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HOT TENSILE PROPERTIES OF INCONEL 706 ALLOY

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ABSTRACT
INCONEL 706 is a high-strength nickel-based super alloy that is commonly used in high-temperature applications such as gas turbines and nuclear reactors. In this study, the hot tensile properties of Inconel 706 were investigated to better understand the material's behavior under high-temperature and high-stress conditions. Tensile tests were conducted at temperatures ranging from 740°, 860°, 940°, 1020°1080°and strain rates ranging from 0.001/s to 1/s. The results showed that the ultimate tensile strength and yield strength of Inconel 706 decreased with increasing temperature, while the elongation increased. The strain rate had a negligible effect on the mechanical properties. Microstructural analysis revealed that the deformation mechanism changed from dislocation slip to dynamic recrystallization as the temperature increased. The activation energy for deformation was calculated to be 421 kJ/mol, indicating that diffusion-controlled mechanisms play an important role in the deformation process. Overall, the hot tensile properties of Inconel 706 were found to be highly dependent on temperature and microstructure, which should be considered in the design and operation of high-temperature components made of this alloy. The output from the tensile testing machine is used for the data in analysis software like MATLAB, Ansys. The aim of investigations conducted in this project is to study the change of the mechanical properties,especially the high temperature mechanical properties of HTPI, at elevated temperatures.
Keywords—INCONEL 706, Temperature, Stress, Strain, analysis

1. Introduction

INCONEL 706, a super alloy based on nickel, finds widespread usage in high-temperature settings such as petrochemical processing equipment, gas turbine engines, and nuclear reactors. Knowledge of the material's hot tensile properties is essential to comprehend its conduct under conditions of elevated temperature and high stress. To appraise mechanical properties at high temperatures, hot tensile testing is a standard practice. This method requires subjecting a specimen to a tensile load at a predetermined temperature, often exceeding the material's recrystallization temperature, to imitate conditions that arise in high-temperature applications. The outcomes of hot tensile testing offer crucial information on the material's strength, ductility, and deformation behaviour at elevated temperatures. Inconel 706 showcases remarkable strength at high temperatures and resistance to oxidation, making it an ideal choice for operation in extreme environments. Acquiring knowledge of its hot tensile properties is pivotal for predicting its performance in such circumstances and ensuring the safety and dependability of equipment that utilizes this

2. Experimental Methods or Methodology

3. INCONEL 706 is a nickel-based superalloy that is primarily composed of nickel, iron, chromium, and niobium, along with other elements such as molybdenum, cobalt, and titanium. The alloy is typically produced using the vacuum induction melting (VIM) method, which involves melting and refining the metal in a vacuum to remove impurities and ensure high purity and uniformity of the material.

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4. Once the metal has been melted and refined, it is usually further processed using methods such as hot forging, hot rolling, or extrusion to shape it into various forms such as bars, sheets, or tubes. The material is then subjected to various heat treatments such as annealing or solution treating to improve its properties such as strength, ductility, and resistance to deformation.

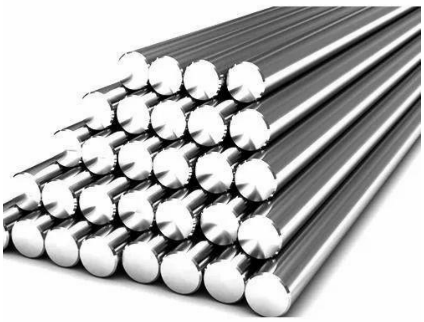

Fig 1. Impact of DOS Attack on Intruder and Authorized User Material

Inconel 706 is known for its excellent high-temperature strength, resistance to oxidation and thermal stability, making it suitable for use in harsh environments that involve high stress and temperature. It is widely used in applications such as gas turbine engines, nuclear reactors, and petrochemical processing equipment.

Inconel 706 is a highly specialized and advanced material that requires careful handling and processing to ensure its quality and performance. It is typically used in critical applications where safety and reliability are paramount, and as such, its production and use are subject to strict quality control measures and standards.

Quenched Tempered Steel

Quenching and tempering are methods utilized to harden and toughen materials like steel and other iron-based alloys. In the quench hardening process, the material is heated and then rapidly cooled to lock its components into place as quickly as possible. The process is precisely controlled, with factors such as heating temperature, cooling method, cooling substance, and cooling speed being dependent on the type of material and desired hardness. The heating range typically falls between 815 and 900 degrees Celsius, with special care taken to ensure stable temperatures as any deviation can lead to distortion in the metal.

