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Study of Creep Test on Austenitic Stainless Steel

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Abstract - Study of creep properties of AISI 316 LN stainless steel has been carried out. AISI 316 LN is a contender material for major structural components for high temperature applications in boilers and heat exchangers due to its good mechanical properties at high temperatures, corrosion resistant with chemicals and adequate welding characteristics. The main aim of this research is to obtain creep data and study the compatibility of AISI 316 LN stainless steel for ultra-super critical (USC) boiler and heat exchanger applications. The creep test is carried out at 600°C and 700°C for constant applied loads below the yield strength. Study result obtained, time to undergo creep deformation for the applied parameters are more for AISI 316 LN compared to AISI 316 L. It is concluded that AISI 316 LN has good creep resistance than AISI 316 L.

Keywords - AISI 316 LN, Boiler, Creep deformation**.**

1. Introduction

Success in today's world requires improvement in efficiency, quality and accuracy of testing facilities and testing equipment. Testing is an essential part of all engineering design process [1].

Iron, steel, aluminium, copper, lead and zinc and their alloys are metals that are mostly used for the making appliances, devices, machines, and buildings. Recent developments associated with the innovative use of stainless steel in structural applications demand accurate engineering data. More specifically, the assessment of structural performance requires data along appropriate range of stress, time, temperature, and strain rate [2].

The spectrum of their properties determines the essential demands on testing data. Creep testing machines are mostly used to measure how a given material will perform under load at a specific temperature [3]. Creep is the time-dependent deformation that happens when a material is subjected to a constant load at high temperature over a period [4-5].

Thus, high temperature creep data is the need of the time. The temperature at which a material starts to creep depends upon its melting point [6-7].

2. Material Properties

2.1 AISI 316LN

Stainless Steel: Austenitic (UNS S31653)

2.2 Specification Coverage

Composition shown in Table 1.

Table 1. Material composition

Element	Minimum	Maximum
Chromium	16.0	18.0
Molybdenum	2.0	3.0
Nickel	10.0	14.0
Manganese		2.0
Phosphorus		0.045
Sulphur		0.030
Silicon		0.75
Carbon		0.030
Nitrogen	0.10	0.16
Iron	balance	

ASTM Specification A 240

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2.3 . Physical Properties in Table 2

Table 2. Physical properties

Properties	Value	Units
Density at 72°F (22°C)	8.0	g/cm³
Melting Range	2450 - 2630	°F
	1345 - 1440	°C
Thermal Conductivity at 212 °F (100°C)	14.6	W/m·K
Thermal Expansion coefficient at 68-212°F (20-100°C)	16.5	µ m/m/°C
Thermal Expansion coefficient at 68-932°F (20-500°C)	18.2	µ m/m/°C
Thermal Expansion coefficient at 68- 1832°F (20-1000°C)	19.5	µ m/m/°C

2.4 Mechanical Properties in Table 3.

Typical Room Temperature properties

Table 3. Mechanical properties

Property	ASTM A 240
Yield Strength, 0.2% offset	205 MPa
Ultimate Tensile Strength	515 MPa
Elongation in 2" (51 mm)	40%
Hardness	217 HBS 95 HRB

3. CREEP

Creep is a time-dependent deformation under a certain applied load. Generally, it occurs at high temperature (thermal creep), but can also happen at room temperature in certain materials (e.g. lead or glass), albeit much slower. As a result, the material undergoes a time dependent increase in length, which could be dangerous while in service [8-9].

3.1 Classical Creep Curve

The rate of deformation is called the creep rate. It is the slope of the line in a Creep Strain vs. Time curve in Fig 1.

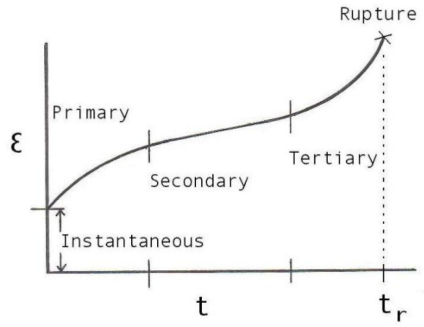

Fig 1. Creep curve

3.2 Creep stages

- Primary Creep: starts at a rapid rate and slows with time.
- Secondary Creep: has a relatively uniform rate [10].
- Tertiary Creep: has an accelerated creep rate and terminates when the material breaks or ruptures. It is associated with both necking and formation of grain boundary voids [11-12].

