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Mechanical Properties of High Temperature Materials: A Review

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Abstract

This paper has been focused the mechanical properties of high temperature materials, hence they are many applications of HTM such as production, Transport, Energy, Packaging, storage tanks, Industry and tools etc. A review has been carried out to make use of high temperature materials-HTM (such as Steel, copper, titanium, aluminum alloy, etc) mechanical properties. Towards there are analysis some area such as slow strain rate and hot tensile test. Slow strain rate (SSR) testing is constant slowly extension rate tensile test for excellent search used by research scientist to survey stress erosion cracking. Hot tensile test is using this method we can find out the tensile strength, elongation, yield strength properties of different materials and its alloy, at high temperature. This review paper provides the more important with slow strain rate and tensile test in discussed the different high temperature materials. This survey paper outcome of study the different materials and mechanical properties analysis. The review paper used in the future research work of scholar and scientist. Finally concludes the review.

Key words: HTM; Slow strain rate; Hot tensile test; Mechanical properties

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INTRODUCTION

Human existence materials have been major to the development of any civilization and determined its level as a full that is why specialists in anthropology, archaeology and sociology define the historical era by the materials used by the different civilizations such as Stone, Copper, Bronze and Iron ages (Ferguson, 2008). However, during all this historical way, the ‘‘main stream’’ in materials development and design has been directly connected with continuing research of higher and higher temperatures in the practice of human society (Gnesin, 2010). Step by step due to the advance materials humanity has been moving from primitive aids and appliances for heating food and water up to the first wall of thermonuclear fusion reactor, from the ambient temperatures of 250-300 K to the ultra high and super high temperatures, which are being measured by thousands and millions of Kelvin’s. Thus a physical parameter such as temperature or better to say the temperature range of materials application and using has become an actual measure of the technical progress of all of human society that was also a good reason to term high-temperature materials as important one. The ‘‘match for temperatures’’ has been rising, the definition of ‘‘high-temperature’’ has changed greatly. On the basis of the currently achieved level in our knowledge and engineering process the most applicable terms for the scaled temperature ranges in materials science and engineering could be arranged as follows:

Table 1
Temperature Range (K)

0-200 K	Cryogenic (additionally sectioned) temperatures
200-300 K	Ambient temperatures
300-700 K	Moderate (or middle) temperatures
700-1500 K	Elevated temperatures
1500-2700 K	High temperatures
2700-5000 K	Ultra-high temperatures
>5000 K	Super-high temperatures

Thus the purpose of the book you have just opened is to give a comprehensiveanswer (with analysis) to the question of what materials or constituents of materials we have to use in machines, mechanisms, installations and devices, which are exploiting in stationary or non-stationary conditions at temperatures of around 1300^{0}C and higher, up to the edge of the existence area of solid substances.You will find only nine chemical elements with the melting points. so, onlythe atoms of carbon (C) and termed as refractory metals tungsten (W), titanium (Ti) vanadium (V), chromium (Cr), molybdenum (Mo), Nickel (Ni), Iron (Fe), zirconium (Zr) and niobium (Nb) can form the elemental substances and materials, which are solid at the temperature of 1500 K or around 1300^{0}C. The higher melting points of tungsten, titanium, vanadium, chromium, molybdenum (Mo), Nickel, Iron, zirconium and niobium (W, Ti, V, Cr, Mo, Ni, Fe, Zr, Nb) have considerably higher melting points than those of corresponding metals (elements) (Shabalin, 2014). The dedicated to high temperature materials. Specially for industry applications. Stating many new materials and processes were invented, the great progress has been made in mechanical modeling and lifing analysis, but a description of these aspects will require a full separate issue. The focal point here is on materials in the hot area of compressors and turbines. These materials have a wide range of applications. Broadly speaking, the papers in this review of activities which are based on the mechanical properties of the materials (Khan, 2011).

Application

High temperature materials used in various industries like production, automotive, construction, Energy, Packaging, general fabrication, pipeline, storage tanks, Industry and tools etc., These type of the materials mainly used in storage tank.

