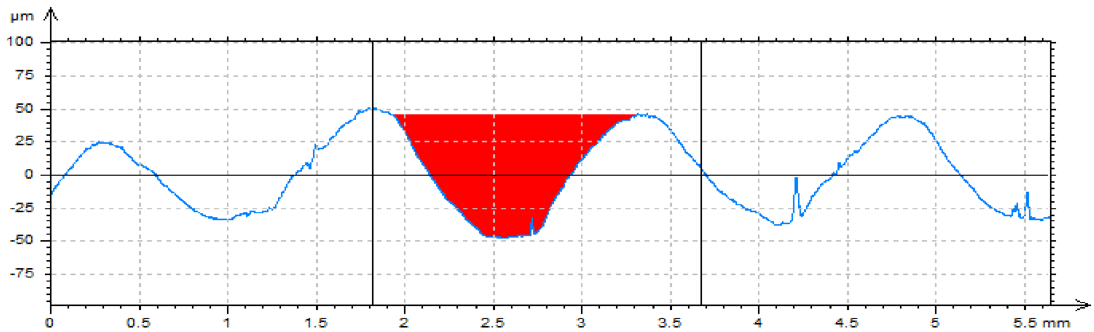
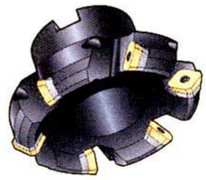


Fig. 4. View of the paded area measured with the profiler Talysurf CCI

When analyzing the results of measurements presented in fig. 4, it has been determined that due to the replenishment of a 0.75 deep simulated defect with laser cladding the acquired surface is characterized with a periodic profile. The measurement of gradient length was of average 1.5 mm, while the average distance from the top to the bottom of the profile - 83.94 µm. The measured space of the hole marked red in fig. 4. was 7398 µm^2. The isometric view of the surface also demonstrated chips of the material that were an unwanted effect of the laser cladding process.

The fourth stage was the process of face milling, with the usage of milling center HERMLE B 300 (table 1), of the clad surface that was conducted in order to achieve a flat surface. The research used the head R245-080Q27-12M produced by Sandvik Coromant that was facilitated with plates of type 245-12T3M-PL4230. The sample was milled with the feed of a cooling and lubricating liquid.

Table 1. View of the machine and the sample after milling with a milling head

General view HERMLE B300	Head R245-080Q27-12M	Parameters of machining	Sample after machining
	 Plate R245-12T3M-PL4230 	v_c, 215 m/min n, 855 rotations/min f_z, 0.1 mm/cutter f_z, 513 mm/cutter a_p, 0.5 mm a_e, 50 mm	

The last fifth stage included measuring the selected parameters of the geometric structure of the clad surface after face milling. Conditions for the measurement remained unchanged.

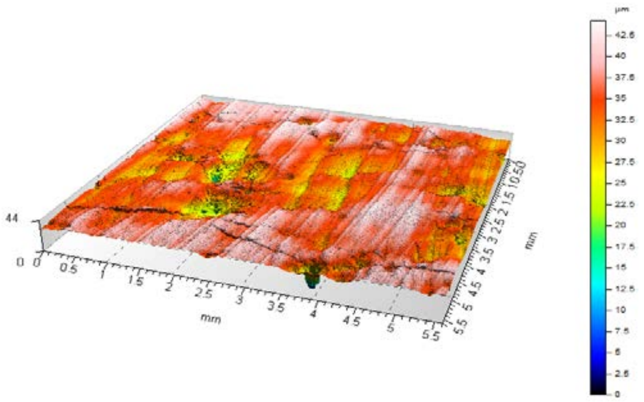


Table 2. 3D parameters of the surface ISO 25178

Sq	9.92	µm
Ssk	-1.02	-
Sku	6.42	-
Sp	9.35	µm
Sv	34.90	µm
Sz	44.26	µm
Sa	3.01	µm

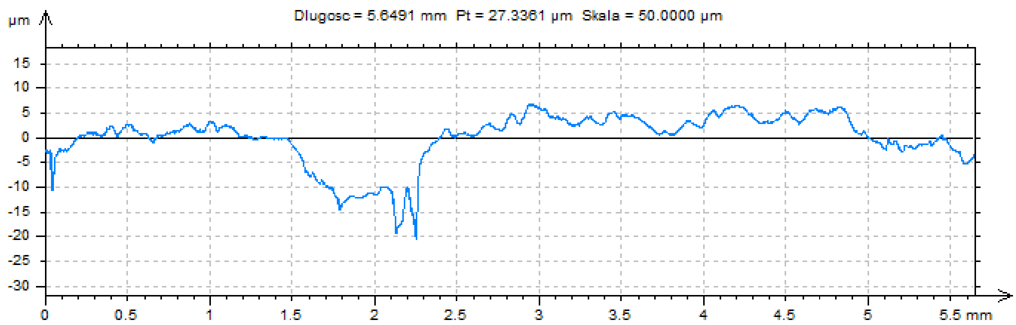


Fig. 5. View of the planned clad area measured with the profiler Talysurf CCI

By analyzing the results presented in table 2 and fig. 5, it has been noticed that after the machining of the clad surface, surface defects such as cracks, gas blisters and porosity were revealed (Graba 2011, 2012). The 2D profile presents the isometric cross-section of the clad surface after face milling in the place, where surface defects occurred in form of a gas blister. The measurement analysis showed that its length is 0.9 mm, while its depth is 21 µm. The surface of 5.5x5.5 mm had 4 gas blisters, three cracks with length of 1÷1.5 mm, and porosity. Table 2 presents the selected parameters of the geometric structure of the surface exposed to laser cladding that has surface defects.

