Pulsed Nd-YAG laser deposition of TiN and TiAlN coating

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Abstract

This paper demonstrates the feasibility of generating a thin clad coating of TiN and TiAlN on SS304 base material by using the pulsed Nd-YAG laser. In the experiment TiN based coating was created with and without the addition of Al-powder. In the post processing, a precision grinder was employed to smoothen the top surface. SEM, XRD and EDS analysis were employed to study the surface topography etc. Microhardness mapping was performed at various points across the surface. The results show the average microhardness of the coating deposited with TiN is lower (1035 HV) than that of using Al-mixed powder (1264 HV).

Keywords: laser cladding; TiN; TiAlN and surface grinder

1. Introduction

In the recent past years the development in surface modification against erosion / corrosion have undertaken a new dynamic turn in laser cladding of hard materials. The unrelenting demand of low erosion, high wear resistance and increased hardness value with low thermal effects have forced the manufacturers to adopt / develop innovative techniques which could meet this demand. This led to the selective use of laser cladding of nitrides onto various base materials. For the last decade, metal nitrides such as TiN have been widely used as a protective hard coating to increase the lifetime and performance of cutting and forming tools. But the main drawback of TiN is its limited oxidation resistance, which however could be improved by the presence of elements such as Al. Therefore, the development of TiAlN coatings is considered as an alternative to TiN because of its higher oxidation resistance. Various techniques are in use for coating of such hard nitrides onto the different base materials [1] - [4]. But the aim of this paper is to study different aspect of such thin clad coating specifically of TiN and TiAlN using a pulsed Nd-YAG laser applicable for tool industries [5] - [6].

2. Fabrication technology

Below, the most widely applicable technique, used in the present study for such an application, is discussed.

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2.1. The cladding procedure

In this process, a molten pool of the ‘pasted’ or blown powder with a complex three-dimensional shape is formed on the substrate by the laser beam interaction with the powder material. The basic principle described elsewhere [7] could be compared to a process of layered coating. In this case pre-blended metal matrix composite powder is delivered into the laser beam thereby it gets melted and deposited onto the substrate. Alternatively, this process can also be accomplished by locally melting the substrate or the alloying element with the laser beam while simultaneously adding the premixed composite powder. The coating can be achieved through layer-by-layer scanning in the horizontal direction.

3. Experimental

The laser cladding experiments were performed with a pulsed Nd-YAG laser system provided with beam bending optics etc., as shown in Fig. 1. The beam was delivered by a lens of focal length $f = 80$ mm so as to produce a defocused spot size of 300 - 400 $\mu$m on the substrate. The study was carried out in two steps. TiN based composite coating was created with and without the addition of Al-powder. The deposition of TiAlN is performed by using a premixed TiN and Al powder as the source material. The average particle size of the TiN and Al-powder used being 75 $\mu$m and 30 $\mu$m respectively. The powder/mixture is then pasted onto the substrate surface using ethanol. The substrate was moved under the stationary laser beam by a numeric XY-table. The tracks were made by using the optimized process parameters (Table 1) so as to generate the desired clad coat on the test samples. Various types of samples were made on SS304 substrates using the line scan process with an overlap degree of 50-60%. In the post processing, a precision grinder was employed to smoothen the top surface. Figs. 2a-2b and Figs. 3a-3b show the test samples fabricated in the present study. A confocal laser scanning microscope was used for surface profiling as well as the thickness measurement. An average layer thickness of about 7.9 $\mu$m and 18.2 $\mu$m was achieved for TiN and TiAlN clad coat after surface finish (Fig. 2c and Fig. 3c).

![Figure 1. Pulsed Nd-YAG laser system](image)

| Table 1: Laser processing parameters |
|--------------------------------------|
| Wavelength $(\lambda)$ = 1.06 $\mu$m |
| Average power $(P)$ = 75 W           |
| Pulse repetition rate (PRF) = 10 Hz  |
| Pulse width $(t_p)$ = 3.0 ms         |
| Energy $(E)$ = 7.5 J                |
| Assist gas Ar (Pressure) = 6 l/min.  |
The X-ray diffraction (XRD) patterns of the laser clad thin coat of TiN and TiAlN were obtained via conventional powder diffractometry (Model: RIGAKU – ROTAFLEX) using Cu-Kα incident radiation (at a wavelength of \( \lambda = 1.54056 \, \text{Å} \)), and a take-off angle of 2°. The generator settings were 40 kV and 100 mA. The diffraction data were collected over a 2\( \theta \) range of 10–100°, with a step width of 0.02° and a counting time of 5 s per step.

The microhardness measurements were done at various points across the smooth clad surface using a Matsuzawa microhardness tester under loading condition of 300 gf and a dwell time of 10 sec. It results an average value of 1035 HV for TiN which is lower than that of using Al-mixed powder (1264 HV). These values are the average value of 9 measurement points across the precision grinded smooth clad surface of the samples.
Figure 2. (a) Bead appearance, (b) after surface grinding, (c) clad thickness profile, (d) SEM surface micrographic structure and (e) XRD spectra of TiN clad coating.
4. Results and Discussion

For the microscopic observations, various samples were cut, surface polished with a precision grinder. The microstructures were examined using scanning electron microscope (SEM). The results are summarized as below:

The phase composition of the clad coating TiN/TiAlN as analyzed by XRD is shown in Fig. 2e and Fig. 3e respectively. From the XRD results, it can be seen that various sharp TiN and (Ti,Al)N peaks appear in the spectrum, which suggests that coating is mainly composed of these phases. Thus, TiN and TiAlN phase is the main composition in composite coating according to XRD analysis. The coating has a yellowish-brown homogeneous shining surface with SEM microstructure shown in Fig. 2d and Fig. 3d respectively. Besides that the shielding gas argon just can partially protect the powder against reaction with N₂ and O₂ in the air, but as the N₂ content is 4 times than that of O₂ in the air, therefore the TiN/TiAlN phase represents a larger fraction of the coating. As observed from the XRD spectra, diffraction peaks of both TiN and TiAlN more or less coincide. The proximity of the positions of the diffraction peaks for the TiN and TiAlN crystals (both having a face-centred cubic structure, fcc) is due to the fact that their lattice constant values are similar: 4.24173 and 4.194 Å, respectively. It is revealed that TiAlN structure is a (Ti,Al)N ternary phase, whose composition, is expressed by the formula Ti₅₅Al₂₆N₃₉. In fact adding aluminum to the TiN phase generally gives a polar interphase resulting in metallic or covalent bonding, thus TiAlN coatings also possesses better properties than do TiN coatings [3].

5. Conclusion

In summary, TiN and TiAlN composite coatings were successfully prepared using pulsed Nd-YAG laser deposition process. The dense and almost defect free clad coat surface is achieved after precision grinding resulting a smooth clad thickness of about 7.9 μm and 18.2 μm respectively. The X-ray diffraction results evidenced the existence of TiN and TiAlN phases in the corresponding coatings. The addition of Al to TiN can improve the anticorrosion character and increase the microhardness value from TiN (1035 HV) to TiAlN (1264 HV) by some extent.
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