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Examples of parts regeneration used in the internal combustion engines made in LMD technology

Abstract: This article presents examples of regeneration of the internal combustion engines parts that have been damaged as a result of wear. Engine parts have been regenerated with the use of laser technology - Laser Metal Deposition (LMD) and selected metal alloy powder. Laser cladding have been done on the surface of the elements, in order to reproduce the shape and material loss. All elements have been presented in the used state and after the regeneration along with a discussion of specific aspects of the process.

Keywords: *regeneration of parts, laser cladding, LMD, durability and reliability of engines*

Przykłady regeneracji części używanych w silnikach spalinowych wykonane w technologii LMD

Streszczenie: W artykule zostaną przestawione przykłady regeneracji części silników spalinowych, które uległy awarii w wyniku ich zużycia eksploatacyjnego. Części zregenerowano z zastosowaniem technologii Laser Metal Deposition (LMD) poprzez trójstrumieniowy nadmuch odpowiednio dobranego proszku stopu metali i laserowe napawanie na zużytą powierzchnię elementów, w celu odtworzenia kształtu i ubytku materiału. Przedstawiono elementy w stanie zużytym i po regeneracji wraz z omówieniem szczegółowych aspektów procesu technologicznego.

Słowa kluczowe: *regeneracja części, laserowe napawanie, LMD, trwałość i niezawodność silników*

1. Introduction

Operating machine parts are subjected to wear which causes change of dimension. This problem is well known in the automotive industry. Excessively using of worn automotive parts can lead to premature wear of whole subassembly or sudden machine breakdown. Dimensional changes of cooperating parts generated during friction leads to formation of excessive backlash. Backlash generate vibrations which adversely affects on propulsion systems of the vehicle. It is recommended to check regularly the condition of frequently wearing parts and replace them. Replacement of high price parts can be avoided by the regenerations of used parts. This article presents the examples of regeneration of internal combustion engine parts Fig.1 and Fig.2.

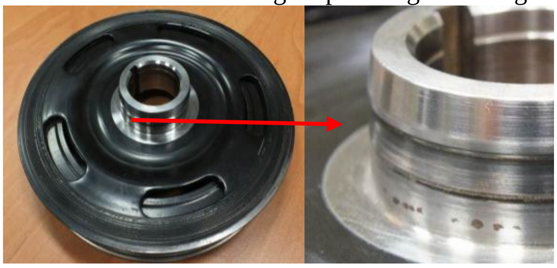

Fig. 1. Crankshaft pulley hub, damaged – used area

Through hardfacing of Co-based alloy powder by laser cladding many used machine and engine parts can be quickly repaired [1-4]. Laser cladding technology allows powder material to be placed directly on the part's surface. Metal powder is melted by the laser beam (in shielding gas) and creates new layer. The use of specialized 5-axis device allows precise laser beam control and powder control during cladding process on any machine part surface. Creation of surface layers with different thickness and degree of mixing with substrate is possible by appropriate selection of process parameters.

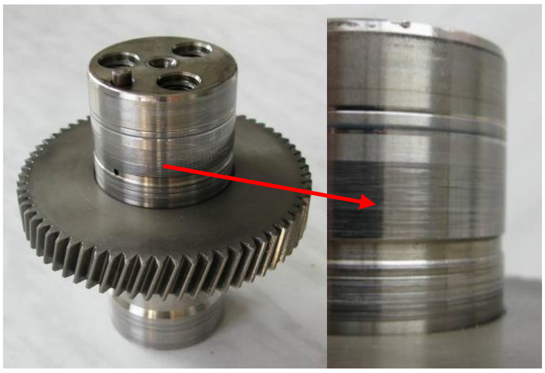

Fig. 2. Gear wheel of oil pump – used area

Currently, laser cladding technology is one of the most advanced technologies used in surface engineering [4,5]. This paper describes an example of laser cladding technology application to produce regenerative material layer on used crankshaft pulley hub and gear wheel of oil pump using laser cladding method – Laser Metal Deposition (LMD) – manufacturer designation.

2. Metal alloy powder

For the regeneration process a commercially available Co-based alloy – Stellite 6 powder have been used. This metal alloy powder among many features has a corrosion resistance and hardness in range 36 – 45 HRC after laser cladding [6]. Alloy powder particles size was in the range of 25 – 53 μm and their shape was spherical. Before laser cladding engine parts have been cleaned and degreased by acetone.

3. Laser cladding process parameters

Co-based alloy coating was melted by laser using a 1.0 kW continuous wave disk laser with powder feeding system. Laser cladding was carried out using a TRUMPF LASER CELL 3008 device with TRUDISK 1000 laser in the Industrial Institute of Agricultural Engineering described in [7]. This device enables 2D and 3D laser processing of small and medium machine parts. Multiple mode laser beam (TEM_{01*}) of circular shape was applied. Different parameters for each element have been used in the experiment:

– For the crankshaft pulley hub: laser output power 650 W, laser beam diameter 1.642 mm, feed rate 9 mm/min, scanning speed 1580 mm/min, overlapping 30% and powder feed rate 8 g/min, angle between nozzle and pulley hub was 38^{o}, Co-based alloy coating was produced in three passes.