3.3 General Procedure for creep testing

- The unloaded specimen is first heated to the required T and the gage length is measured.
- The predetermined load is applied quickly without shock.
- Measurement of the extension are observed at frequent interval [13-19].
- Average of about 50 readings should be taken in Fig 2.

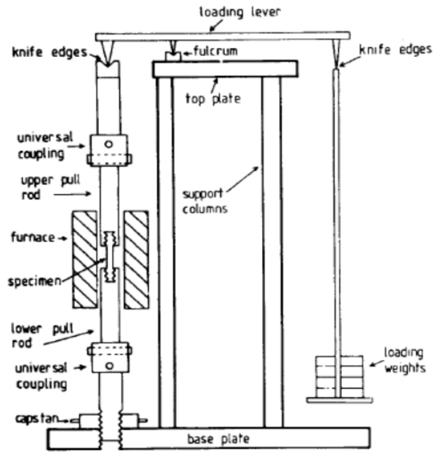

Fig 2. Creep testing machine 1

The above diagram shows the experimental setup used to measure the creep data in Fig 3.

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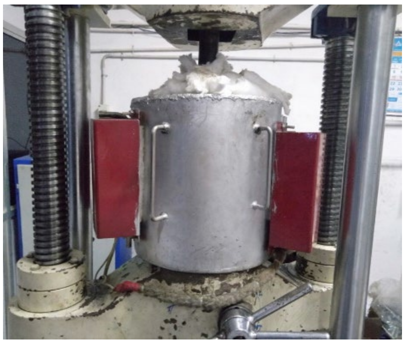

Fig 3. Creep Testing Machine 2

4. Creep Data

Parameters

Temperature = 600°C

Load = 200 MPa

Soaking Time = 1200 minutes

The creep data for the first test has been recorded as shown the data shows the elongation in mm vs time in min for the applied load of 200 MPa at 600°C for a time of 1200 minutes in Fig 4.

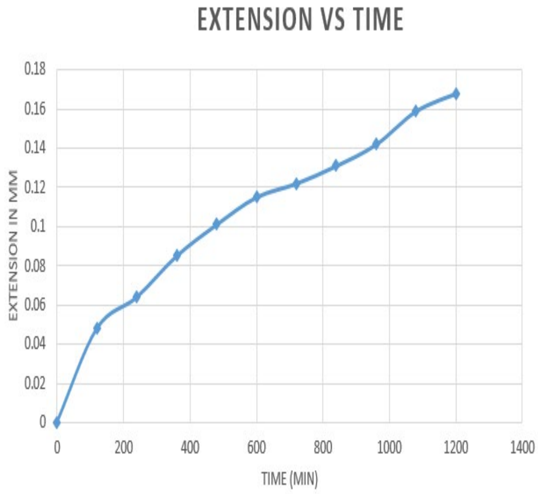

Fig 4. Specimen 1 Extension Vs Time

The graph shows the linear increase in the length of the specimen. The gauge length of specimen was originally 50mm and after when it is subjected to creep load the length has been elongated to 50.19 mm. It is a 0.38 % increase in the original gauge length. Soon after the application of the load there is sudden increase in the length due to tensile stress induced. Aftermath the creep starts to propagate slowly

Test 2

Parameters

Temperature = 700°C

Load = 200 Mpa

Soaking Time = 1200 Minutes

The creep data for the first test has been recorded as shown in the figure the data shows the elongation in mm vs time in min for the applied load of 200 MPa at 700°C for a time of 1200 minutes shown in Fig 5.

