LASER CLADDING OF STELLITE 6 ON LOW CARBON STEEL
FOR REPAIRING COMPONENTS
IN AUTOMOTIVE APPLICATIONS USING DISK LASER

This paper describes results of a repair process of crankshaft pulley hub made of low-carbon steel using laser cladding method. Widely used Co-based alloy powder (Stellite 6) was applied as cladding material. After laser cladding process crankshaft pulley hub has been subjected to grinding to nominal size. 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. Produced layer was non-porous and metallurgically bonded with steel substrate. On the cladding weld a much higher microhardness relatively to substrate material has been measured.

Key words: laser cladding, Stellite 6, automotive, microhardness, parts regeneration

1. INTRODUCTION

Cooperating machine parts are subjected to wear phenomenon. This problem mainly relates to parts used in automotive industry. Excessively using of worn automotive parts can lead to premature wear of whole subassembly. Dimensional changes of cooperating parts generated during friction leads to formation of excessive backlash. These backlash generate vibrations which adversely affects on propulsion systems of the vehicle. Another factor contributing to wear is
corrosion phenomena. It is recommended to regularly check the condition of frequently wearing parts and replace or repair them. In order to reduce repair cost of expensive or unique cars the regenerations of worn parts can be applied. Frequently destroying automotive parts relate to crankshaft pulley, and more specifically their hub. Replacing this parts is associated with relatively high costs. Through hard-facing of Co-based alloy powder by laser cladding worn parts can be quickly repaired [1, 3, 5]. Laser cladding technology allows to enter of powder material directly to a laser beam with shielding gas. Use of specialized 5-axis device allows precise laser beam control and powder control during process on any machine part place. Creation of surface layers with different thicknesses and with different degree of mixing with substrate is possible by appropriate selection of process parameters. Currently, laser cladding technology is one of the most advanced technologies used in surface engineering [2–4, 6–8]. This paper describes an example of laser cladding technology application to produce regenerative material layer on used crankshaft pulley hub. Commercially available Co-based alloy (Stellite 6) powder was used. It characterized inter alia enhanced corrosion resistance.

2. RESEARCH METHODOLOGY

2.1. Materials

Low-carbon steel specimens, cut from pulley crankshaft hub before and after laser cladding have been investigated. Chemical composition of substrate is given in Table 1. In this study, commercially available Co-based alloy (Stellite 6) powder was used. Size of powder particles was in the range of 25–53 μm. Powder particles shape is shown in Figure 1. Before laser cladding pulley crankshaft hub was sanding and then cleaned and degreased by acetone.

<p>| Chemical composition of substrate (Wt %) |</p>
<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.047</td>
<td>0.064</td>
<td>0.188</td>
<td>0.020</td>
<td>0.005</td>
<td>0.034</td>
<td>0.013</td>
<td>0.026</td>
</tr>
</tbody>
</table>
2.2. Coating preparation

Co-based alloy coating was prepared by laser cladding technology using a 1 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. This device enables 2D and 3D laser processing of small parts. Multiple mode laser beam (TEM$_{00}$) of circular shape was applied. Parameters used in the experiment were: 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. 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 were 8 l/min. The nozzle is designed so that three powder streams converge at the same point on laser beam. Pulley crankshaft was fixed in the grip chuck. Distance between tip of nozzle and surface of pulley crankshaft hub (substrate) was 12 mm. Angle between nozzle and pulley hub was 38°, due to the collision possibility. Co-based alloy coating was produced in three passes. Laser cladding process is shown in Figure 2.
2.3. Machining

In order to reduce surface roughness after laser cladding and to obtain the required dimensions machining has been done, which was performed on a TUM-35D1 toolroom lathe. Machining parameters used in the experiment were: cutting speed 1.71 m/s, depth of cut 0.11 mm, feed rate 0.2 mm/rev. Due to the high hardness of coating, NTK25 tool reinforced by CVD coating with TiN and Al_2O_3 from Baildonit company was used.

![Image of machining process](image_url)

Figure 2. Repairing of pulley crankshaft hub by laser cladding process using Trudisk 1000 laser and Laser Cell 3008 device

2.4. Macroscopic observation and dye penetrant inspection

To analyze the surface condition after laser cladding process stereoscopic microscope was used. Also photographic documentation of pulley crankshaft hub surface was performed. Damaged pulley hub and pulley hub after laser cladding process and after machining were observed and then were examined by dye penetrant inspection. It is non-destructive method used for determining consistency of weld but it can also be used for determining the overlay weld quality. In this method flaws (cracks range from 30 to 50 μm) appear as red marks on a white background. In this study cleaner, dye penetrant and white developer Skincric from Weldline company were used. The process consists of: surface cleaning, red dye penetrant application, excess red dye penetrant removing, white developer application and finally inspection the surface.
2.5. Microstructure observation and chemical composition

After laser cladding several specimens were cut from pulley crankshaft hub, and then carefully 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% HNO₃ 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.