It is also essential to maintain a constant temperature for the cooling element to avoid brittleness in the metal. Over time, different cooling substances have been used, starting from water and advancing to mineral oils and inert gases such as nitrogen or helium.

After quenching, the material achieves its maximum hardness, and tempering is then used to increase toughness and ductility by reducing the hardness. Tempering involves heating the quenched material to below the critical point for a specific duration and then allowing it to cool in still air. Both the temperature and duration of heating depend on the material composition, and they determine the amount of hardness removed during tempering

METHODOLOGY

Ultimate Tensile Strength

Tensile strength, also known as ultimate tensile strength (UTS) or simply TS, refers to the maximum stress a material can endure before breaking while being stretched or pulled. In brittle materials, the material often breaks shortly after the yield point is reached. Conversely, in ductile materials, the yield strength is observed, and the ultimate strength is achieved as the material continues to elongate until it reaches the breakpoint.

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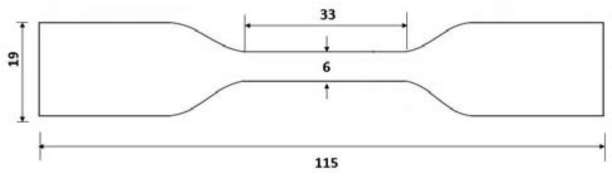
The behaviour of a ductile material under tensile stress can be illustrated using a chart showing its elongation (strain). During the initial stage, elongation is linearly proportional to stress and is elastic in nature, meaning the material returns to its original length once the stress is removed. The point at which the strain becomes non-linear to stress is known as the yield point, and the material elongates more rapidly until the ultimate tensile strength is reached. Once the ultimate strength is achieved, the material will then neck down until it ultimately fractures.



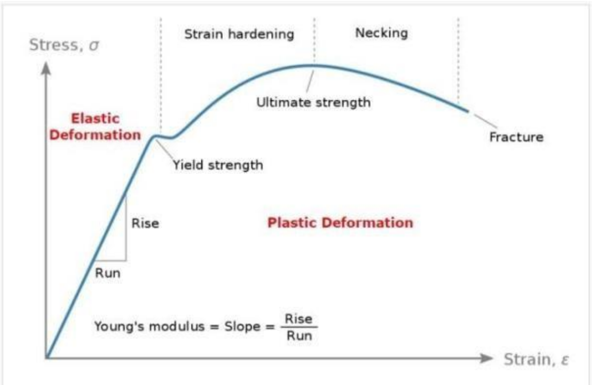


Fig 2.2: Stress Strain Graph Fig 2.3: Tensile Specimen

Compressive Test

A compressive strength test is a mechanical test used to determine the maximum amount of compressive load a material can withstand before fracturing. The test typically involves compressing a test piece, which is usually in the form of a cube, prism, or cylinder, between the platens of a compression-testing machine using a gradually applied load.

Brittle materials such as rock, brick, cast iron, and concrete may exhibit high compressive strengths, but ultimately, they will fracture under sufficient compressive stress. For example, the crushing strength of concrete, determined by breaking a cube and often referred to as cube strength, can reach values of around 3 tons per square inch. In comparison, granite has a crushing strength of around 10 tons per square inch, while cast iron can range from 25 to 60 tons per square inch.

True Stress

True stress is the stress determined by the instantaneous load acting on the. Instantaneous cross-sectional area. True stress is related to engineering stress: Assuming material volume remains constant.

True Strain

True strain is the natural logarithm of the ratio of the instantaneous gauge length to the original gauge length.

Flow Stress

The flow stress changes as deformation proceeds and usually increases as strain accumulates due to work hardening, although the flow stress could decrease due to any recovery process.

Flow Strain

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The flow stress is the stress that must be applied to cause a material to deform at a constant strain rate in its plastic range. Because most materials work harden under these conditions the flow stress is a function of the degree of plastic strain.

Yield Strength

The point at which a material transitions from elastic to plastic behavior is called the yield strength. This is a constant value that represents the upper limit of the material's elastic behavior. Ductile materials, such as metals, typically have higher yield strength values than plastics.

