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H. Smoleńska[1], W. Kończewicz[2]
[1]Gdańsk University of Technology, Faculty of Mechanical Engineering, Department of Materials Science and Engineering, Gdansk, Poland
[2]Gdynia Maritime University, Department of Mechanical Engineering, Gdynia, Poland

MICROSTRUCTURE AND PROPERTIES OF THE COBALT BASE CLAD LAYERS AFTER LONG TIME SERVICE

ABSTRACT

The cobalt base laser cladding layers were investigated after two years of service in two laboratory diesel engines. The microstructures of the clads after service did not demonstrated serious degradation process. Chemical compositions of the used layers and changes in hardness were described. These sorts of layers are suitable for long time service with out substantial damages.

***Key words**: cobalt base alloy, laser cladding, wear*

INTRODUCTION

The engines, gas turbine or industrial applications like for example: moulds for glass and ceramics; automotive valves; chemical and petrol-chemical valves needs special material. For such a sever service conditions materials must have high strength and adequate resistance to gaseous corrosion at elevated temperatures. There are a wide range of compositions based on nickel, cobalt and nickel–iron. Their various applications are based largely on their suitability at higher temperatures to a particular environment [1-4]. The high temperature and high pressure which are typical conditions for heavy-duty diesel engines result in high stress and severe work condition for exhaust valves. Not only tensile, creep and fatigue properties are important but also excellent oxidation resistance and forge ability are necessary. The increasing demands which increasing the stress levels or temperature, changes in fuels and lubricants and possibility of repairing were the main reason for seeking new materials and technologies. Also the development in petroleum industry – which mean more extent extraction processes and in the result worse quality of the heavy fuel led to the heavier condition of the service for engine parts. As a result cobalt base alloys are still important group of the cladding materials [5-8].

EXPERIMENTAL

In that experiment, the exhaust valve heads of the ship engines were made of A-R-H10S2M valve steel (which is corresponding with an X40CrSiMo10-2 steel). The vale faces were claded by a high power diode laser HDPL ROFIN SINAR DL 020 with maximum power beam of 2.5 kW. The powder was delivered straight to the melt pool. The parameters of the process are as follows: the laser power -1.0 kW, laser scanning rates – 0.2 m/min, powder feeding rate – 5.0 g/min, the layer thickness – 1.0 mm and width - 6mm. The subsequent laser tracks were overlapped by 30 %. . The chemical composition of the powder, which was used for creating the clad layer, was as follow: C – 1.55%, Si – 1.21%, Cr – 29.7%, W – 9.0%, Ni – 2.0%, Mo – 0.01%, Fe – 1.7% and Co as balance. The whole clad layer consisted of three sublayers with three tracks on each one. After cladding, the surface was machined to obtain proper geometry. In order to conduct further investigation, the one valve head, was cut perpendicular to the cladding layer and was characterized by optical and scanning electron microscopy (SEM). Micro hardness of the specimens was measured with PMT-3 hardness meter. The concentrations and distributions of the alloying elements were determined using EDAX analyser. The other two valve heads were installed in two engines: the laboratory designed L22 – two stroke engine and real working on the ship 3AL25 – two stroke engine. The valve heads were examined by real working conditions for two years. The L22 engine was fuelling by both ordinary light fuel and biodiesel fuel and 3AL25 engine only by light fuel. After exploitation tests the valve heads were fully inspected using the optical and SEM microscope. These analyses allowed choosing the places of the face were the samples for further investigations were prepared. The cross-sections of these samples underwent SEM and chemical analysis as well as microhardness measurements.

RESULTS AND DISCUSSION

The laser deposited layers presented a typical surface welding solidification structure which is presented in the Fig. 1.

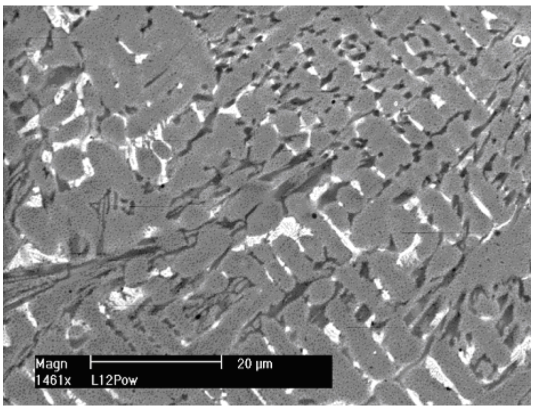

Fig. 1. SEM photograph of the cross-section of the clad layer close to the surface. The grey regions are dendritic while light and dark domains are placed in interdendritic regions, respectively

After service the surface of the faces of the both valve heads presented shining surfaces (Fig. 2) in the great deal but some dark “spots” on them were noticed (Fig. 3, 4). There were no visible damages. However SEM observations showed some results of wear. There were small amount of wear pits which were fill up with wear debris and possible the scale (Fig. 4).

