LASER CLADDING OF TIN BASED COATINGS FOR INDUSTRIAL BEARINGS APPLICATION

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Abstract

The quality and friction properties of sliding surfaces in industrial bearing are fundamental to their performance. Tin-based coatings applied by centrifugal and static casting are commonly used for bearing lining. Due to limitations of this technology, alternatives for applying the tin-based lining are sought. This study focuses on one possible alternative to applying tin-based coatings – laser cladding. The influence of laser cladding processing parameters on the properties and applicability of tin-based coating is analyzed. The goal of the process optimization is to achieve high productivity with the well-bonded coating without defects. The microstructural of cladded coating as well as the adhesion properties and presented and discussed. The processing parameters which lead to coatings fulfilling manufacturer requirements are selected.

Keywords: Laser cladding, bearings, tin alloys, coatings

1. INTRODUCTION

For the lining of sliding surfaces of hydrodynamic bearings, a tin-based alloys are usually used. The key criterium for the functional lining is to be applied without unwanted particles, which have a higher hardness than the applied composition. These unwanted particles could damage the shaft, the entire bearing, and the system. Furthermore, sufficient adhesion strength is required at the interface of the base material of the bearing and the liner. The usual method of tin-based lining applications is centrifugal and static casting with these methods, the adhesion of the coating is given by the diffusion of tin into the steel base.

The still growing demands for a higher quality of the lining, sufficient adhesion strength, economic and environmental requirements leads to test new methods for lining applications. The possible methods for applying the tin-based coating is for example thermals spraying [1].

Laser cladding is a modern technology capable of producing homogeneous coatings without structural defects and thickness limitations. At the same time, it makes it possible to achieve a strong, metallurgical bond between the coating and the substrate. On the other hand, in the case of laser cladding, it is necessary to take into account the formation of a heat affected area to a certain depth below the surface, significant internal stresses and related deformations of the part, although compared to other welding technologies, more precise control of energy input [2]. Laser cladding is usually used for producing coating with materials such as Fe, Co, and Ni [3-5] based alloys or Metal matrix composite – hard carbides in Co or Ni-base matrix [6-8]. Nevertheless, it can be possibly used to produce coating other materials, such as Tin-based alloy. In this case, the significant difference in the melting point of coating and material can cause significant problems. However, it can still be achievable as documented by [9].

The aim of the development activities is to test laser cladding as an alternative technology for applying tin-based compositions, which will meet the requirements for heavily loaded bearings. The process parameters are optimized to achieve high production speed and productivity. The key criterion is the adhesion of cladded coatings to the substrate as well as the final composition and quality of produced coatings.

2. EXPERIMENTAL PROCEDURE

Laser cladding was realized by the Solid state laser Trumpf TruDisk 8002 with Precitec coaxial 4-way cladding head YC52. The powder used for the cladding was BABTEC 29240 by Castoline with chemical composition Sn7,5Sb3,5Cu, the particle size distribution is 45 – 125 µm. The carbon steel S235JR was used as a substrate.

Starting parameters for laser cladding were based on previous experiments witch Tin-based composition. The experiment was designed to highly increase the process speed while maintaining an efficient layer thickness. The test parameters were: Process speed S = 100 – 200 cm/min; Laser Power P = 200 – 3000 W; powder feed rate F = 15 - 34 g/min; laser spot diameter was 3,4 mm; argon was used as a transporting and shielding gas. Individual beads were cladded as well as one- and two-layer coating from selected parameters. Finally, two sets of parameters were chosen and from both variants a sample with dimensions 150 · 100 mm was cladded. The final parameters were as follows:

1) 2 layer coating, S = 100 cm/min, P = 1800/1600 W (for the first/subsequent layer),
2) 3-layer coating, S = 200 cm/min, P = 2400/2200 W, (for the first/subsequent layer).

The microstructures were evaluated on the coating's cross sections, prepared by the standard metallographic procedure using a 3D optical microscope HIROX KH7000 and further using electron microscopy on an EVO MA25 from Zeiss, with an EDS detector SDD X Max 20 from Oxford Instruments. The adhesion of the coating was evaluated by a tensile test at room temperature according to DIN ISO 4386-2. Six samples for each variant of the coating was prepared and tested, the sample for the tensile test is shown in **Figure 1**.

Figure 1 Prepared sample for the tensile test (left), sample after test with torn out coating.