1. LITERATURE REVIEW IN SLOW STRAIN RATE

Yue Jiang et al (Jiang & Jiang, 2018). Ultrafine grained Copper with a wide transportation of grain size and an ordinary grain size of *d*= 110 nm was prepared by electric brush plating producer. The tensile properties and surface development of this ultrafine grained copper were similar with two results an electric brush plated nano crystalline Copper (*d*= 59 nm) and electro transfer ultrafine grained Cu (*d*= 200 nm) previously prepared through our class. That comparison the strain rate dependences of strength and ductility of these three materials and basic mechanisms were planned.

R. Ghosh et al (Ghosh, et al, 2017). AA2195 alloy exhibited better general corrosion resistance than AA2219 alloy. This was due to less intensity of corrosion attack along with lower depth as measured from the non-contact optical profilometry technique. The slow strain rate test-SSRT results indicate that the environmental cracking resistance of alloys AA2195 and AA2219 are comparable without any stress correction cracking -SCC susceptibility under the strain rate conditions used in the present wok. The higher stress correction cracking -SCC resistances for AA2195 alloy than the earlier reported results are suggested to be due to the cold working (7%) prior to artificial aging and lower aging temperature (150 °C).

FangfeiSui et al (Sui & Sandström, 2016). Slow strain rate tensile tests have been implement on phosphorus alloyed copper under uniaxial and multiaxial stress states at 75 and 125°C with two strain rates 10^{-6} and 10^{-7} $s^{-}1$. Multiaxial stress states have been introduced by incorporating three different notch geometries on the uniaxial specimens. The presence of a notch decreased the tensile strength the elongation and the reduction in area. The sharper the notch, the lower the ductility.

Hisao Matsunaga et al (Matsunaga, et al, 2015). SSRT tests at the temperatures of 233 K, RT and 393 K, Cr-Mo showed no degradation in tensile strength, although its ductility was significantly reduced by hydrogen-enhanced, surface cracking during the necking process. In contrast, carbon steel showed certain degradation in tensile strength linked to a higher reduction of ductility at a low temperature, as determine by the surface cracking observed prior to the start of the necking process.

Y. Chen et al (Chen, et al, 2014). SSRT tests were control on irradiated tensile specimens at strain rates between 3 and 7×10^{-7} s^{-1} to calculate cracking sensitivity of austenitic stainless steels in simulated light water reactor environments. Important increases in yield strength were observed for all irradiated specimens and a dose dependence of irradiation hardening was access at temperatures relevant to light water reactors. Ductility and strain hardening efficiency were also found decrease rapidly with the increase of dose.

LokeshChoudhary et al (Lokesh Choudhary & Raman, 2013). Magnesium alloys will together encounter mechanical loading and corrosive physiological environment, which can cause premature failure due to stress corrosion cracking (SCC). Therefore, it is essential to characterize the SCC behavior of magnesium alloys, before they can be actually used as implants. In the present analysis, the stress corrosion cracking behavior of a common magnesium alloy, biocompatible alloy, Mg-3 wt. % Zn-1wt. % Ca was evaluated in the physiological environment using slow strain rate tensile (SSRT) testing.

Pilar De Tiedra et al (Tiedra & Martín, 2013). The UTS of cold worked and non-welded slow strain rate test specimen's increases with increasing cold work level due to strain hardening. The ultimate tensile test of cold worked and a welded slow strain rate test specimen does not show important variations with prior cold work. Ultimate tensile test is not sensitive to the corrosive environment for any cold work level. Time to failure of cold worked and non-welded slow strain rate test specimens decreases with increasing cold work level, as an effect of the decrease of ductility due to strain hardening.

B. Long et al (Long, Dai, & Baluc, 2012). The irradiated Ferritic/ Martensitic (FM) steels tested in liquid lead-bismuth eutectic-LBE display additional embrittlement effects induced by lead-bismuth eutectic-LBE, which increase with irradiation-induced hardening, in arrangement with what was observed for tempering hardened materials in our previous research. The fracture strain of irradiated specimens can be reduced down to a very low level of about 2-3. A mix of the model of adsorption induced reduction in cohesion of atomic bonds for brittle break fracture was used to describe qualitatively the observation reported in the present paper.