3. Conclusions

Tests with the optical profiler allowed to conduct a quality assessment of the laser cladding process of C45 steel after machining. One of the significant factors that decrease the usage properties of clad surfaces are the hidden surface defects. Gas blisters, porosity and cracks in the clad surface are defects that are difficult to be revealed due to their size, but their presence greatly disqualifies the clad surface since its resistance properties become significantly lower and, consequently, the quality of the surface decreases (Adamczak et al., 2010).The surface defects observed after the measurements made with the profiler Talysurf CCI – Lite Non–contact 3D could result from the fact that the clad overlay was applied in two stages (5 layers, 2 layers). Additionally, so many layers of clad overlay resulted in material shrinkage. The research and scientific aim of the conducted work is to choose such parameters for the process of laser claddding that in the future it will be possible to avoid formation of surface defects.

References

Adamczak, S., Bochnia, J., Kaczmarska, B. (2014) Estimating the uncertainty of tensile strength measurement for a photocured material produced by additive manufacturing. Metrology and Measurement Systems [online]. 2014, roč. 21, č. 3, s. 553–560. ISSN 08608229. Dostupné z: doi:10.2478/mms-2014-0047

Błasiak, M., Kotowski, R. (2009). Propagation of acoustic waves in piezoelectric crystals. Przeglad elektrotechniczny, roč. 85, č. 12, s. 40–43. ISSN 0033-2097.

Graba, M. (2011), The influence of material properties and crack length on the Q-stress value near the crack tip for elastic-plastic materials for single edge notch plate in tension, Archives of Civil and Mechanical Engineering, vol. XI, No. 2, pp. 301-319.

Graba, M. (2012), The influence of material properties and crack length on the Q-stress value near the crack tip for elastic-plastic materials for centrally cracked plate in tension, J. Theor. Appl. Mech., 50, 1, pp. 23-46.

Harnicarova, M., Valicek, J., Zając, J., Hloch, S., Cep, R., Dzubakova, I., Tofil, S., Hlavacek, P., Klich, J., Cepova, L. (2012). Techno-economical comparison of cutting material by laser, plasma and oxygen. Tehnicki Vjesnik-Technical Gazette, 19/ 4, s. 813 – 817.

Klimpel, A. (2000), Napawanie i natryskiwanie cieplne. Technologie. Warszawa, WNT, s. 339- 365

Klimpel, A. (2012), Technologie laserowe. Gliwice, WPŚ, s. 1820-229

Koruba, Z., Krzysztofik, I., Dziopa, Z. (2011) An analysis of the gyroscope dynamics of an anti-aircraft missile launched from a mobile platform [online]. ISBN 0239-7528. Dostupné z: doi:10.2478/v10175-010-0069-4

Miko, E., Nowakowski Ł. (2012). Analysis and Verification of Surface Roughness Constitution Model After Machining Process. Procedia Engineering [online], roč. 39, s. 395–404. Dostupné z: http://www.sciencedirect.com/science/article/pii/S1877705812024290

Miko, E., Nowakowski Ł., (2012). Vibrations in the Machining System of the Vertical Machining Center. Procedia Engineering [online]. 2012, roč. 39, s. 405–413. ISSN 18777058. Dostupné z: doi:10.1016/j.proeng.2012.07.044

Sęk, P., Tofil, S. (2014) Laser Cold Ablation as a Cutting Edge Method of Forming Silicon Wafers used in Solar Cells. Advanced Materials Research. Terotechnology, s. 113-118

Takosoglu, J E., Łaski P A., Błasiak S. (2012). A fuzzy logic controller for the positioning control of an electro-pneumatic servo-drive. Proceedings of the institution of mechanical engineers part i-Journal of systems and control engineering [online], roč. 226, č. I10, s. 1335–1343. ISSN 0959-6518. Dostupné z: doi:10.1177/0959651812456498

Takosoglu, J E., Łaski P A., Błasiak S. (2014) Innovative modular pneumatic valve terminal with self – diagnosis, control and network communications. . In: FUIS, V, ed. Engineering Mechanics 2014. Dolejskova 5, PRAGUE 8, 182 00, Czech Republic: Acad sci Czech Republic, Inst thermomechanics, s. 644–647. Engineering Mechanics. ISBN 978-80-214-4871-1.

Wijas M., Nowakowski Ł., (2015). Suraface milling after laser cladding. Mechanik, Vol. 8-9, pp. 320-328