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Adaptive work performance analysis of INCONEL-738 for use in Gas turbine Blade and its application in Turbo machinery

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Abstract- *Turbo machinery is basically Describe in mechanical engineering, there Describe turbine, Compressor, diffuser, combustion chamber and nozzle. The IN-738 is nickel base super alloy. This is high performance super alloy, this super alloy produce high temperature strength with high strength. In this experiment test Tensile and thermal expansion are concluded, In order to perform successfully and economically at high temperatures, a material must have at least two essential characteristics: it must be strong, since increasing temperature tends to reduce strength, and it must have resistance to its environment. Since oxidation and corrosion attack also increase with temperature.*

Keywords- IN-738; Ni-based Super alloy; Turbo machine; Gas turbine materials; alloys; tensile Test; thermal expansion

Introduction-

The IN-738 is nickel base super alloy. This is high performance super alloy. Super alloys are heat-resisting alloys, this are primarily used in Turbo machinery, gas turbines, coal conversion plants, and chemical process industries, and for other specialized applications requiring heat and/or corrosion resistance. A note worthy feature of nickel-base alloys is their use in load-bearing applications at temperatures in excess of 80% of their incipient melting temperatures, a fraction that is higher than for any other class of engineering alloys.

Inconel 738 is most commonly used for gas turbine blades and vanes for industrial use and its Excellent Corrosion Resistance of Inconel-738.

This super alloy produces high temperature strength with high strength. High temperature alloy are also super alloy and in turbo machinery many super alloy are used. Any devices that extract energy from or impart energy to a continuously moving stream of fluid can be called a Turbo machine. Elaborating, a turbo machine is a power or head generating machine which employs the dynamic action of a rotating element, the rotor; the action of the rotor changes the energy level of the continuously flowing fluid through the machine. Turbines, compressors and fans are all members of this family of machines.

High Temperature Materials-

A metal or alloy, which is use in Gas turbine blade, serves above about 1000°F (540°C). More, specifically the materials which operate at such temperatures consist principally of some stainless steels, super alloys, refractory metals, and certain ceramic materials. The giant class of alloys called steels usually sees service below 1000°F. The most demanding applications for high-temperature materials are found in aircraft jet engines, industrial gas turbines, and nuclear reactors. However, many furnaces and electronic and lighting devices operate at such high temperatures.

High-temperature materials, always vital, have acquired an even greater importance because of developing crisis in providing society with sufficient energy. The machinery which produces electricity or some other form of power from a heat source operates according to the basic Carnot cycle law, where the efficiency of the device depends on the difference between its highest operating temperature and its lowest temperature. Thus, the greater this difference, the more efficient is the device a result giving great impetus to create materials that operate at very high temperatures.

A definition of high temperature can be confusing. One often used definition in materials science and technology is that it is a temperature equal to, or greater than, about two-thirds of the melting point of a solid. Another definition, attributed to Leo Brewer, is that high temperatures are those at which extrapolations of a material's properties, kinetics, and chemical behavior from near ambient temperatures are no longer valid. For example, chemical reactions not favorable at room temperature may become important at high temperatures-thermodynamic properties rather than kinetics tends to determine the high temperature reactivity of a material.

While some applications involve the use of these materials at high temperatures, others require materials processed at high temperatures for room temperature uses. In electrochemistry, the interaction of these materials with each other, the atmosphere, and the movement of electrons are of high importance

Experimental Analysis-

An important characteristic of high-temperature strength is that it must always be considered with respect to some time scale. The tensile properties of most engineering metals at room temperature are independent of time, for practical purposes The tensile test and thermal expansion are evaluated on ASTM Standard specimens, All testing specimens are prepared as per as ASTM Standard. Tensile tests methods cover the tension testing of metallic materials in any form at room temperature, specifically the methods of determination of yield strength, yield point elongation, tensile strength, elongation, and reduction of area. Tension tests provide information on the strength and ductility of materials. This information may be useful in comparisons of materials, alloy development, quality control, and design under certain circumstances and we also discuss the thermal expansion test that can provide useful information about metallic materials may correlate to tensile strength, wear resistance, ductility, or other physical characteristics of metallic materials, and may be useful in quality control and selection of materials. The results of tensile of specimens machined to standardized dimensions from selected portions of a part or material may not totally represent the strength and ductility properties of the entire end product or its in-service behavior in different environments. These test methods are considered satisfactory for acceptance testing of commercial shipments. The test methods have been used extensively in the trade for this purpose and the stress rupture test is used to determine the time necessary to produce failure while material is subjected to constant load at a constant temperature.

The cast nickel-based Super alloy IN-738 is used as a blade material in the first row of the high pressure stage of gas turbines.

