PROLONGING LIFETIME OF MILLING TOOLS BY LASER CLADDING OF WEAR RESISTANT COATINGS

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Abstract

The tools used for milling and grinding can have a limited lifetime due to excessive wear. Their lifetime can be prolonged by application of suitable coatings. Highly wear resistant coatings can be easily applied by means of laser cladding. The goal of this study is to effectively prolong the lifetime of milling screw used in sawdust processing. The coating consisting of tungsten carbide spherical particles in NiCrBSi matrix excels with high hardness and excellent wear resistance. This coating is laser cladded to the areas of the tool, which degrade first due to rapid wear rate. The cladded milling screw is then tested in production. The treated part exhibit with significantly less wear rate than the untreated part of the tool. The lifetime of the whole milling screw is prolonged, however additional optimization of areas treated by cladding can bring further improvement.

Keywords: Laser cladding, wear resistance, tungsten carbide

1. INTRODUCTION

The tools and parts utilized for milling, grinding suffer from abrasive wear. The excessive wear can significantly limit their lifetime. For prolonging lifetime, the wear resistant coating can be applied to functional areas of the tool.

The metal matrix composites (MMCs) are materials which excel in their high wear resistance due to the tough matrix and hard reinforcing particles [1]. Among them, the combination of Ni-based alloy and tungsten carbide is widely used. In various studies, the role powder composition - the percentage and the shape of the carbides on final coating hardness and wear resistance was tested [2] [3] [4]. The influence of process parameters on the microstructure of WC-reinforced Ni-based matrix single clads was studied previously [5] [6] [7].

Laser cladding is a technology capable of producing compact functional coatings from a variety of materials and it is also widely used for the production of wear resistant layer. In the laser cladding, the functional properties and structure of final coating are strongly dependent on the right selection of process parameters [8].

A milling screw used in pressing sawdust for briquette manufacturing yield to rapid wear degradation, the first revolution of the screw is significantly damaged only after 4 hours in production. The goal of this study is to effectively prolong the lifetime of the milling screw used in sawdust processing by laser cladding of coating with high resistance to abrasive wear.

2. EXPERIMENTAL PROCEDURE

The design of milling screw is depicted in **Figure 1.** The abrasive wear resulting in part low lifetime occur on the first revolution of the screw thread. This first revolution is machined, the diameter of the thread is lowered by 3 mm to prepare for the application of the abrasive coating. The part prepared for laser cladding is shown in **Figure 2**.

