Analysis and Testing of Nanomaterial Coating on Turbine Blade of Gas Turbine Engine

Suresh R
Assistant Professor
Dept of Aerospace Eng-
Periyar Maniammai Inst of Science & Technology

Archana P
Dept of Aerospace Eng
Periyar Maniammai Inst of Science&Technology

Praveen.M
Dept of Aerospace Eng-
Periyar Maniammai Inst of Science&Technology

Sampoornam S E
Dept of Aerospace Eng
Periyar Maniammai Inst of Science&Technology

Nivashini P
Dept of Aerospace Eng
Periyar Maniammai Inst of Science & Technology

Abstract:- **Nickel based super-alloys are used in high temperature applications such as turbine blades of gas turbine engine. As they possess high strength, good creep resistance, good oxidation and corrosion resistance, they are used in high temperature applications. In Present work, the Inconel 718 was tested by using Thermo gravimetric analysis (TGA), Energy Dispersive X-ray analysis (EDAX) and Physical vapor deposition (PVD). Before coating of Inconel 718 with silicon nitride, TGA and EDAX is measured to find the decomposition and chemical composition at high operating temperature. The Inconel 718 was coated with Silicon Nitride Nano powder particles by using PVD (Sputtering coating) to achieve thermal conductivity. After coating the same TGA and EDAX process are repeated and measured to check whether the operating range (Temperature) is improved or not. According to TGA for coated sample (Inconel 718) the operating range has been improved. The results of the coated and uncoated samples are compared and conclude.**

Keywords- Nano powder coating (Silicon Nitride); High temperature resistance; Thermo gravimetric analysis; Energy Dispersive X-ray analysis; Physical vapor deposition (Sputtering).

INTRODUCTION

Super alloys are mainly used for high temperature applications like used in turbine blades of gas turbines and jet engines [6]. In thermal power plant and aerospace application the components have to operate under severe conditions, such as high operating temperature, high speed and fatigue loading [6]. Inconel 718 is a Nickel based superalloys which is very stronger and resistance to degradation in corrosive or oxidizing environment, so that it is widely used in high temperature parts of aircraft turbine blades. The grain boundaries of superalloys are most likely to provide adequate creep resistance for nickel based super-alloy at high temperature.

During operation, the blades of gas turbines are responsible for extracting energy from the high temperature gas produced by the combustor [1]. So, it is impossible for the superalloy material to retain their properties in high temperature along with ease manufacturing. It is only possible with protective coating on the base material to increases the thermal resistivity. Therefore, protective Coating are used on superalloys in energy conversion and gas turbines to protect their surfaces from oxidation and high temperatures [6].

In general, coating systems can be classified as either diffusion or overlay type, which are distinguished principally by the method of deposition and the structure of the resulting coating substrate bond. Three methods are in current use to deposit coatings, these being chemical Vapour deposition (CVD), physical Vapour deposition (PVD) and Plasma spraying. The CVD process comes under the category of Diffusion coatings. Whereas in PVD and Thermal spraying processes comes under the category of Overlay coatings, in which the desired material is placed over the substrate material [6].

The Nano structured silicon nitride coating exhibit thermal resistance at elevated temperature and provides low thermal conductivity[2] Te most important advantage of silicon nitride coatings on turbine blades is that possess high thermal stability than most metals due to its high melting point. The silicon nitride coating containing about 60 at % silicon exhibits enhanced oxidation resistance in air up to 1400 degree Celsius.

In present work the uncoated and coated substrate of Inconel 718 with silicon nitride has been studied under 1200 ℃.

SUBSTRATE MATERIAL SELECTION

INCONEL 718

Inconel is a Ni–Cr based superalloys family which is used wide range of applications in automobile, aerospace, electronics mechanical properties. Ni and Cr provide resistance to corrosion, oxidation, carburizing and other damage mechanism acting at high temperature. Inconel alloys have good cryogenic properties, good fatigue and mechanical strength at moderate temperatures and relatively good creep behavior [3]. These superalloys are indented for heat treatment recipients, turbines, aviation, nuclear power plants, and so on