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A High Carbon Version Designated IN-738C and a low Carbon Version Designated IN-738LC . The Data reported on this bulletin were obtained primarily on high carbon (c) material. Where data are reported low carbon (LC) modification, they will be so indicated.

Specimen

In this study, tensile tests were conducted to evaluate the mechanical characteristics of IN-738. The specimens prepared for testing as per ASTM E-8 which is cylindrical in shape. Fig.1 shows the shape of the specimens used in the tests.

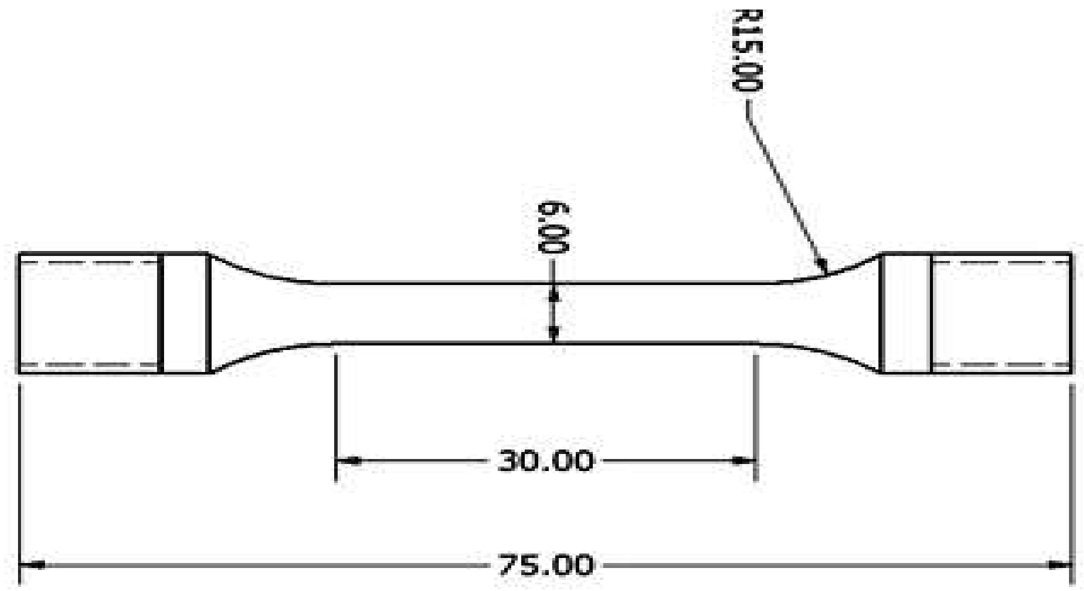

Fig.1 Tensile test specimen (mm)

A tensile specimen is a standardized sample cross-section. It has two shoulders and a gauge length (30 mm) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area.

The Nominal Compositions and Recommended range to which alloy IN-738 is produced are shown in Table-I. Two versions are shown: high carbon IN-738C and low carbon IN-738LC.

Tensile Test

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure-

TABLE I

Nominal Composition of Alloy IN-738

Composition (wt %)				
Element	IN-738C		IN-738LC	
	Range	**Nominal**	**Range**	**Nominal**
Carbon	0.15-0.20	0.17	0.09-0.13	0.11
Cobalt	8.00-9.00	8.50	3.00-9.00	8.50
Chromium	15.70-16.30	16.00	15.70-16.30	16.00
Molybdenum	1.50-2.00	1.75	1.50-2.00	1.75
Tungsten	2.40-2.80	2.60	2.40-2.80	2.60
Tantalum	1.50-2.00	1.75	1.50-2.00	1.75
Columbium (Niobium)	0.60-1.10	0.90	0.60-1.10	0.90
Aluminum	3.20-3.70	3.40	3.20-3.70	3.40
Titanium	3.20-3.70	3.40	3.20-3.70	3.40
Aluminium+Titanium	6.50-7.20	6.80	6.50-7.20	6.80
Boron	0.005-0.015	0.010	0.007-0.012	0.010
Zirconium	0.05-0.15	0.10	0.03-0.08	0.05
Iron	0.05max	LAP[1]	0.05max	LAP[1]
Manganese	0.02max	LAP	0.02max	LAP
Silicon	0.30max	LAP	0.30max	LAP
Sulfur	0.015max	LAP	0.015max	LAP
Nickel	Balance	Balance (61)	Balance	Balance (61)

Turbine blades and vanes in gas turbines and aero engines are subjected to very high temperatures and mechanical loads. These hot section components especially behind the combustion chamber are made of single crystal nickel-based super alloys in order to withstand the critical loadings resulted from the complex combination of high thermal and high mechanical loadings. Accordingly, the creep properties in the single crystal nickel-based super alloys have been studied in great detail. The material tested in the present work is a second generation of IN-738 super alloy. These Super alloy's elements are produce different effective strength, some elements which are produces effective strength.

