The erosion resistance of laser surface alloyed sintered stainless steels

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ABSTRACT – The sintered stainless steels of the different microstructure (austenitic, ferritic and duplex) were laser alloyed with different carbides (SiC, Si₃N₄) and powders (Cr, FeCr, FeNi) to obtain complex steel microstructure on the surface with improved corrosion and wear resistance. Laser alloying processing conditions on the material erosion resistance was evaluated. Different strategies for introducing alloying powder during laser alloying were applied: direct feeding to the molten metal pool during alloying and filling grooves machined on the sample surface by powder, and then laser surface melting.

1. INTRODUCTION

Sintered stainless steel provides excellent advantages for traditional manufacturing routes like milling for small size components of complex shape produced in large series, i.e. for automotive applications. Sintered stainless steels are cost effective and offer adequate corrosion resistance, oxidation resistance and mechanical strength. However, when compared to wrought stainless steels with the similar chemical composition the sintered materials show lower mechanical properties due to inherent porosity of powder metallurgy (PM) components. The laser surface treatment (remelting, alloying, cladding, etc.) shows many possibilities to improve PM stainless steel properties, like the corrosion resistance, cavitation erosion resistance and wear resistance. Different strategies of laser surface treatment can be adopted for such improvement. One of the most promising is the laser alloying with hard particles (carbides, nitrides, borides) or their compound with the addition of passive state improving elements [1,2].

2. METHODOLOGY

Three types of sintered stainless steel were sintered. The austenitic 316LHD powder of 16.4%Cr, 13.0%Ni, 2.5%Mo, 0.9%Si, 0.1%Mn, 0.02%C. The ferritic stainless steel 410LHD of 11.9%Cr, 0.15%Ni, 0.8%Si, 0.08%Mn, 0.09%C. The third one was produced using 410LHD as starting base powder and then mixed with addition of alloying element powders, such as Fe-Cr, Ni and Mo in the right quantity to obtain chemical composition similar to duplex stainless steel - 22.72Cr, 8.1%Ni, 2.0%Mo, 0.70%Si, 0.06%Mn, 0.03%C - corresponding to duplex stainless steel X2CrNiMo22-8-2 acc. to EN designation system.

Prepared powders were compacted at 700MPa and sintered in a vacuum with Ar backfilling at 1250-1260°C per 60 min. The laser surface alloying was done using Rofin DL 020 (HPDL) laser with rectangular laser beam spot of 1.8-6.8mm at Ar atmosphere with the laser beam power of 0.7 kW, 1.4 and 2.1 kW. The surface of sintered stainless steel was alloyed with different powders: Cr, FeCr, FeNi, SiC, Si₃N₄ using different strategies: the powder injection directly into the molten metal pool by the feeder applied on the surface by filling the parallel grooves (depth of 0.5 and 1.0 mm of a triangular shape) machined on the sample surface.

The erosion tests were performed to determine the erosion rate by solid particle impingement in a gas stream. The solid particles used for the erosion tests were natural angular alumina sands with a size of 80 μm. The erodent particle velocity was 70 m/s, and the feed rate of the erosive sand was 2.0 g/min. The distance from the nozzle tip to the tested surface was kept at 10.0 mm. The angle of the particle impingement on the surface was 90°. The erosion test duration was 10 min. The samples were weighed before and after the erosion test to calculate weight loss.

3. RESULTS AND DISCUSSION

The erosion tests of laser alloyed stainless steels with different alloying strategies, where the Cr powder (feed directly to the molten pool) and FeCr, FeNi (feed directly to the molten pool and alloyed by filling the parallel grooves machined on the samples) and carbides SiC and nitride Si₃N₄ filled into parallel grooves machined on the samples, shows a relative weight loss in the wide range from 0.08 to 0.7 ‰ (Figs. 1, 2).