UNIVERSAL TESTING MACHINE: -

A material testing machine, also known as a universal testing machine (UTM), is used to measure the tensile and compressive strength of materials. The machine was previously called a tensometer. The term "universal" in the name indicates that it can perform numerous standard tensile and compression tests on materials, components, and structures

Fig 2.4: Hot Tensile Testing Machine

Tensile Test: The tensile strength of a material is measured by subjecting a single piece of the material to a pulling force applied at one end until it breaks into two parts. This process measures the amount of tension/elongation that the material can withstand before breaking. Compression Test.

5. Results and Discussion

The results showed in stress and straingraph at various temperature is shown below.

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HOT TENSILE TEST AT 740°C

Fig 3.1: Engineering stress and strain at 740°C

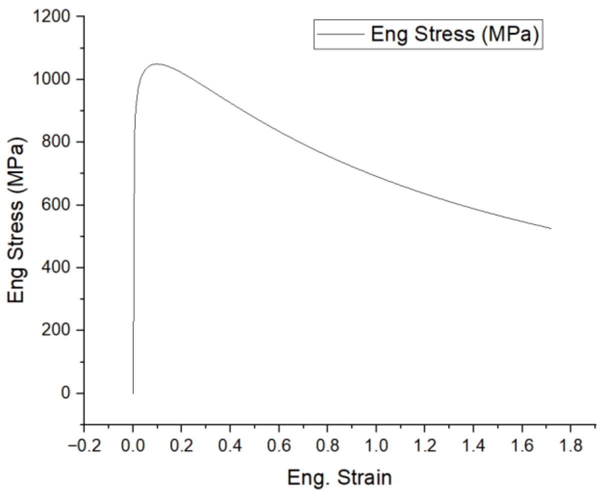
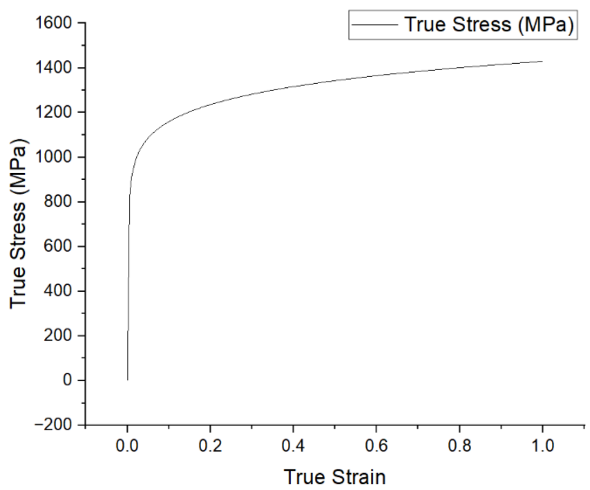


Fig 3.2: True stress and strain at 740°C



TEMPERATURE – 740°C		
PROOF STRESS	YOUNG'S MODULUS	STRAIN RATE
819.1 MPa	152.4 GPa	0.01(1/s)

Table 3.1: Mechanical properties at 740°C

HOT TESILE TEST AT 860°

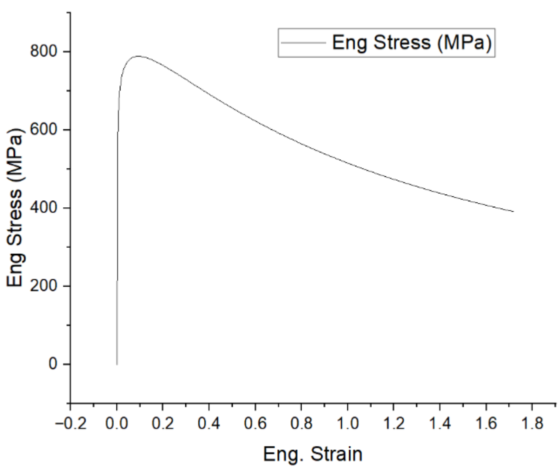
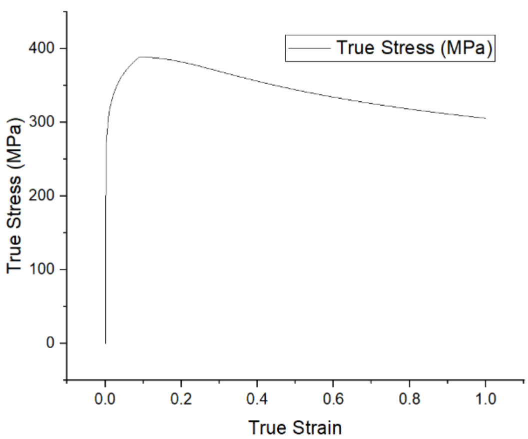