– For the gear wheel of oil pump: laser output power 650 W, laser beam diameter 1.426 mm, feed rate 10 mm/min, scanning speed 1570 mm/min, overlapping 25% and powder feed rate 8 g/min, angle between nozzle and pulley hub was 28^{o}, Co-based alloy coating was produced in two passes.

Helium (He) was used as the powder carrier gas and argon (Ar) was used as shielding gas to protect the molten pool from oxidation. Both gas flow rates for both elements were 8 l/min. Distance between the nozzle and the element surface was 12 mm.

4. Macroscopic surface observation

To analyze the surface condition after laser cladding process stereoscopic microscope was used. Different number of LMD passes for each element have been used, due to the different level of wear. For the crankshaft pulley hub the machining allowance after the laser cladding was ca. 0,8 mm on diameter (nominal shaft diameter was ϕ 40 mm (Fig.3). For the gear wheel of oil pump the machining allowance after the laser cladding was ca. 0,5 mm on diameter (nominal shaft diameter was ϕ 50 mm (Fig.4). Investigation of laser cladding surface proved that no surface cracks have been observed.

After laser cladding process crankshaft pulley hub and gear wheel of oil pump have been subjected to machining and grinding to nominal size (Fig.5) and (Fig.6).

Non-destructive testing (dye penetrant inspection) as well as microscopic and chemical composition examination of surface layer and substrate were performed on the cross-section of a control specimen, cut from pulley hub. The second element have not been cut in a cross section because it was meant to be installed again in the engine.

Fig. 3. Crankshaft pulley hub after laser cladding

Fig. 4. Gear wheal of oil pump after laser cladding

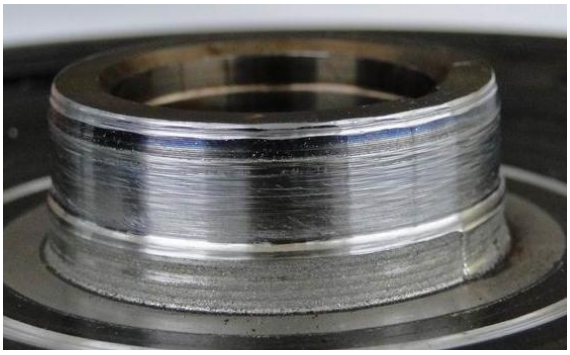

Fig. 5. Crankshaft pulley hub after machining

Fig. 6. Gear wheal of oil pump after grinding

control specimen, cut from pulley hub. The second element have not been cut in a cross section because it was meant to be installed again in the engine.

Pulley hub with the penetrant applied on repaired surface layer is shown in Fig.7. Dye penetrant inspection have confirmed high quality of produced stellite metal layer. There were no cracks, discontinuities, porosity and other surface defects ranging in size from 30 to 50 microns.

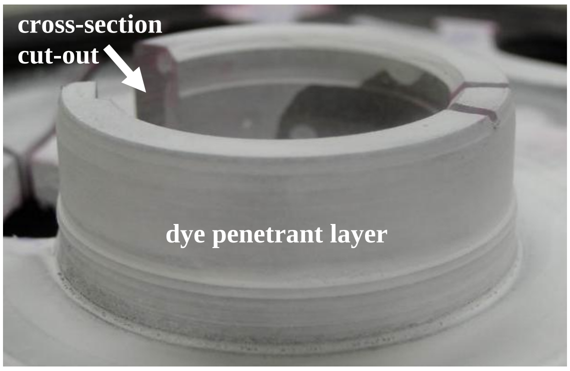

Fig.7. Crankshaft pulley hub during dye penetrant inspection

5. Microstructure observation

After laser cladding several samples were cut-out from pulley crankshaft hub (Fig.7), and then polished. Two-step etching procedure was used. A 2% nital was used for etching specimens to reveal microstructural features of substrate. Solution of 25% HCl and 75% HNO_3 was used for etching specimens to reveal coating microstructure. Specimens microstructures were observed using Neophot 32 optical microscope and TESCAN VEGA 5135 scanning electron microscope.

Powder metal layer consists of two zones – outer, clear and which not etching in nital and heat affected zone of fine grain bainite structure. Outer zone with a high cobalt content and other cladding powder components is characterized by a dendritic microstructure (typical for stellite) and is shown in Fig. 8.

