Project Title: Coating of γ-TiAl alloy using in gas turbine blades via two-stepped process of gas-phase aluminizing and subsequent fluorination

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Project Necessity:

For the cases in which materials have to meet extreme conditions, development of high-temperature materials may play an essential role in technological advancement. The outstanding thermo-mechanical properties of γ-TiAl intermetallic alloy such as good structural stability, low mass density and low diffusion coefficient make it an excellent candidate to fulfil extreme requirements for using in various industrial applications, such as turbine blades, exhaust valves and turbocharger rotors. Recently, an experimental study has been carried out for electromechanical removal behavior of pressed and casted γ-TiAl alloy for aero engine applications. The specific weight of components manufactured from the γ-TiAl alloys is reduced by a factor of 2 compared to the presently used Ni-based superalloys. On the hand, this type of intermetallic alloy suffers from insufficient oxidation resistance at temperatures above 750°C. This inconvenience may be related to this fact that γ-TiAl intermetallic compounds could not form a protective and dense Al_2O_3 layer, but form a brittle, porous and non-protective TiO_2 + Al_2O_3 mixed layer on their free surfaces at oxidation environment in higher temperatures. This matter has caused to restrict the application range of γ-TiAl alloy.

Project Goals:

The aim of the present work is to investigate the microstructure of TBC coating formed on γ-TiAl[Ti-48Al-2Nb-2Cr (at. %)] alloy by using the APS process. Also, the high temperature oxidation of the resulting TBC coating was

evaluated in this study. Moreover, in order to improve the erosion resistance of γ-TiAl super-alloys, a TiN coating is applied to the free surface of this type of super-alloy using PVD technique. Thereafter, the coated samples are subjected to a fretting load to estimate the obtained improvement in the erosion resistance of samples via the considered coating process and TiN coating material.

Abstract:

Among various coating processes to improve the resistance of an alloy against high-temperature oxidation, the slurry techniques, especially the powder segmentation method, are so simple to perform, as well as they have the capability to make resistive layers against oxidation on the free surface of an alloy. Also, this type of coating techniques have been widely utilized to coat hos sections of power plant turbines. Recently, several investigations have been carried out to employ this coating technique for γ-TiAl super-alloy to obtain coating as more efficient as possible.

One of novel methods to improve the resistance of γ-TiAl super-alloy against high-temperature oxidation is the two-stepped process of gas-phase aluminizing and subsequent fluorine treatment. In the current study, nano-powder is used to perform the associated aluminizing process. Therefore, the goals of study include:

- Creation the simple alominized coating and the modified one using fluorine treatment on the samples of γ-TiAl super-alloy using the employed slurry coating method.
- Study in the resistance against high-temperature oxidation of γ-TiAl super-alloy with the aid of cyclic-temperature oxidation test ao 1000℃.
- Accurate study on the microstructures of created coating layers with the aid of scanning electron microscope (SEM).
- Study on the mechanical properties and adhesion of the developed coatings
- Study on the influence of using alumina nano-powder on the developed coatings

Steps and Methodologies:

- Creation the simple alominized coating and the modified one using fluorine treatment on the samples of γ-TiAl super-alloy using the employed slurry coating method.
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Main Results (technical outputs, patents, papers, books, reports, etc.):

It is found that the formation of Ni-based single-layered coating on γ-TiAl substrate via AMDRY 365-2 [NiCoCrAlY] powder and using APS process leads to enhance significantly the high temperature oxidation resistance of the γ-TiAl alloy. This prediction is due to making protective oxides of Al_2O_3 together with a little of Y_2O_3, and the oxides of other elements in the single-layered coating during the service in high temperature. Accordingly, the best high temperature oxidation resistance is obtained by the two-layered TBC coating on the γ-TiAl substrate which includes a ceramic top coat of YSZ and a metallic bond coat of NiCoCrAlY. The reason of such anticipation is due to the presence of ZrO_2 and Y_2O_3 protective oxides in the top layer and formation of Al_2O_3, Y_2O_3 and the oxides of other elements in the bond coat.

It is indicated the chemical composition of the bond coat has two separate parts. The first one is the matrix part of bond coat which is made of Ni-based alloy compound. The second one is gray and dark oxides including Al_2O_3 together with a little of Y_2O_3. The presence of these compounds together with the oxides of other elements in the bond coat results in to make adherent thermally growth oxide (TGO) layer with the substrate. This layer causes to enhance the high temperature oxidation of the γ-TiAl alloy. In addition, the map results given in Figure 5 demonstrate the presence of ZrO_2 and Y_2O_3 oxides in the top layer and creation of Al_2O_3 and Y_2O_3 in the bond coat.

Based on the obtained results and discussion, 3 ISI papers published in high-ranked international journals are extracted as below:

- S. Nouri, S. Sahmani, M. Asayesh, M.M. Aghdam. Microstructural characterization of YSZ-CoNiCrAlY two-layered thermal barrier coating formed on γ-TiAl intermetallic alloy via APS process. *Intermetallics* 118 (2020) 106704.
- S. Nouri, S. Sahmani, M. Asayesh, M.M. Aghdam. Improvement of high-temperature oxidation resistance of γ-TiAl intermetallic alloy by YSZ-NiCoCrAlY coating using APS process. *Materials Research Express* 6 (2019) 126541.
- S. Nouri, S. Sahmani, M. Asayesh, M.M. Aghdam. Study on the oxidation resistance of γ-TiAl intermetallic alloy coated via different diffusion coating processes. *Materials Research Express* 6 (2020) 106522.