In the case of non-laser treated stainless steels (as sintered conditions) the lowest relative weight loss was found for 410LHD ferritic steel, which was 0.09 ‰, while for austenitic 316LHHD and duplex X2CrNiMo22-8-2 steel was 0.10 and 0.11 ‰ respectively. The sintered stainless steels in as sintered conditions, without laser surface treatment, show a lower relative weight loss of material during the erosion test compared to most of the laser alloyed samples. This phenomenon can be explained by the low hardness of the sintered material, and high plasticity and porosity, which during the erosion test undergoes plastically deforms by erodent impingement and causes its local densification, thus not causing the observed loss of material weight. The erosion resistance of stainless steel surface layers after laser alloying was made for an erosive angle of 90°, for which the material is consumed as a result of spalling out of micro-sized hardened material particles, exhibiting brittle-type behaviour, characteristic for brittle materials.
The results of erosion tests depend on the amount of alloying material delivered to the liquid metal pool during alloying. Basing on relative weight loss after erosion test, it was found that the increase of the laser power during alloying of the austenitic steel 316LHD with Cr and FeCr powders introduced to the liquid metal pool by the feeder reduces the erosion rate of the surface layer. In the case of ferritic steel 410LHD alloyed with FeNi powder also introduced to the alloying zone by the feeder, the lowest relative weight loss of 0.08 ‰ was obtained for alloying with a 2.1 kW laser beam power (Fig. 1a). The results of alloying using the powder feeder are strongly related to applied laser beam power. In general, the use of a maximum laser beam power of 2.1 kW increases the resistance to erosion of the alloyed surface of studied stainless steels. For samples with milled grooves filled with alloying powder and then remelted, it was found that the higher resistance to erosion wear shown alloyed layers obtained on the surface where 2 grooves of 1.0 mm were prepared (Fig. 1b).

Figure 1 The relative weight loss in erosion test of stainless steels alloyed with a) Cr, FeCr and FeNi powders feed directly to the molten metal pool and alloyed with different laser beam powers, scanning rate 0.5 m/min, b) FeCr and FeNi powders filled into grooves machined on the surface, laser beam power 2.1 kW, scanning rate 0.3m/min.

Figure 2 presents the relative weight loss after the erosion test for austenitic 316LHD, ferritic 410LHD and duplex X2CrNiMo22-8-2 steel, alloyed with SiC and Si₃N₄ powders, where the powder filled grooves milled on the surface sample. The SiC alloyed surfaces (Fig. 2a) shows the lowest weight loss for a surface with 3 grooves with a depth of 0.5 mm. The SiC alloying of 410LHD ferritic steel with 3 grooves of 1.0 mm increases the relative weight loss of the samples to 0.7 ‰, which is the maximum value compared to the other tested samples. In this case, numerous cracks in the alloy layer and porosity were observed in the area of erosion crater. Such low resistance to erosive wear results from high saturation of the surface layer in carbon, which created many precipitates of hard carbides and silicides which break brittle under the influence of the erodent and accelerate the weight loss of the surface in an expedited manner.

In the case of laser surface alloying with Si₃N₄ (Fig. 2b), the relationship between surface preparation technology by milling grooves and resistance to erosive wear was not disclosed. For austenitic and ferritic steel alloyed with Si₃N₄ powder, filled into 3 grooves with a depth of 0.5 mm in areas of erosion crater test various porosities were observed, which testify an intensive spalling of micro-sized material volume because of surface fatigue during the test. The lowest relative weight loss of 0.36‰ was registered for duplex steel grade where the powder filled two grooves of 1.0 mm.

4. CONCLUSION
The erosion resistance of the tested steels slightly deteriorates depending on the applied surface laser treatment conditions with respect to as the sintered state. Sintered stainless steels without laser alloying undergo local compaction during perpendicular striking of erodent to the surface, but after they have been laser alloyed, thus hardened, starts to brittle breaks and crumbling in an accelerated manner of successive layers of hardened material. The erosion wear is lower for Cr, FeCr, FeNi laser alloying, where powders were dissolved in the microstructure, and hard phases were not precipitated – introducing powder directly to the molten metal pool. The erosion wear at the incidence angle of 90° of the erodent is high for hard and therefore brittle surface layers obtained as a result of alloying by hard particles (SiC, Si₃N₄). On this basis, it can be expected that at lower incidence angles close to 45° their erosion resistance can be higher.

REFERENCES