Fig 3.3: Engineering stress and strain at 860°C



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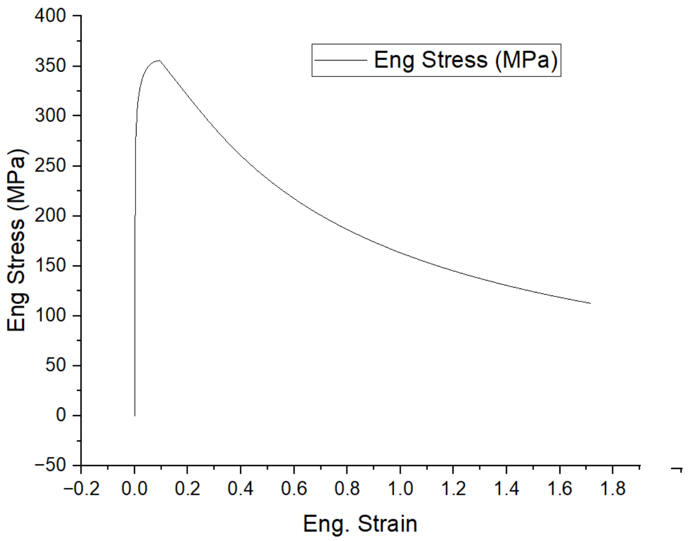
3.4: True stress and strain at 860°C

TEMPERATURE – 860°C		
PROOF STRESS	YOUNG'S MODULUS	STRAIN RATE
623.8 MPa	142.1 GPa	0.01(1/s)

Table 3.2: Mechanical properties at 860°C

HOT TENSILE TEST AT 940°C



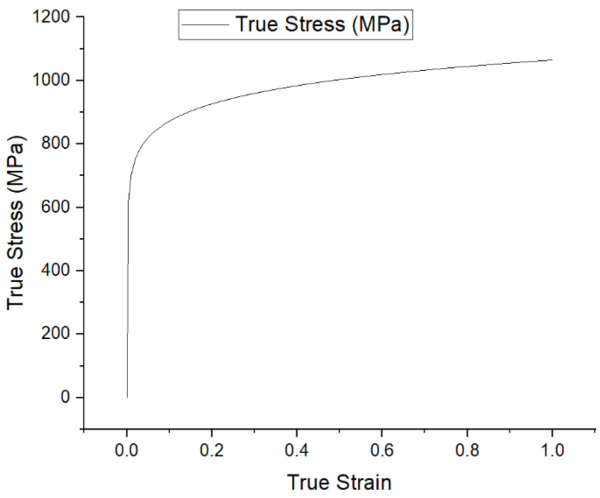


Fig 3.5: Engineering stress and strain at 940°C
Fig 3.6: True stress and strain at 940°C

TEMPERATURE – **940°C**		
PROOF STRESS	YOUNG'S MODULUS	STRAIN RATE
268.4 MPa	134 GPa	0.01(1/s)