3. RESULTS AND DISCUSSIONS

The microstructure of the laser cladded Sn-based coating cladded with process parameters selection 1 is depicted in **Figure 2**. The overall structure is depicted in **Figure 2a** from an optical microscope (OM) without etching. The coating homogeneous without any significant porosity or any structural imperfections. The interface of the coating with base materials is not clear on OM. The layers of the coating are ideally connected, the interface between these layers is not detectable. **Figure 2b** is from OM of the sample after etching. The inner structure of the coating is more pronounced, the distribution mixture of individual phases is clearly visible. The individual phases create small fractions which are distributed very homogenously in the structure. **Figure 2c** shows detail of the coating-substrate interface from SEM (Scanning electron microscopy), it can be seen that the interface is created by a thin layer of a mixture of both materials. This layer ensures adhesion of the coating to a base material. The interface is without any pores, impurities, or any other imperfections. The details of the inner structure from SEM with the BSE (Backscattered-Electron) detector are depicted in **Figure 2d**, it shows the details of phase fractions.

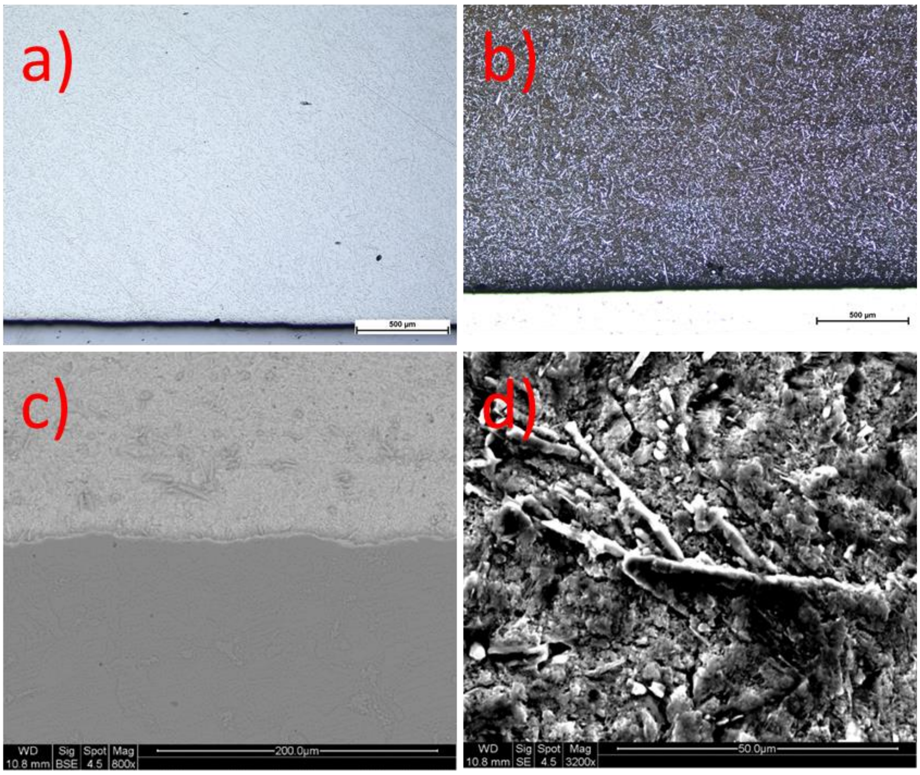

Figure 2 Microstructure of laser cladded coating variant 1
a) OM, b) OM of the etched sample, c) SEM, detail of interface, d) SEM, BSE detail of the inner structure.

Figure 3 shows the locations of EDX (Energy-dispersive X-ray spectroscopy) analysis on the coating of variant 1. The content of the elements Sn, Sb, Cu, and Sn in given locations is presented in **Table 1**, as well as the corresponding phase delivered from Sb-Sn binary diagram [10]. The majority of coating consists of the αSn phase (light gray) with evenly distributed precipitated Sb_2Sn_3 (dark). Rarely there are areas of the β phase (darker grey). The content of Fe in the coating is minimal due to the very low dilution of the coating to the substrate.