ELEMENT OF INCONEL	COMPOSITION IN %
Nickel	55.0
Cobalt	1.00
Chromium	17.0 to 21.0
Molybdenum	2.8 to 3.3
Iron	17.0
Silicon	17.0
Manganese	0.35
Carbon	0.35
Aluminum	0.08
Titanium	0.60
Copper	0.90
Phosphorous	0.30
Boron	0.015
Sulphur	0.006
Tantalum	4.75 to 5.5

TABLE1. COMPOSITION OF INCONEL 718

SILICON NITRIDE

Silicon Nitride Powder is a ceramic material which is used in wide range of applications in industries such as automobile, aerospace, electronics and so on. Because of their low-density, very reliable low maintenance operation high-temperature strength, and thermal conductivity, ceramics are being investigated as potential materials for replacing ordinary metals that are currently used for engine hot section components [9]. Ceramic structures can withstand higher operating temperatures and other harsh environmental factors. In engine turbine blade material is experiencing high temperature environment to prevent the damage, silicon nitride is used as a coating material for its long sustainability in the aircraft engine.

DEVELOPMENT OF COATING

Rectangular specimens were cut to dimensions of 0.5×0.53X3 mm in a wire cut EDM machine in which we can achieve accurate cutting and there will not be any modification within the chemical bonding of the sample provided.

In this work, a nanostructure coating selected for silicon nitride. The sample is placed at the target then the reactive gas like silicon and nitrogen is used to sputter on the sample material [10]. The deposition of coating was done by gas sputtering. From this coating the sample observes the gases well and it is able withstand high temperature and can survive at harsh environment [17].

SPUTTERING PROCESS

The technique of Sputter deposition is a widely used physical vapor deposition method so as to supply a deposit on a substrate is renowned. Sputtering generally involves the disintegration (erosion) of a cathode by inflicting gas ions in an exceedingly air mass surroundings to impinge upon the cathode and physically eject atoms from the cathode surface[11]. The ejected atoms square measure then caused to impinge upon a substrate placed in an exceedingly appropriate location to be within the path of the ejected atoms, thereby leading to a deposit on the surface of the substrate[12].

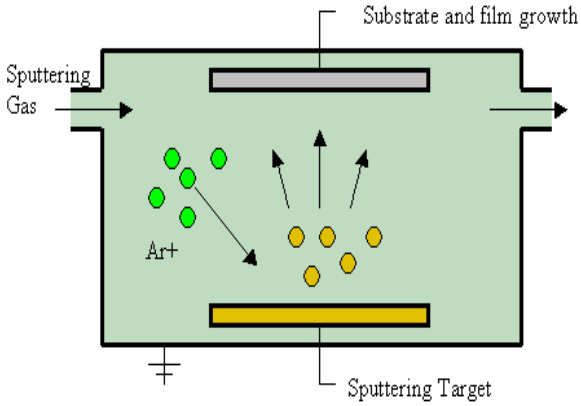

FIG 1 SPUTTERING PROCESS

sputter deposition is that even materials with very high melting points are easily **sputtered** while evaporation of these materials in a resistance evaporator. It takes place at low temperatures for polymer fibers [4].

RESULTS AND DISCUSSION

The present study was an attempt to know about the sustainability of turbine blades in the high operating temperature. Here we discussed about the coated and uncoated sample of Inconel 718 substrate with silicon nitride using the method of EDAX and TGA analysis

EDAX ANALYSIS

In EDAX analysis the micrographs of silicon coated Inconel 718 and Inconel 718 substrate showing surface scale morphology. Micrograph as shown in fig 2 for uncoated Inconel 718 and fig 4 for uncoated Silicon nitride has shown. In EDAX analysis the major elements present over the surface are Oxygen, Silicon, Chromium, Nickel, Iron, Titanium, Sulphur. The substrate on the top of the surface indicates that it is good for heat resistant.

Micrograph as shown in fig 3 is for silicon nitride coated Inconel 718 substrate. Te major elements present over the surface are Oxygen, Silicon, Chromium, Aluminum, Chloride ion, Nickel, Iron. The yellow portion of the micrograph indicates that the presence of composition of elements.