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Tensile Properties

Typical Room temperature tensile properties of low carbon (LC) and high carbon (C) alloy IN-738 are compared in Table II. The Properties are essentially the same, with the low carbon version having lower strength and higher ductility.

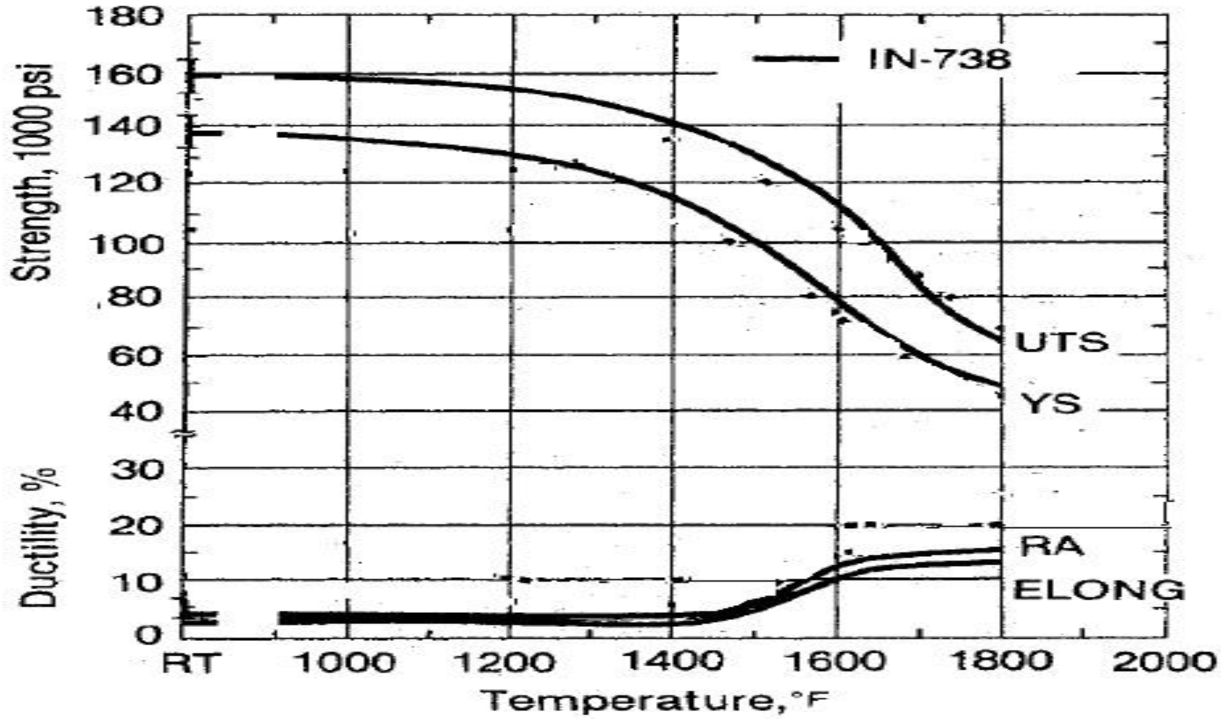

Fig.2 Typical Tensile Properties of Alloy IN-738

TABLE II

Room Temperature Tensile Properties of Alloy IN-738*

Properties	Low Carbon IN-738LC	High Carbon IN-738C
0.2% Yield Strength, psi	130,000	138,000
Tensile Strength, psi	150,000	159,000
Elongation, %	7	5.5
Reduction of Area, %	9	5

* Determined on cast-to-size test bars.

The main reason for the existence of super alloys is their outstanding strength at elevated temperatures, which make them suitable for the fabrication of gas turbine components. During the operation of power generation gas turbines, the blades and other elements of hot gas path undergo service-induced degradation, which may be natural or accelerated due to different causes. The degradation or damage may have a metallurgical or mechanical origin and results in reduction of equipment reliability and availability. To identify the causes of the blade failures, a complete investigation has to be carried out, integrating both the mechanical analyses and metallurgical examination.

The Short time e Elevated Temperature Tensile Properties of Alloy IN-738 are tabulated in below:-

TABLE III

Short-Time Elevated Temperature Tensile Properties of Alloy IN-738

Temperature	Yield Strength (0.2% offset) Psi	Tensile Strength Psi	Elongation (2in.) %	Reduction of Area %
70	138,000	159,000	5.5	5
1200	132,000	153,000	7	7
1400	115,000	140,000	6.5	9
1600	80,000	112,000	11	13
1800	50,000	66,000	13	15

Metallurgical examination can be very effective in determining whether the failure is related to material defects, mechanical marks, poor surface finish, initial flaws or heat treatment. There are different factors, which influence blade lifetime, as design and operation conditions but the latter are more critical.

