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DEPOSITION OF STEEL COATINGS USING LENS TECHNOLOGY

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Abstract: *Many failures on work components occur because of corrosion, wear, erosion or friction. Laser coating is an attractive alternative to conventional techniques for surface improvement. When depositing a material which properties are very different from the properties of the substrate material, difficulties, such as cracks, can occur. In this paper we investigate the deposition of AISI H13, stainless steel 316L and FeCrV15 powder on two different cast irons with the LENS ™ technology. The coatings were deposited with different process parameters, using the integrated control program.*
Key words: *laser deposition, coatings, tool steel*

1. INTRODUCTION

Lasers are often used to produce metallurgical coatings for different components to improve wear, corrosion and/or chemical resistance and other properties. Technologies such as Selective laser sintering (SLS), Laser Engineered Net Shaping (LENS) or laser cladding are capable to deposit various materials without making any significant change to the bulk characteristics of the structure. When a material is applied in the form of a protective coating, difficulties arise due to miss match in elastic modulus, thermal expansion coefficients, and hardness between the surface layer and the base material. Such differences in material properties cause residual stresses, and may lead to peeling or crack formation (Bandyopadhyay et al.). This problem can be solved with the use of functionally graded materials. In a functionally graded coating, an intermediate layer is applied between the top coat and the substrate. This layer consists of several sections with gradual change in the microstructure and reduces the discontinuity of the thermal expansion coefficient (Balla et al.).

Many other researchers have reported to successfully deposited various materials on different components. It was reported that thick Co-based coatings were successfully deposited on gray cast iron and compacted graphite iron substrates with a high power Nd:YAG laser. (Ocelik et al.).

The idea presented in this paper is to enrich a relatively cheap material that is easy to cast with a material with better mechanical properties. Multiple coatings with different powders and process parameters were deposited on two different cast irons. The microstructures of the coating and the bonds were analyzed.

2. EXPERIMENTAL PROCEDURE

2.1 Equipment

A LENS 850-R machine (Optomec, Albuquerque, USA) was used for producing test samples. The machine uses a 1 kW ytterbium fibre laser (IPG Photonics) to create a small molten pool on the substrate. In the molten pool powder is blown through four nozzles with the help of a carrier gas. Some of the powder bounces of the surface and some is caught by the molten pool. The powder melts quickly when entering the molten pool and solidifies when the laser head moves away. The solidification is very quick because the heat is rapidly conducted away from the melt pool. The material is deposited in a shape of a line, which dimensions are set by the process parameters. One layer is made of a number of lines of deposited material. When one layer is finished, the laser head moves up for one layer thickness and begins building the next layer. The procedure continues until the whole part is finished.

2.2 Powders

For coating of the samples the following powders were used: AISI H13 hardening hot work tool steel powder, stainless steel 316L with good corrosion resistance and FeCrV15, (chromium based tool steel powder). The average size of all the mentioned powders was between 45 and 150 µm.

2.3 Substrate

Two types of cast iron were used as substrates: EN-GJS-600-3 and EN-GJS-700-2. The substrates were plates with dimensions: 50 x 30 x 10 mm. The surfaces where material will be deposited were milled to a surface finish of R_a = 0,4. The plates were washed and rinsed with acetone just before the coating process.

2.4 Coating

The deposition took place in a controlled atmosphere (working chamber was filled with argon), where the oxygen level varied between 2 and 5 ppm during the process. The deposition of the material was controlled with the integrated control program called MPS (Melt Pool System) which adjust the laser power so that the size of the melt pool remains constant during the whole process. This is very important because of the substantial differences in laser beam absorption at the cast iron surface. In an area of direct laser beam illumination the graphite flakes act as sites of strong heat sources and therefore non homogeneous thermal fields may be created (Ocelik et al.).

Five tests plates made of EN-GJS-600-3 and five plates made of EN-GJS-700-2 were coated with each powder. The coating covered an area of 40 x 20 mm on each plate. None of the test substrates was preheated. Each layer was made of an outer contour and an inner hatch. The distance between two successive laser scans was 0,5 mm and the hatch angle was increased for 30^0 in each next layer. A total number of five layers were deposited on each plate, with different process parameters.