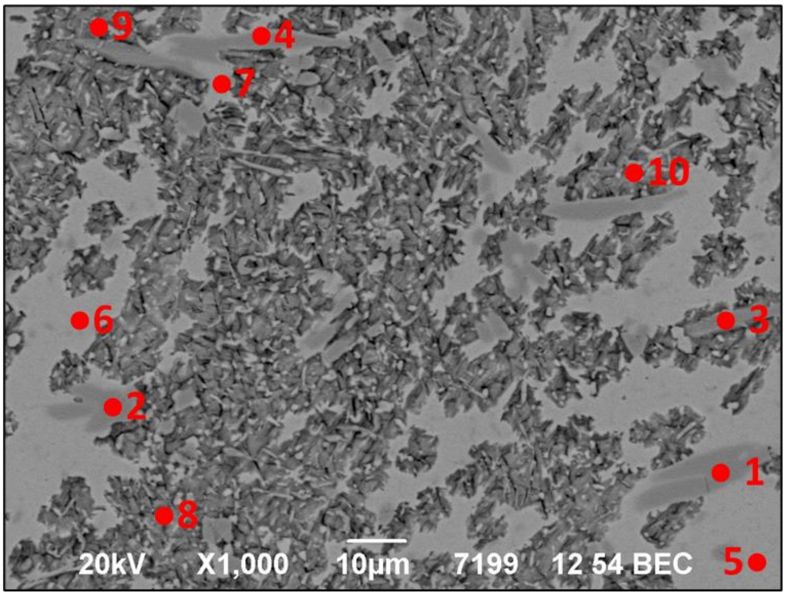

Figure 3 Location of EDX analysis, 1-4 β phase, 5-7 αSn, 8-10 Sb_2Sn_3.

Table 1 The weight percentage of individual elements from EDX analysis

Location	Sn	Sb	Cu	Fe	Phase
1	60.3	2.1	34.1	1.4	β
2	58.2	2.4	34.0	2.2	
3	61.2	2.9	35.4	0.5	
4	59.7	2.6	34.6	0.6	
5	90.5	7.7	0.3	0.0	αSn
6	92.8	6.1	0.4	0.2	
7	92.5	5.0	1.1	0.0	
8	77.2	16.2	5.0	0.2	Sb_2Sn_3
9	80.1	16.4	1.9	0.3	
10	80.8	18.0	0.0	0.0	

The detailed EDX analysis of interface coating-substrate is depicted in **Figure 4** for the coating cladded with parameters variant 1 and **Figure 5** for variant 2. Both pictures show the dependence of the element content in dependence on the distance from the interface. As well as the actual picture from the interface. The dilution of the coating to the substrate is minimal, the interface layer with a mixture of materials is several micrometers thin.

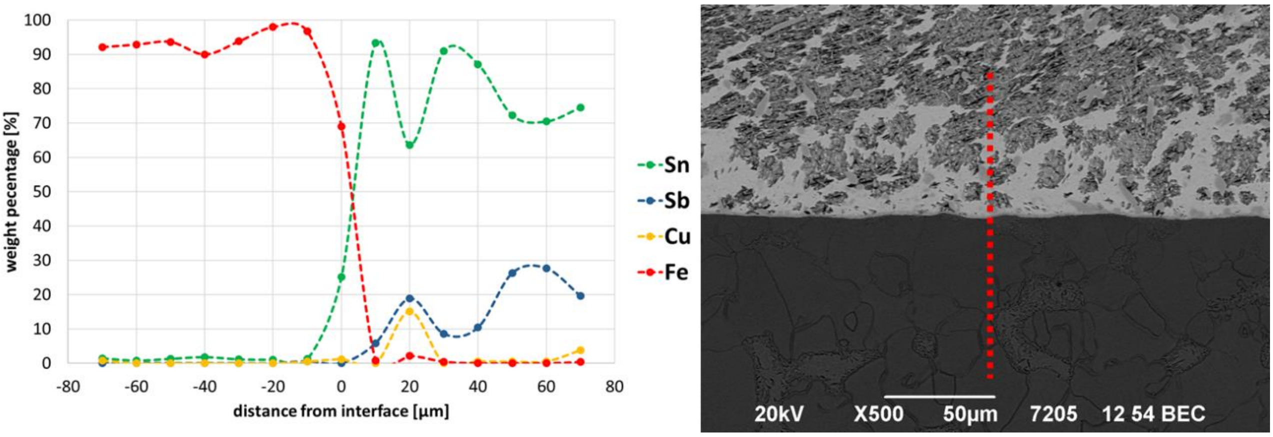

Figure 4 The EDX analysis of interface for the coating cladded with parameters variant 1