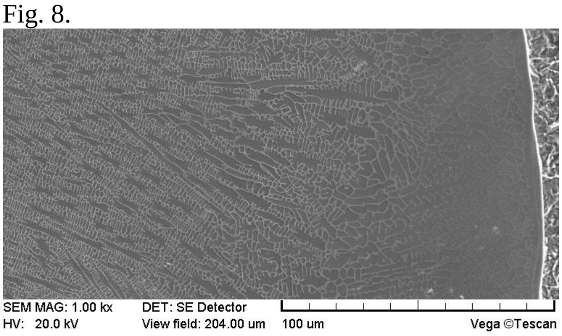

Fig. 8. Microstructure of Stellite 6 metal layer

At substrate zone border the stellite layer is mixed with steel what indicates good binding with substrate. No porosity and no cracks in outer zone have been observed. Thickness of cobalt zone after machining was ca. 160 µm.

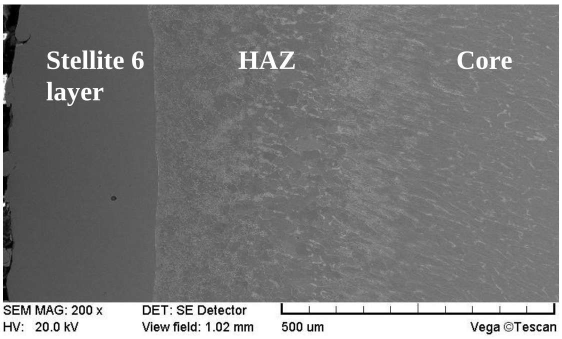

Fig. 9. Microstructure of surface layer and substrate of pulley hub after the laser cladding and machining

Under this zone was lacated heat affected zone (HAZ), which had 200 µm thickness and was characterized by a fine grain. Both zones (HAZ and core) had a low-carbon bainite microstructure.

6. Microhardness analysis

Microhardness change across cross-section profile of regenerated crankshaft pulley hub is presented in Fig.1 10. Laser cladded layer have increased hardness in comparison to substrate steel. Substrate microhardness was about 160 HV0.2, while maximum value in clad layer was 633 HV0.2. It was found out that microhardness had increased also in heat affected zone.

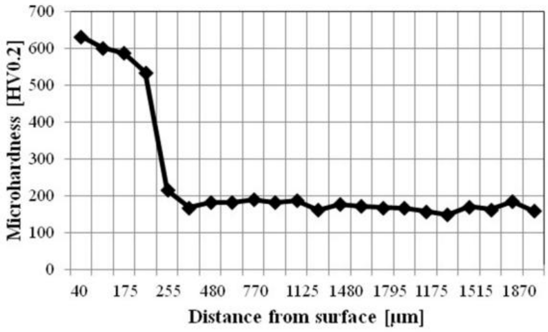

Fig. 8. Microhardness profile on cross-section of repaired crankshaft pulley hub specimen

7. Economic aspect analysis

When machine brakedown occuours there is a need to replace or regenerate the damaged element. One of the most significant decision factor is a economy; cost of repair. Based on the presented regeneration process of two engine parts some calcuction and data can be presented. For the gear wheel of oil pump time spent on regenerartion proces per part can be estimated as about 15 – 20 minutes. The process cost for a single part (including metal powder and machining) was about 400 zł net. The cost of a new part was about 1500 zł net. The benefit of repair cost reduction is obvious. It should be noted that the regeneration process of the pump wheel can be performed many times for a given element. However each element can be used / damaged in a different manner. If we can assume that this type of element's damage will always be similar then regeneration process will be only slightly modified and the overall cost of repair will decrease.

For the regeneration process cost of crankshaft pulley hub based on the experience with presented part it can be noted that the time of process was shorter than above. The surface subjected to laser treatment was smaller, but the cladded metal layer was thicker and more uneven, therefore three pases were needed with different width. The overall cost of repair for that element shoul be much smaller that the cost of a new part – 800 zł net.

Regenerated element of gear wheel of oil pump have been commited to the company Ive-Mark Marek Hołdyński and installed in the oil pump assembly. After operating time 6 months no complain or any further damage of that element have been noted. The element is still in use.

8. Conclusion

As a result of laser cladding a surface layer consisted of a Co-based alloy has been successfully created. It was found out that clad layer had increased hardness and very good process parameters. Applied cladding layer by laser method allows production of layer which is well-bonded with substrate. Results encourage to undertake further study on practical application of the laser cladding method for different machine parts and applications. Based on the obtained results it can be stated that the regeneration process of both parts was successful. Laser cladding of Stellite 6 probably will extend pulley durability in comparison with pulley made of low carbon steel (increased hardness). From the economic point of view regeneration of parts has a strong decision factor: lower that replacement cost of repair. Regeneration of machine parts by LMD method is a very good alternative to traditional methods of regeneration..In some cases, it can be superior to existing technologies, and significantly reduces the time element's processing.

Acknowledgements

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Nomenclature / *Skróty i oznaczenia*

LMD Laser Metal Deposition - *laserowe napawanie metali*

HAZ - Heat Affected Zone - strefa wpływu ciepła

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