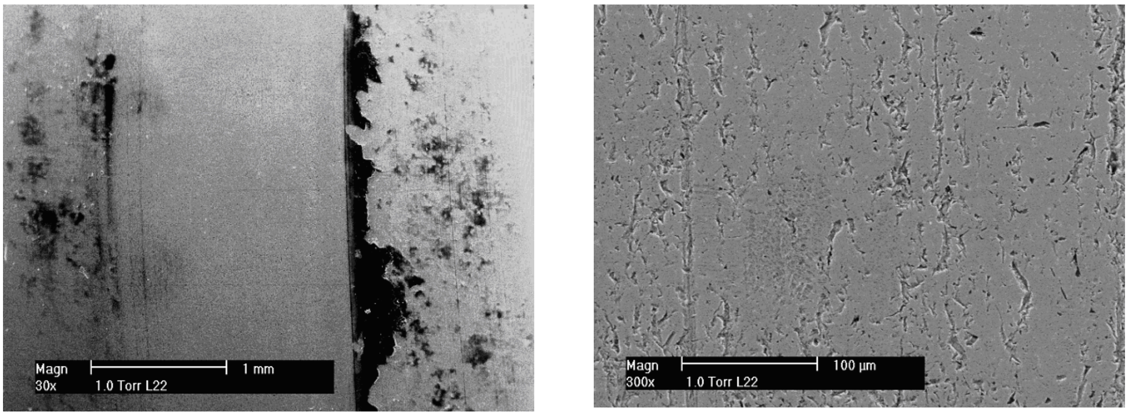

Fig.2. SEM of the vale face after two years of service; valve head from L22 engine – shining region under different magnification

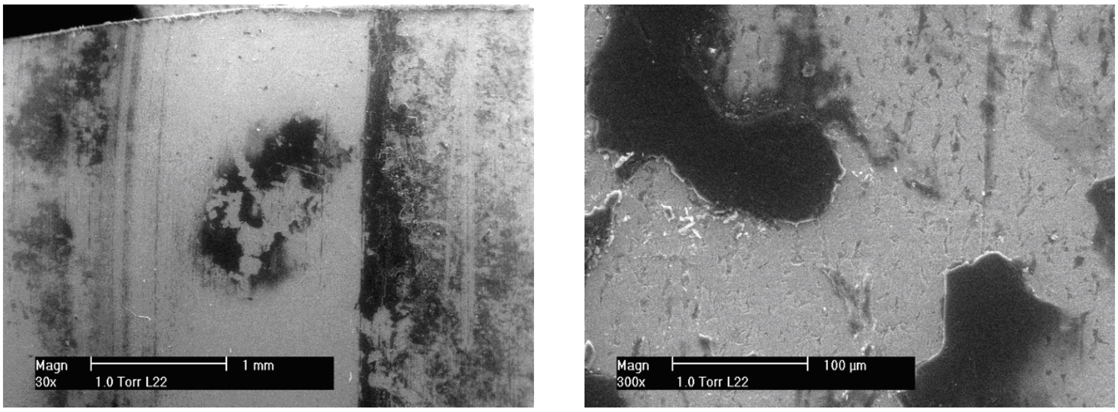

Fig.3. SEM of the vale face after two years of service; valve head from L22 engine – dark “spot” region under different magnification

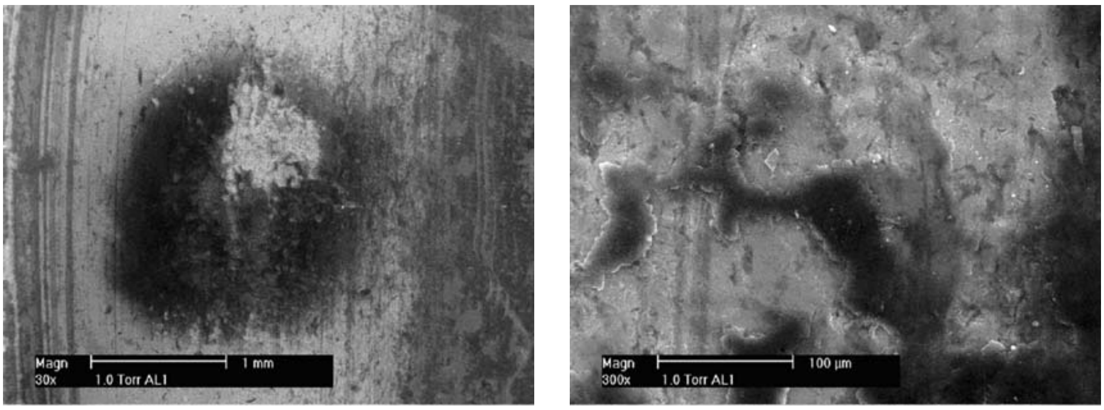

Fig.4. SEM of the vale face after two years of service; valve head from 3AL25 engine - – dark “spot” region under different magnification

On the cross section of the claded layers general visible changes in microstructure were no found (Fig. 5). On the surface some small pits were observed (Fig. 5a) but in the great deal the surface was smooth (Fig. 5b).