INCONEL 718 BEFORE COATING		INCONEL 718 AFTER COATING WITH SILICON NITRIDE	
Composition	**Weight%**	**Composition**	**Weight%**
Oxygen	5.35	Oxygen	10.10
Silicon	0.66	Silicon	28.24
Chromium	16.93	Chromium	12.05
Iron	19.82	Iron	13.40
Nickel	54.72	Nickel	30.20
Titanium	0.73		
Sulphur	0.73		

TABLE 2 TABULATION OF IN CONEL 718 AND INCONEL 718 COATED WITH SILICON NITRIDE

According to the EDAX analysis the amount of chemical composition for uncoated samples of Inconel 718 and coated samples of Inconel 718 with silicon nitride has been shown in the above table 2.**FIG 2 COMPOSITION OF INCONEL 718**

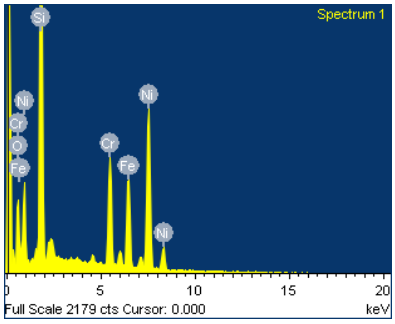

FIG 3 COATED COMPOSITION

Micrographs are shown in figure 2 and fig 3 for uncoated and coated Inconel 718 substrate. The EDAX analysis of fig 2 and 3 shows the major elements present over the surface are Oxygen, Silicon, Chromium, Nickel, Iron, Titanium, Sulphur. The yellow portion shows that amount of composition of each element.

SILICON NITRIDE BEFORE COATING		**INCONEL 718 AFTER COATING WITH SILICON NITRIDE**	
Composition	**Weight %**	**Composition**	**Weight%**
Oxygen	47.94	Oxygen	10.10
Silicon	40.65	Silicon	28.24
Aluminium	2.11	Chromium	12.05
Chloride Ion	9.29	Iron	13.40
		Nickel	30.20

TABLE 3 TABULATION OF SILICON NITRIDE AND INCONEL 718 COATED WITH SILICON NITRIDE

According to the EDAX analysis the amount of chemical composition for uncoated samples of silicon nitride and coated samples of Inconel 718 with silicon nitride has been shown in the above table 3.

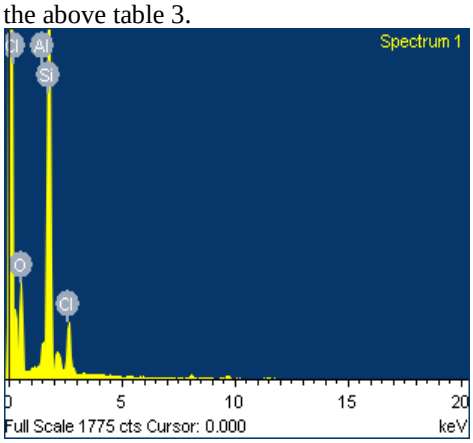

FIG 4 UNCOATED COMPOSITION OF SILICON NITRIDE

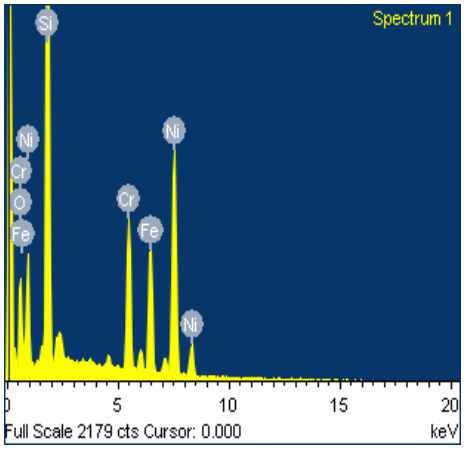

FIG 5 COATED COMPOSITION OF INCONEL 718

Micrographs are shown in figure 2 and fig 3for coated and uncoated Inconel 718 substrate. The EDAX analysis of fig 17 and 18 shows the major elements present over the surface are Oxygen, Silicon, Chromium, Aluminum, Chloride ion, Nickel, Iron. The yellow portion shows that amount of composition of each element.

TGA ANALYSIS

Thermo gravimetric analysis was done to know the chemical and physical properties of materials are measured as a function as a increasing temperature[13].Therefore, it is used in the analysis of volatile products, gaseous products lost during the reaction in thermoplastics, thermosets, elastomers, composites, films, fibers, coatings, paints, etc[14]. In this paper the TGA is used for coating analysis and the graph is plotted between temperature and weight has been shown in the below fig 7.