A.sexena et al (Saxena, Singh Raman, & Muddle, 2006). This paper investigates application of slow strain rate-SSR testing as a laboratory method to describe caustic cracking sensitivity of mild steels. Slow strain rate-SSR tests were carried out at 120 ^{0}C in 200gpl NaOH at different strain rates (1.7×10^{-7} to 16.3×10^{-7} s^{-1}). The results submit that the mild steel is affected to caustic cracking in a very narrow window of strain rates (around 3×10^{-7} s^{-1}). This study also supports slow strain rate-SSR testing as a dependable laboratory testing technique for further research.

1.1 Literature Review in Hot Tensile Test

M. Vinoth Kumar et al (Kumar & Balasubramanian, 2018). The GTAW joints presented lower tensile strength than the parent metal and the failure show in the weld metal region for all test temperatures. Constant load Stress Corrosion Cracking (SCC) test data of the GTAW weld joints tested in boiling $MgCl_2$ environment at different applied stress level are presented. SCC curves obtained from the test were analyzed to derive SCC parameters such as rate of steady state elongation, the time required for set-in of tertiary region, and time to complete fracture.

HongjunZhang et al (Zhang, et al, 2018). Cold-rolling with reduction 30-45% led to the continuous decrease of elongation from 6.9% to 3.4%, compared to 7.2% for strain-free structure. The ductility degradation can be attributed to the interactions of necking, microstructure instability and oxidation process induced by cold deformation. The cold-rolling is proved to enhance the resistance to crack propagation.

Wenchao Xiao et al (Xiao, et al, 2017). The flow behavior of AA7075 at uniaxial hot tensile tests was analyzed. Average grain size can be refined with increasing deformation amount, temperature, and decreasing strain rate.

M. Vinoth Kumara et al (Vinoth Kumara, Balasubramanianb, & Gourav Rao, 2016). Tensile tests were carried out on stainless steel material using nominal strain rate of $1\times 10^{-3} s^{-1}$ at room temperature, 550◦C, 600◦C and 650◦C. The tensile strength and elongation were found to decrease with increase in test temperature. The tensile strength, yield strength and elongation of stainless steel material decrease with increase in test temperature. The strain hardening capacity of the stainless steel material increases up to 600◦C and decreases at 650◦C.

Yong-cheng LIN et al (Lin, et al, 2016). The effects of initial δ phase on the hot tensile deformation behaviors of the studied Ni-based super alloy are significant. The peak stress increases with the increase of initial δ phase. With the further straining, initial δ phase promotes dynamic softening behaviors, and the flow stress is reduced.

M. H. GHAVAM et al (Ghavam, et al, 2015). To predict the hot tensile flow behavior of IMI834 titanium alloy. Hot tensile tests were performed at 800−1025 °C and 0.001−0.1 s^{-1}. At low temperatures and high strain rates, titanium alloy prior to the UTS is observed and the hot tension leads to grain boundary cracks. With decreasing the strain rate, the strain to failure increases. At high temperatures and low strain rates, with increasing the strain rate, flow stress curves exhibit a peak stress followed.

1.2 Literature Review Hot Tensile Test in Notch Root Radius

J. S. Kim et al (Kim, et al, 2018). This paper the effect of constitutional integrity assessment of steels, Smooth tensile, notched bar tensile and multi specimen single edge notched bend tests with different notch acuities have been performed and show an increase in direct ductile fracture toughness with increasing notch radius. The influence of notch radius on fracture assessment has been discussed and assessments have been shown to become more collapse dominated with increasing notch bluntness.