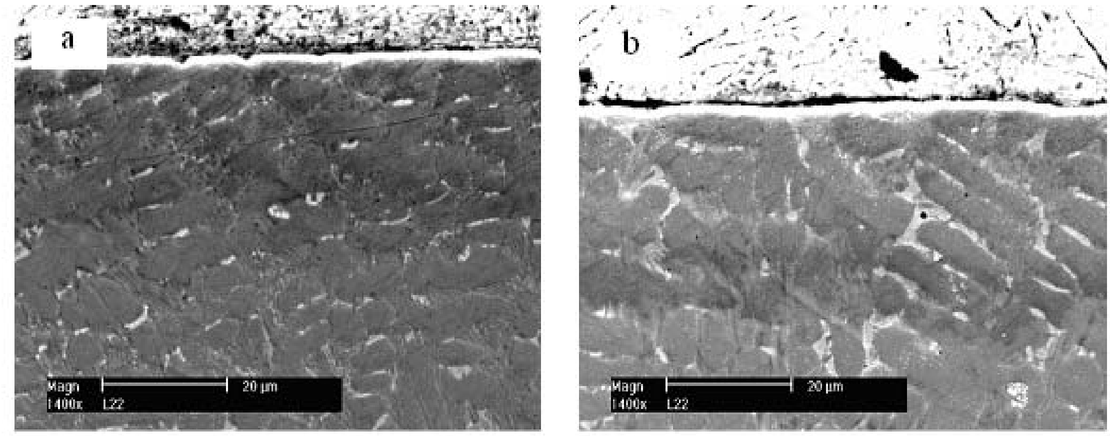

Fig. 5. SEM of the cross-section of the clad; valve head from L22 engine; a- region where the small pits were observed; b- typical structure for the most of the faces

The chemical analysis EDS in the micro region on different part of the clad layer allowed establish the trends of chemical changes. Fig. 6 presented result of chemical analysis on the cross section of the clad layers, close to the surface for faces from the both engines after service in comparison to clad state and powder composition

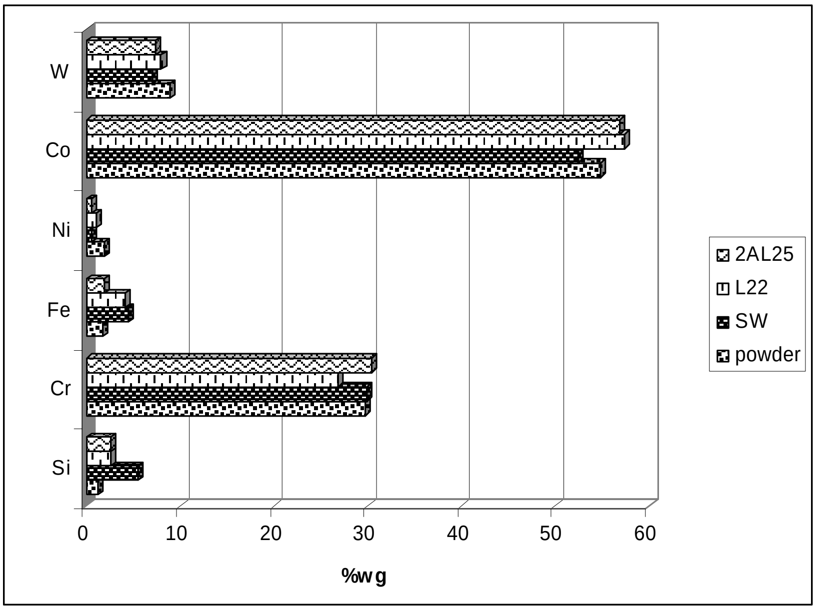

Fig. 6. Chemical composition of the powder and composition of the surface region for: SW – as clad state, L22 – surface region of the face from L22 engine, 2AL25 - surface region of the face from 2AL25 engine

The small changes in the composition corroborated earlier metalographical results about not significant structural changes. Different service conditions resulted with differences in diffusion of some elements. Lower amount of chromium for L22 engine indicated more intensive oxidation and building a chromia scale. For les demand condition the "use" of chromium was less intensive.