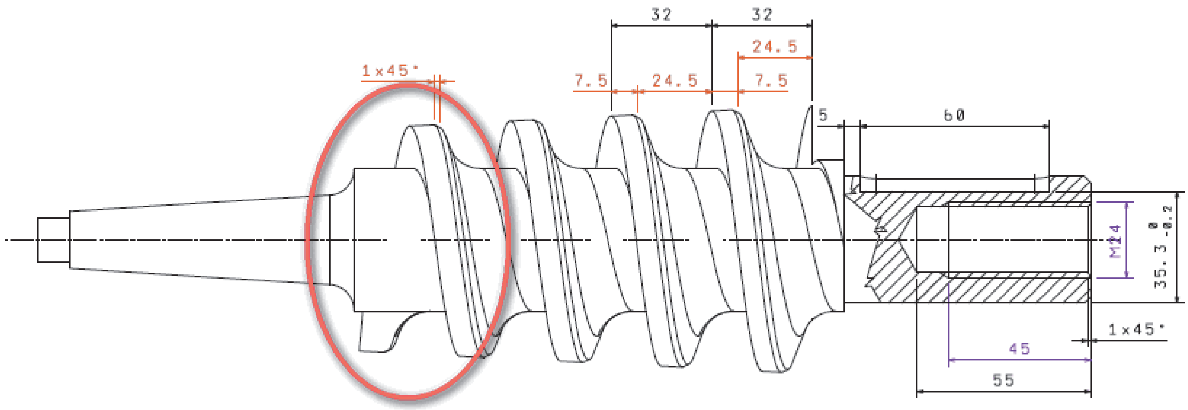

Figure 1 The milling screw with depicted treated area

Figure 2 The milling screw prepared for laser cladding

The feedstock powder from Oerlicon Metco company designated as MetcoClad 52052 was used for cladding. The powder is composed of 60% of WC spherical particles blended with 40% of gas atomized NiCrBSi (8.0Cr3.5Si1.6B0.3C Ni bal.) particles. The particle size distribution lays between 45-106 µm. The WC was manufactured in a unique way, resulting in non-acicular shape with higher hardness than conventional fused and crushed WC [9].

Laser cladding was realized by the Solid state laser Trumpf TruDisk 8002 with Precitec coaxial 4-way cladding head YC52. The parameters for laser cladding were derived from previous experiments, laser power P = 2800 W, process speed S = 30 cm/min, powder feed rate F = 42 g/min.

The portion of the coating was cladded on the steel plate to perform the coating characterization. The microstructure of the coating was evaluated on the cross sections (ground and polished by an automatic Leco grinding and polishing equipment) by optical microscope Nikon Epiphot 200, digital optical 3D microscope

Hirox KH7700, and SEM Quanta 200 from FEI equipped by EDAX NEWXL-30 Silicon doped by Lithium detector. The microhardness HV1 was evaluated on the coatings cross-section. Due to the non-homogenous coatings microstructure, the microhardness was measured in the sub-surface region, relevant for wear response. Six measurements were done in similar distance from the surface, the average values are reported. The abrasive wear resistance was evaluated by Dry Sand Rubber Wheel Test according to ASTM G-65. Test parameters were as follows: 22 N Load; Al_2O_3 abrasive media; AG 29 rubber counterpart; 718 m total abrasive distance. The samples were weighted after every 143 m and the cumulative mass loss [g] was calculated. The wear rate [g/m] was determined from two independent measurements. The surface of the coating was left in the as-received state, not to exclude the upper coatings layers from evaluation.

3. RESULTS AND DISCUSSION

3.1. Coating characterization

The coating microstructure lengthwise and crosswise to individual beads is presented in **Figure 3**. The microstructure of the coatings is highly non-homogenous. Under the coating surface, the high amount of WC spherical particles is preserved. In the coating, the majority of the carbide particles were dissolved during cladding and solidify again in different shapes and sizes, in dependence on the location. Both needle-like and blocks-shape WC/W2C carbides morphology was observed, similarly to the shapes reported in [10]. In the clad coatings microstructure, the significant influence of overlapping was identified: the subsequent melting of previous laser bead leads to a sharp needle-like carbide morphology. In the coatings cross sections, the regions with the different chemical composition can be also observed.