Chemical composition of surface layer produced by laser cladding method was investigated using scanning electron microscope (SEM) equipped with PTG Prism Si(Li) energy dispersive x-ray spectrometer (EDS). EDS linear analysis on specimen cross-section was performed.

2.6. Microhardness

Microhardness along the depth of polished and etched specimen in the cross-section was measured by the use of Buehler Micromet II microhardness tester. Indentation load of 200 g and loading time 15 seconds was used in the study. Microhardness values were averaged by at least 5 measurements.

3. RESULTS AND DISCUSSION

3.1. Macroscopic observation and dye penetrant inspection

Disassembled crankshaft pulley before the regeneration process is shown in Figure 3a. Originally on the hub circumference was located wear and deep corrosion pits as well as corrosion tarnish. Such a bad surface condition of part prevented its further exploitation. Excessive exploitation of damaged engine parts can affect on work of other their components. on the Figure 3b is shows crankshaft pulley hub after laser cladding with Co-based alloy powder (Stellite 6). The hub diameter was measured after each of three laser passes. Tracks are parallel arranged and without defects which could be discernable with naked eye. Overlay weld was produced with appropriate machining allowance. Machining process after the laser cladding was the final repair stage. Its purpose was to achieving desired surface roughness and final dimension. After the machining process no defects in the structure of surface geometry were found. In addition, a non-destructive testing (dye penetrant inspection) was performed. Its aim was to detect the presence of defects in overlay weld which are invisible by naked eye.
or with a stereoscopic microscope and also to search for porosity and cracks. In order to avoid penetrant impact in microstructure image before proceeding to dye penetrant inspection a specimen has been taken for the microscopic examination. Pulley hub with the penetrant applied on repaired surface layer is shown in Figure 3d. Dye penetrant inspection have confirmed high quality of produced overlay weld. There were no cracks, discontinuities, porosity and other surface defects ranging in size from 30 to 50 microns, which are in overlay weld often found by performed by other methods.

![Figure 3. Crankshaft pulley hub: a) damaged, b) after cladding, c) repaired (after machining), d) during dye penetrant inspection](image)

### 3.2. Microstructure observation and chemical composition

Surface layer microstructure and clad steel substrate of pulley hub after the laser cladding are shown in Figure 4. 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 Figure 5.
It was found that the distribution of elements in cobalt zone is regular (Figure 6 and 7). This means regenerated material layer is well mixed. At a depth of 250 µm, the step change of chemical composition associated with different chemical composition of layer and substrate were observed (Figure 7). At substrate zone border iron content is increasing what indicates good binding with substrate Clad Stellite 6 microstructure in clear separation of outer zone are tungsten and chromium carbide in cobalt matrix. There was no porosity and no cracks in outer
zone. Thickness of cobalt zone after machining was 160 μm. Under this zone was located 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.
3.3. Microhardness profile

Microhardness change across cross-section profile of repaired crankshaft pulley hub is presented in Figure 8. Microhardness decreases sharply at depth of 250 μm on the border of layer and substrate because Co-based alloy layer is characterized by increased hardness in comparison to substrate steel. Substrate microhardness is about 160 HV0.2, while maximum value in clad layer is 633 HV0.2. It was found out that microhardness had increased also in heat affected zone.

![Microhardness profile on cross-section of repaired crankshaft pulley hub specimen](image)

4. CONCLUSIONS

As a result of laser cladding on a surface layer consisted of a Co-based alloy has been created. It was found out that clad layer had increased hardness of pulley hub. 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 hard facing of powder mixtures using a more complex composition. Based n the obtained results it can be stated that the regeneration process of pulley hub was successful. Laser cladding of Stellite 6 probably extend pulley durability in comparison with pulley made of low carbon steel.
REFERENCES


LASEROWE NAPAWARNIE STOPU STELLITE 6
NA STAŁ NISKOWĘGŁOWĄ Z UŻYCIEM LASERA DYSKOWEGO
W CELU NAPRAWY CZĘŚCI STOSOWANYCH
W PRZEMYSŁE SAMOCHODYM

S t r e s z c z e n i e


Słowa kluczowe: laser cladding, stellite 6, przemysł samochody, mikrotwardość, regeneracja części

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