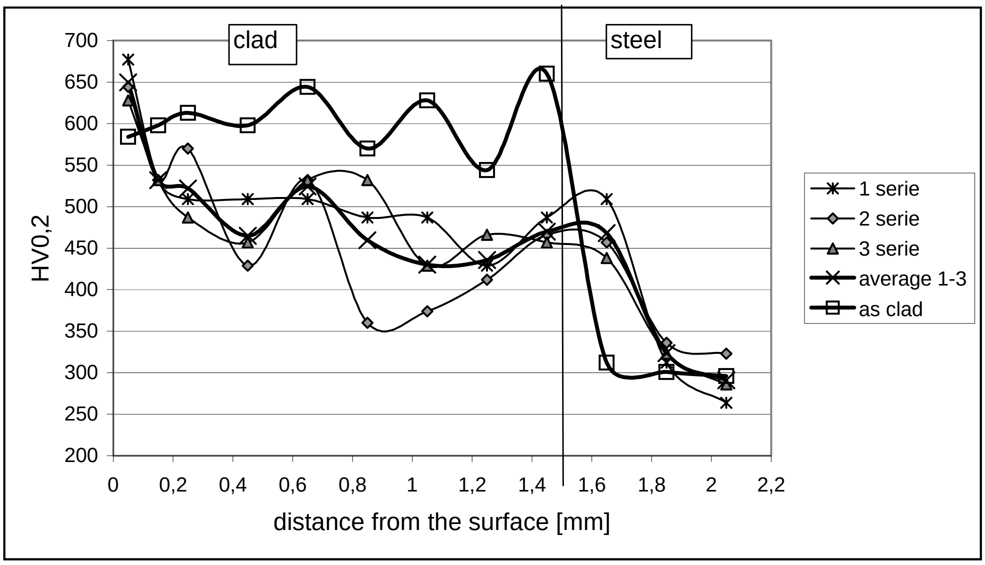

Fig. 7. Microhardness profile of cross-section specimen from the L22 valve head after two years of service

The microstructure observations were followed by hardness measurements which were carried on the same way for as clad layer and the samples from the valve heads after service. Because of the high measured differences on hardness numbers, three microhardness profiles were obtained in order to improve the statistical significance of the data. For the sample from the valve head from the L22 engine the results of measurements and average values which were calculated were showed on the Fig. 7. The decrease of the hardness numbers was observed but still clad layer presented higher hardness than steel base. Also variation of the hardness across the layer was limited which was a result of the diffusion processes during the long time of heat influence however this changes were not noticed in the microstructure.

CONCLUSIONS

After performed investigations some conclusions may be established:

- Laser cladding with a cobalt base powder is an effective material processing that produces a surface layer with good wear and corrosion properties. It may be a new good solution for consolidation of the valve head faces.
- The obtained layers present good fusion with to the steel, lack of the cracks and porosity and little distortion of materials produced by this process.
- After two years of service no general failure was observed.

REFERENCES

1. J.L.De Mol Van Otterloo, J.Th.M. De Hosson; Microstructural features and mechanical properties of cobalt-based laser coating; Acta Materalia, vol. 45, no .3, 1997.
2. A.S.C. d`Oliveira, R. Vilar, C.G. Feder; High temperature behaviour of plasma transferred arc and laser Co-based alloy coatings; Applied Surface Science 201(2002).
3. A.S.C. d`Oliveira, P.S.C.P. da Silva, R.M.C. Vilar; Microstructural features of consecutive layers of Stellite 6 deposited by laser cladding; Surface and Coatings Technology 153 (2002).
4. Elliott P., Choose materials for high-temperature environments, Chemical Engineering Progress, 97, 2 (2001) 75-85.
5. Schlager D., Theiler C., Kohn H., Protection against high temperature corrosion with laser welded claddings, applied and tested on exhaust valve discs of large diesel engines burning heavy fuel oil, Materials and Corrosion 53, (2002) 103-110.
6. Smoleńska H., The gas corrosion of the cobalt base layer at elevated temperature, Journal of Achievements in Materials and Manufacturing Engineering. - Vol. 18, iss. 1/2 (2006), s. 235-238.
7. Smoleńska H., Kończewicz W., Analiza własności napawanych laserowo powierzchni przylgni zaworów wylotowych silników okrętowych po korozji w powietrzu i gazach spalinowych, Inżynieria Materiałowa. - R. 27, nr 3/151 (2006), s. 536-539.
8. Kończewicz W., Smoleńska H., The resistance investigation of the marine engine exhaust valve using the modelling chamber, Journal of KONES: Powertrain and Transport. - Vol. 15, nr 4 (2008), s. 255-262.