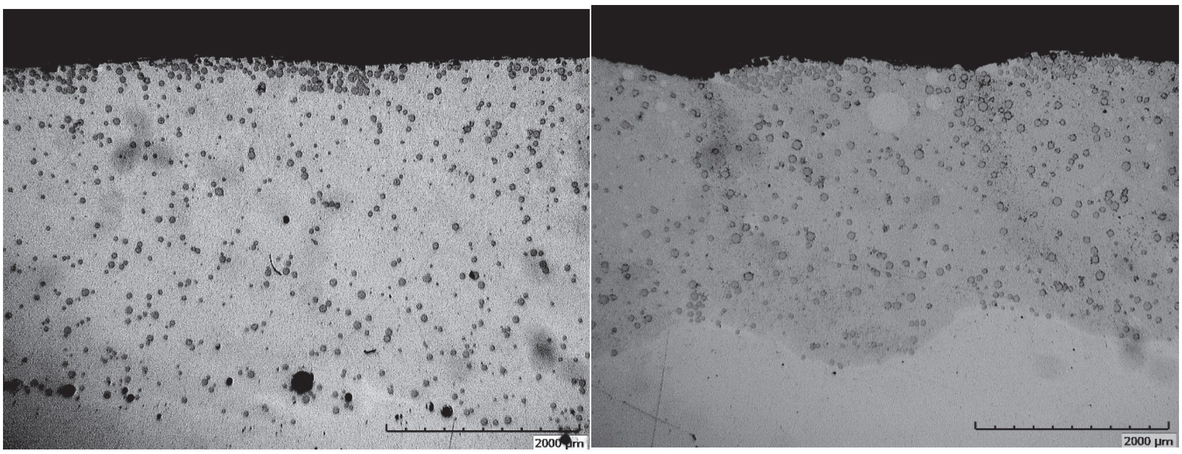

Figure 3 The cross-section of the coating lengthwise (left) and crosswise (right) to a single bead

The average hardness in the sub surface region of the coating is HV1 = 797. The wear rate measured by dry sand rubber wheel test is $9.09 \cdot 10^{-4}$ g/m. The hardness and wear rate are influenced by carbide dissolution and by Fe dilution from the substrate to coating. As the coatings microstructure is not homogenous and the distribution of spherical particles in the subsurface region follows the direction of cladding with stripes of needle-like carbide precipitates, the wear of the coating was not homogenous either.

3.2. Final part

The milling screw with a cladded coating on the first revolution of the thread is shown in **Figure 4**. The treated part was tested in production. The laser cladded milling screw after utilization in production is shown in **Figure 5**.

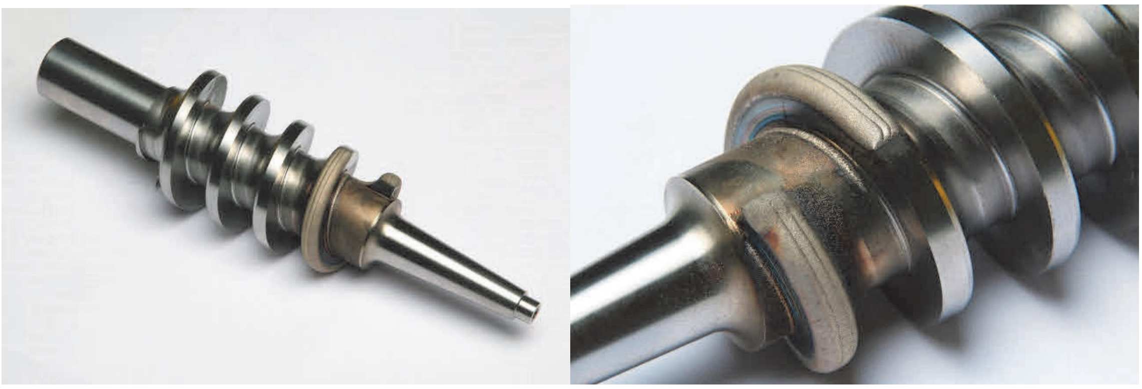

Figure 4 The milling screw after laser cladding

Figure 5 The laser cladded milling screw after testing in production

The cladded milling screw was 4 days in production when the abrasive wear degradation prevents further utilization. This is a significant improvement, the untreated part last only 4 hours. Moreover, the cladded top of the first thread does not show any signs of abrasion, but the abrasion now appeared on the forefront of the screw thread. This shows, that the laser cladded WC-NiCrBSi coating has high potential to protect the part from the abrasion, but further optimization of treated areas is necessary to achieve best results and prolong the lifetime of the milling screw much more.

4. CONCLUSION

The wear resistant WC-NiCrBSi coating was successfully cladded by solid state laser on the thread of the milling screw used in sawdust processing. The microstructure of the coating is nonhomogeneous, a higher amount of undissolved carbide particles appeared under surface, while in the coating the majority of the carbide particles is dissolved. The milling screw with cladded coating shows significant incensement in a lifetime. Untreated part lasts only 4 hours and the cladded part up to 4 days. Moreover, the cladded coating does not show any wear signs, but newly area where the abrasion took part on the forefront of the thread. This means that further optimization of the treated area is necessary to achieve more incensement in part lifetime.

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