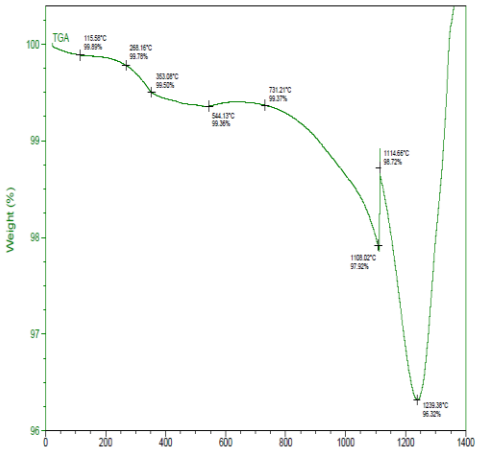

FIG 6 TGA OF INCONEL 718 WITH SIN COATING

In this analysis the weight of the sample gets decreased by increasing its temperature. The weight of the sample is 16.2470 mg. At 1108.02°C the coated sample of Inconel 718 substrate gets decomposed with the sample weight of 97.92%. Compare to the before coated TGA analysis of Inconel 718 and Silicon nitride which is shown in fig----- the operating range of the sample is improved.

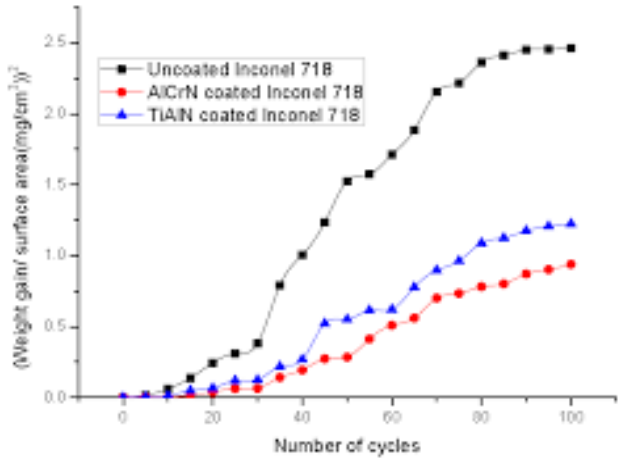

FIG 7 TGA FOR INCONEL 718

The weight of the sample 3.5 is mg. The sample of Inconel 718 gets decompose at 700℃ has been shown in the above fig 7. This graph is taken from the references paper "High Temperature Oxidation Behavior of Nanostructure AlCrN and TiAlN coated Inconel 718 Substrate".

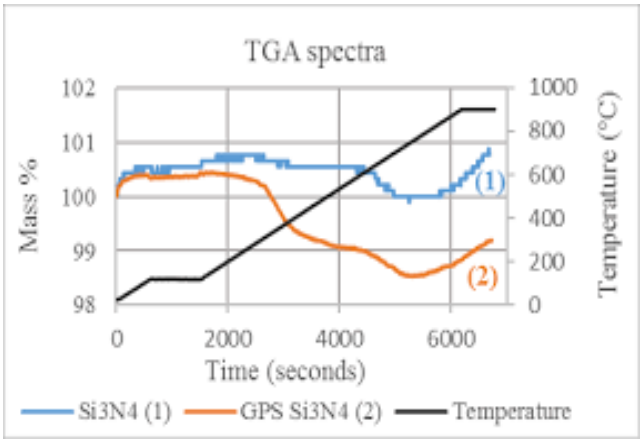

FIG 8 TGA FOR INCONEL 718

The sample of Silicon nitride gets decomposed with the weight of at 700℃ has been shown in the above fig 20. This graph is taken from the references paper "Functionalized silicon nitride as reinforcement in epoxy polymer composites with enhanced mechanical properties".

CONCLUSION

Above experimentation shows that optimum value can be found out by using TGA analysis. The major characteristics of EDAX analysis for coated sample are Oxygen, Silicon Chromium, Iron and Nickel.

The decomposition rate for coated sample of TGA analysis is 1108°C with sample weight of 97.92%.

By comparing the coated and uncoated samples of EDAX and TGA analysis, the coated sample proves that it can better sustain in high temperature environments compared to uncoated samples of Inconel 718 substrate.

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