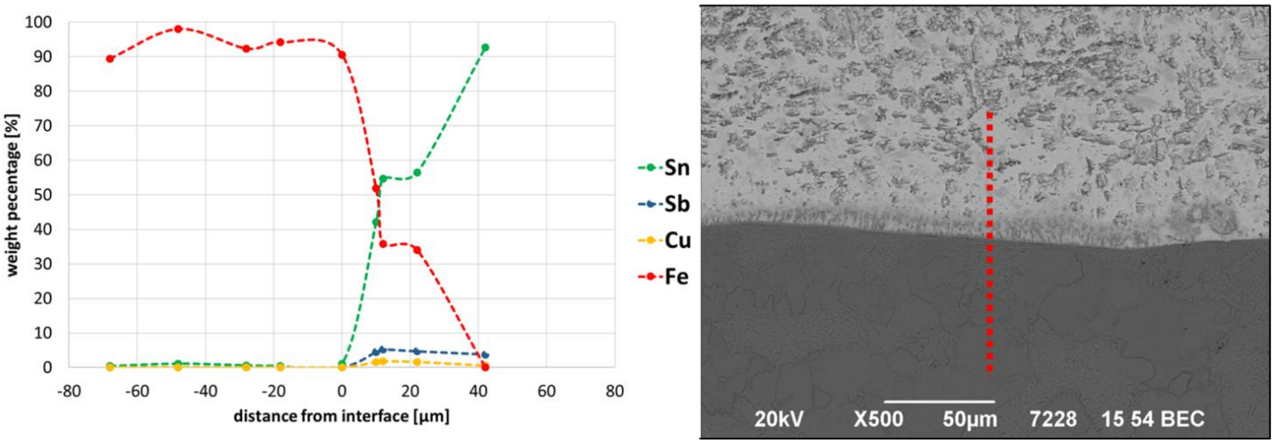

Figure 5 The EDX analysis of interface for the coating cladded with parameters variant 2

Table 2 Results of the tensile test according to norm DIN ISO 4386-2

Sample	A [mm^2]	Fmax [N]	Rch [MPa]	Sample	A [mm^2]	Fmax [N]	Rch [MPa]
1.1	200	10 010	50.05	2.1	200	8 900	44.50
1.2	200	11 160	55.80	2.2	200	8 621	43.11
1.3	200	9 883	49.42	2.3	200	8 152	40.76
1.4	200	9 674	48.37	2.4	200	7 579	37.90
1.5	200	9 375	46.88	2.5	200	8 304	41.52
1.6	200	8 590	42.95	2.6	200	7 886	39.43
		Average	**48.91**			**Average**	**41.20**

The results from the tensile test (DIN ISO 4386-2) are summarized in **Table 2**. According to this norm, the R_{ch} should be minimally 0,6·R_m of the tested material. The required R_{ch}, in this case, is 46,2 MPa. The coating cladded with parameters variant 1 fulfill the minimal adhesion, the measured adhesion of the coating cladded with variant 2 is slightly lower. It has to be noted, that both coatings do not meet the required thickness for this test given by norm and this is 3,9 mm. The thickness of the coatings was 3,4 mm for the variant 1 and 3 mm for the variant 2 respectively. The insufficient thickness could negatively influence the results of the tensile test. Nevertheless, the adhesion of the coatings is very good, slightly lower in the case of the coating cladded with higher speed. The lower adhesion in this case is given by higher process speed during laser cladding.

4. CONCLUSION

Laser cladding of tin-based coating was presented as an alternative process to centrifugal and static casting for applying inner lining in an industrial bearing. The goal of the experimental work was to achieve high productivity and obtain sufficient thickness of the coating while producing coatings without inner structural errors and with high adhesion to the substrate. Two variants of the coating cladded with different process speeds were tested. Both coatings exhibit a very similar inner structure, without pores or any structural imperfections and with a thin bonding layer with the substrate. The bonding strength tested by the tensile test was sufficient for the coating cladded with lover process speed. However, both coating does not have sufficient thickens demanded for the tensile test and for required applications. Adding more layers cladded with the same selection of the process parameters for achieving thicker coating is not time efficient. Therefore, additional experiments are in process to optimize the parameters of the laser cladding of the tin-based coating to be more efficient and applicable in industrial applications.

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