Thermal Expansion

Thermal expansion is the tendency of matter to change in space, area and volume in response to a change in temperature, through Heat transfer. Thermal expansion coefficients for Alloy IN-738 are given in table IV. Mean and instantaneous coefficients of thermal expansion are shown in figure 1.

Specimen size:

For the TMA, the test specimen should be between 2 and 10 mm. in length and shall not exceed 10 mm in lateral dimension. The specimen must be flat on both ends. For the dilatometer, the test sample should be approximately 12.7mm (0.5") wide x 75mm (3") long.

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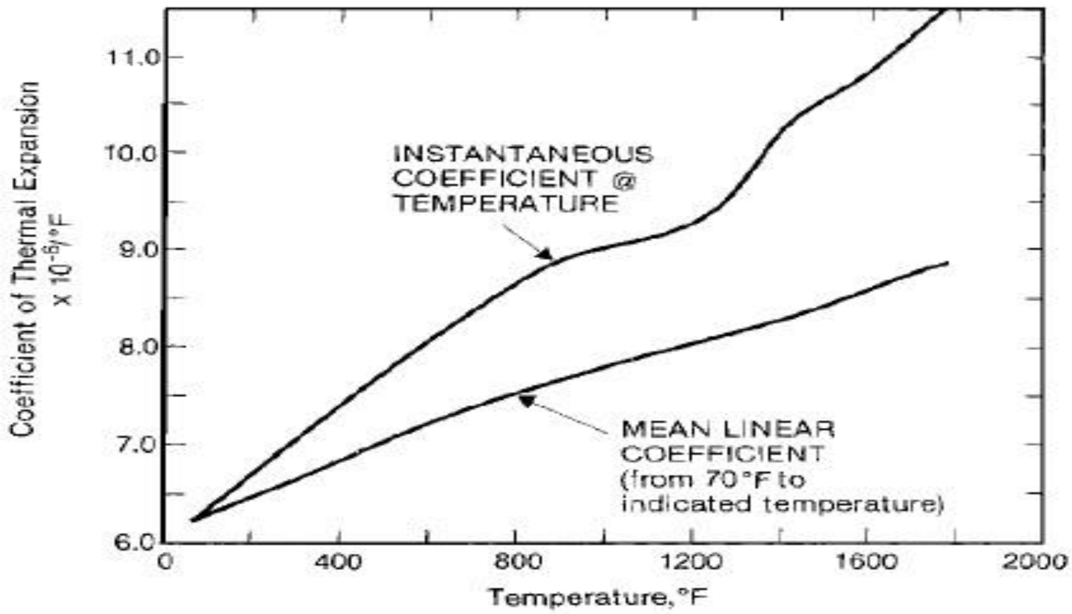

Fig.3 Thermal Expansivity of Alloy IN-738

The Mean Coefficient of Thermal Expansion of Alloy IN-738 is tabulated below:-

TABLE IV

Mean Coefficient of Thermal Expansion of Alloy IN-738

Temperature Interval ^{0}F	Mean Coefficient of Thermal Expansion per ^{0}F
70 to 200	6.45×10^{-6}
70 to 400	6.75
70 to 600	7.15
70 to 800	7.55
70 to 1000	7.75
70 to 1200	8.05
70 to 1400	8.25
70 to 1600	8.55
70 to 1800	8.55

The coefficient of thermal expansion describes how the size of an object changes with a change in temperature. Specifically, it measures the fractional change in size per degree change in temperature at a constant pressure. Several types of coefficients have been developed: volumetric, area, and linear. Which is used depends on the particular application and which dimensions are considered important. For solids, one might only be concerned with the change along a length, or over some area. It is necessary to consider whether the body is free to expand or is constrained.

Conclusion- IN-738 is higher in temperature and strength which sustain to temperature ranges of Gas turbine Blade. In Experimental analysis tensile test, Short-Time Elevated Temperature Tensile test, Room Temperature Tensile test and thermal expansion graph it is clearly suit for Gas turbine Blade.

IN-738 offers a combination of outstanding strength and corrosion resistance better than many high-strength super alloys with lower chromium content. IN-738 is a nickel-based alloy, vacuum-cast and precipitation-hardened, offering exceptional mechanical properties to 1800°F (982°C). IN-738 holds up to the hot corrosive environments found in the turbine industry.

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