Chandan Pandey et al (Chandan Pandey, et al, 2017). Ferritic P91 steel was tested by temperature tensile test in Vertical Tensile Testing Machine. Effect of various types of notch calculation, notch depth and angle on mechanical properties were also considered for various strain rates. A continuous decrement was noticed in reduction in area with increase in strain rate and minimum of 62 % was noticed for higher strain rate of 4×10^{-2}/s. In case of notched specimen, notched strength and fracture toughness were also measured higher for the higher strain rate of 4×10^{-2}/s. Maximum notched strength and fracture toughness were obtained for U-notch at notch depth of 1 mm and strain rate of 4×10^{-2}/s.

F. Berto et al (Berto, Cendón, & Elices, 2016). This paper is divided in two parts. In the first part of preliminary results of 25 gray cast iron notched specimens tested under torsion loading are provided. V-notch (with an opening angle of 120^{0}) geometry is considered with root radii ranging from 0.1 to 2.0 mm. Plots of torque loads versus twist angles are reported for all notch root radius tested. Such results can help in classify analytical and theoretical models for fracture of notched components under mode III loading. The second part of the paper deals with an analysis of the experimental results by using the Strain Energy Density criterion.

T. García et al (García & Cicero, 2015). This paper is analysis of the apparent fracture toughness within the ductile-to-brittle transition zone of ferritic steels in notched conditions. With this aim, a new parameter has been defined named the notch reference temperature, which varies with the notch radius. Expressions relating to notch reference temperature and the notch radius have been obtained for steels S275JR and S355J2. In order to validate the application of the notched materials, an experimental has been completed in specimens, and covering six different notch radii (from0mmup to 2mm) and two different steels. The predictions provided by the Notched Curve, revealing the temperature ranges where each prediction tool provides the best results.

C. Butcher et al (Butcher & Chen, 2011). An experimental and numerical test conducted to analysis damage induced ductile fracture in notched tensile sheet work piece of an aluminum magnesium alloy. The resulting nucleation stress of 466 MPa determined using notched tensile work piece is in very good understanding with a past study of this alloy for a stretch flange forming operation. Future work will further address the issue of transferability and verification of the nucleation model using quantitative metallurgical analysis.

2. PROPOSED WORK

After reviewing the literature it was found that as we increase the processors of high temperature materials and mechanical properties analysis. Towards that, a GLEEBLE 3500 thermo-mechanical testing machine will be used. From these study, deformation domain would be identified and predict the changes in the deformed microstructure. Analysis the thermo mechanical deformation in high temperature materials.

Problem definition

• This problem is basically due to non-availability of tensile property data to the design engineers.

• In view of this tensile property data are very useful in designing machine and structural components which are safe but not oversized and overweight.

• The Structural components operating at higher temperature are subjected to stress which arises due to change in geometry, microstructure in homogeneity as in also due to the mode of loading during service.

• Due to for realistically assessment of life of such components, it is important to evaluate and predict the behavior under tensile stress.

• The effect of stress on tensile properties of hardened steel is generally studied by the introduction of notch in cylindrical and square specimens.

3. OBJECTIVE

There are following objectives associated with the proposed approach.

• To improve the service life of hardened material predicting mechanical properties under elevated thermal condition

• To study the thermal- mechanical simulation test in high temperature materials.

• To estimate the notch effect, by introducing notch in the tensile test specimen

• To find the fracture strength, ultimate strength, Yield strength, %elongation and young's modulus of the high temperature materials.

• To study hot tensile, thermo mechanical deformation properties of the specimen

• To validate the analytical results of stress in high temperature material with thermal- mechanical simulation analysis

• To study the FE analysis was used the effect of notch acuity on the stress distribution across the notch throat plane to assess its influence on tensile properties of steel.

CONCLUSIONS

The literature survey shows that there was very less work reported on high temperature behavior of material example of slow strain rate test (SSRT) and hot tensile test (HTT), analysis of mechanical properties of high temperature materials. Slow strain rate test (SSRT) is very important to study the cracking may not be visible from result of tests at too low or too high strain rate. Hot tensile test (HTT) is very important to study the thermal stress developed in components which are subjected to high temperature to avoid failure of components. Most of the work done on high temperature material. So there will be scope to apply this test for low weight and more weight of material for application in production, Transport, Energy, Packaging, storage tanks, Industry and tools etc.

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