3. RESULTS

Because of the different process parameters, the height of coatings varied from 1,2 to 1,8 mm. The top of each coating was grinded and the hardness was measured on five different locations. The hardness was measured with a Rockwell hardness tester. All of the coatings made from the same powder, showed similar values. The hardness for H13 coatings varied between 56 and 59 HRc. The coatings that were made with less energy input showed a little higher hardness than the coatings that were produced with a bigger amount of energy. On figure 1 the representative microstructures from the cross section of the bond between AISI H13 and cast iron EN-GJS-600-3 are shown. The EN-GJS-600-3 has a perlite-nodular microstructure. On the figure changes in the transitional zone are visible. The top of the substrate was partially melted, because eutectics cells with a non circular precipitated ferrite are visible. This is because of inadequate thermal gradients. There was also degradation of the graphite nodules and an increase of ferrite along them. All the samples were crack free.

Fig. 1. Microstructure of the bond between AISI H13 tool steel and cast iron EN-GJS-600-3

The samples with 316L as coating material showed hardness between 34 HRc (more heat input) and 40 HRc (less heat input and smaller powder feed rate). The bonds of all the samples were very good with a small heat affected zone. On figure 2 the bond on EN-GJS-700-2 is shown. The stainless steel appears white because it is very resistant to etching. All the samples were crack free, the only defect that was noticed were trapped gas bubbles. These bubbles are visible as round, black circles in the stainless steel microstructures.

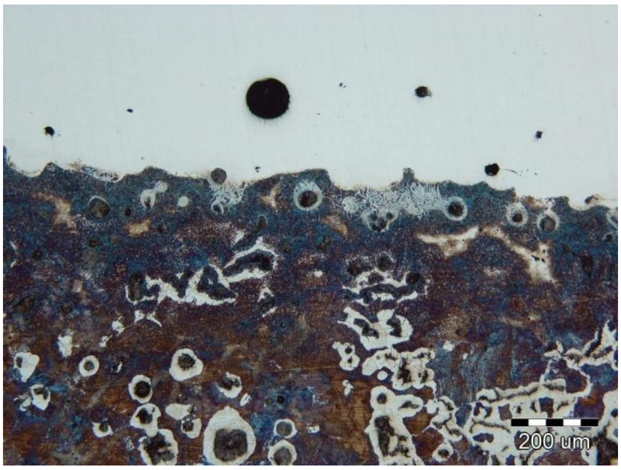

Fig. 2. Microstructure of the bond between 316L and cast iron EN-GJS-700-2

The samples coated with FeCrV15 showed the greatest hardness of all the coating materials. Hardness of up to 64 HRc was measured. The bonds with both cast irons were appropriate, but all the coatings were full of defects in form of cracks. Most of the cracks travelled through all the deposited layers, from the substrate all the way to the surface of the coating. We have also made some additional samples and used the 316L as puffer material. Analyze of the samples showed no change; the coatings were still full of cracks (figure 3).

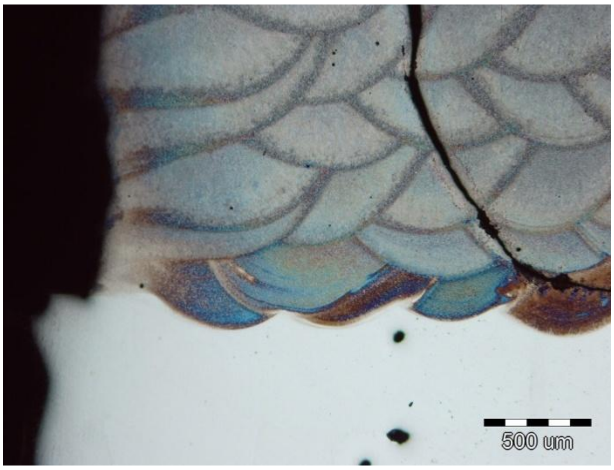

Fig. 3. A crack in the bond between FeCrV15 tool steel and 316L stainless steel

4. CONCLUSION

Even without preheating of the substrates, crack free coatings made of AISI H13 tool steel have been deposited on two different types of cast iron with the LENS technology. The microstructures showed a quality bond between the coating and the substrate with no cracks on all specimens. The coatings made of stainless steel were also well bonded on the substrate, but contained trapped gas. This is probably due to excessive heat input, because the samples that were made with less heat input contained less bubbles.

All the coatings made of FeCrV15 were well bonded on the substrates, but the cracks were a sign of great tensions in the coatings. We tried to minimize the tensions that occur because of different thermal expansion coefficients by adding a puffer layer, but with no effect. It seems that heat conduction and thermal gradients play an important role when depositing this material.

Further studies will include more coating materials and substrates. Our goal is to find appropriate combinations of materials where no preheating is required to achieve a quality bond and coating properties.

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