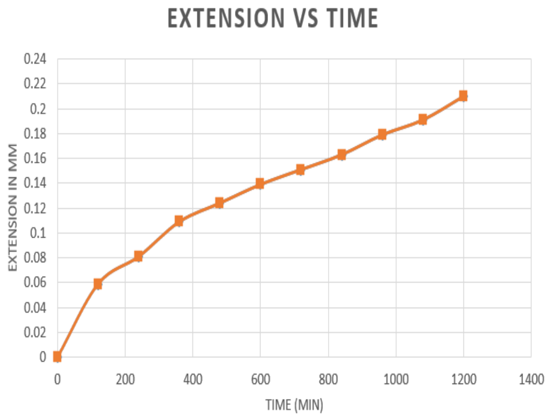

Fig 5. Specimen 2 Extension Vs Time

The graph shows the linear increase in the length of the specimen. The gauge length of specimen was originally 50mm and after when it is subjected to creep load the length has been elongated to 50.21 mm. It is a 0.42 % increase in the original gauge length. Soon after the application of the load there is sudden increase in the length due to tensile stress induced. Aftermath the creep starts to propagate slowly.

The figures show the comparison of the creep propagation for the AISI 316 LN specimen for the temperature 600°C and 700°C. The creep is directly proportional the applied temperature. Higher the temperature, higher the creep rate in Fig 6.

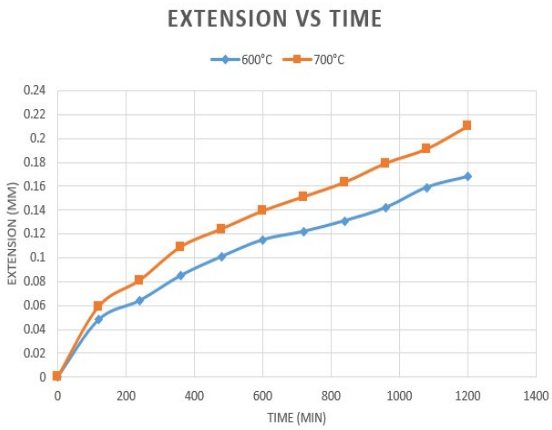

Fig 6. Comparing Result 1 and 2

The above comparison shows that the creep propagation is observed to be higher for steel at higher temperature. The creep is observed to increase with rise in temperature for the steel at the same applied external load.

5. Creep Rate

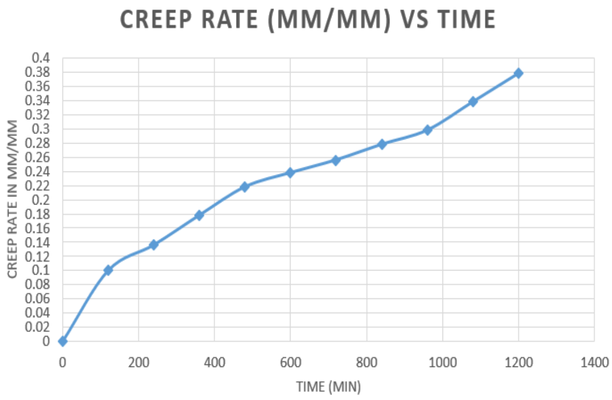

Fig 7. Creep Rate for Specimen 1

Fig 8. Creep Rate for Specimen 2

The Fig 7 and Fig 8 show the comparison of the creep propagation for the AISI 316 LN specimen for the temperature 600°C and 700°C. The creep is directly proportional the applied temperature. Higher the temperature, higher the creep rate. For the above results creep strain rate ε (mm/mm) has been calculated using the Arrhenius relation of creep.

6. Conclusion

The creep test for AISI 316 LN has been studied at 600°C and 700°C at an applied load of 200Mpa. The creep data obtained shows that the creep propagation increases with rise in temperature. The specimen which has been exposed to 700°C has higher creep rate than that of the specimen exposed to 600°C temperature. Nitrogen was found to be beneficial to creep properties at all the stress levels. Creep rupture strength increased substantially with increase in nitrogen content; creep rupture life increased almost 10 times by increasing nitrogen content from 0.07 wt.% to 0.22 wt.%. Steady state creep rate showed a decrease with increase in nitrogen content. The AISI 316 LN has significantly high creep resistance compared to AISI 316 due to additional nitrogen content which makes it suitable for boiler applications.

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