Table 3.3: Mechanical properties at 940°C

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HOT TESILE TEST AT 1020°C

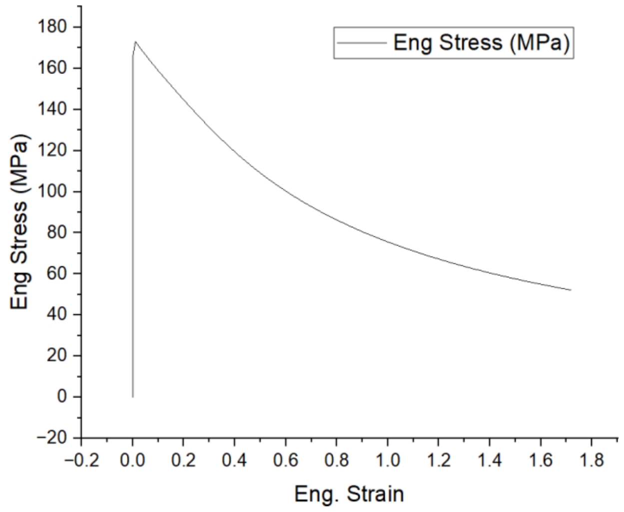


Fig 3.7: Engineering stress and strain at 1020°C

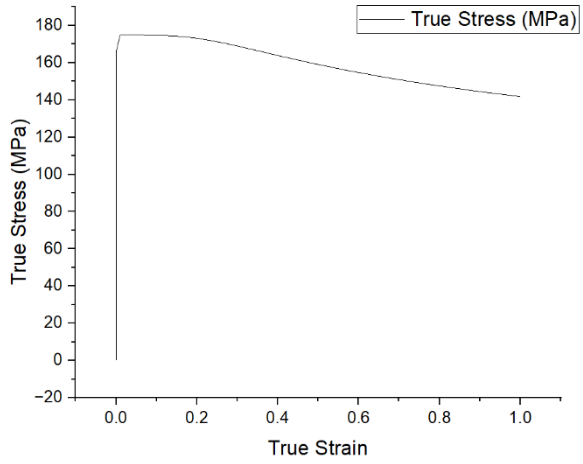
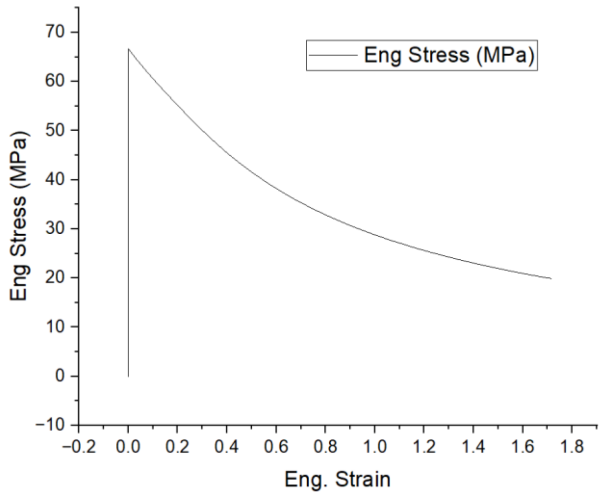


Fig 3.8: True stress and strain at 1020°C

TEMPERATURE – **1020°C**		
PROOF STRESS	YOUNG'S MODULUS	STRAIN RATE
166.6 MPa	127.3 GPa	0.01(1/s)

Table 3.4: Mechanical properties at 1020°C

HOT TENSILE TEST AT 1080°C



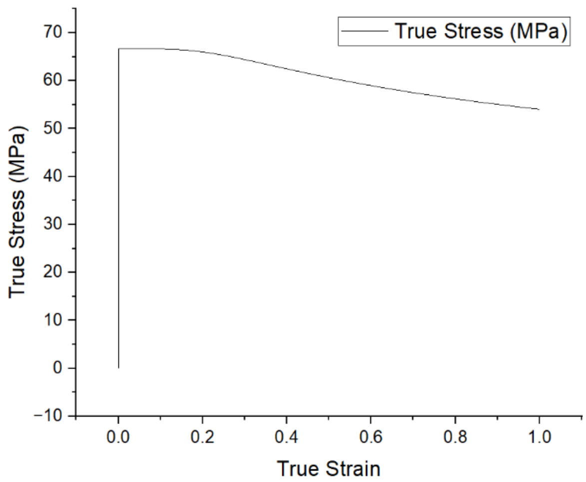


Fig 3.9: Engineering stress and strain at 1000°C
Fig 3.10: True stress and strain at 1080°C

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TEMPERATURE – 1080°C		
PROOF STRESS	YOUNG’S MODULUS	STRAIN RATE
66.7 MPa	113.8 GPa	0.01(1/s)

Table 3.5: Mechanical properties at 1080°C

CONCLUSION

Inconel 706, an alloy primarily composed of nickel, is known for its impressive strength at high temperatures and its ability to resist corrosion and oxidation. Due to these desirable properties, it is frequently employed in industries such as aerospace and gas turbine, where harsh and elevated-temperature environments are prevalent. It is crucial to conduct further research on Inconel 706 to enhance its performance and tailor its properties to suit specific applications. Continuation of such research would ensure the safe and effective use of this material across various industries, making it a critical area of study in the field of materials engineering.

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