An analysis comparing the mechanical properties of ASS 316L at high and Sub-zero temperatures

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Abstract Austenitic Stainless Steel 316L is one among most frequent ASS scores utilized in modern industry. It is more resistant to corrosion in normal atmospheric conditions in severe settings such as seawater with salt and situations that require protection against chloride corrosion and pitting.While operating effectively at high temperatures, it can also retain because to its resilience and strength at low temperatures, it is a great option for use in the automotive, nuclear, water treatment, marine, and aerospace industries.The mechanical metrics yield quality (YS), percentage elongation, and ultimate tensile strength (UTS) were assessed and compared in this studyusing experimental data through uniaxial isothermal tensile testing.

1 Introduction

Because of their exceptional properties and range of uses, stainless steels are now considered necessary in today's society.As theyhave a wide range of uses, from home to high-level.These uses include space exploration, medical stents, kitchenware, furnishings, and nuclear reactors.spacecraft, and so forth.It is critical to identify their practical applications [1-4].

Stainless steels are mostly composed of iron.The term there's stainlessbecause this is enhanced by chromium compound, which makes it able to withstand rusting.In general, up to 16% are pre-sent [5].Increased ChromiumStrengthens resistance against pittingand corrosion in adverse conditions.Aside from Cr, additional elements for alloying are

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added.toenhance the ideal properties composed made of Stainless Steel.Among these are Ni to create an austenitic structure and Mo to boost resistance to pitting [6].

Stainless steel has 3 primary frameworks: martensite, ferrite, and austenite. In 316L, L represents low carbon content, indicating a strong resilience to rust.Austenitic and ferriticphases are frequently seen in these grades.The limited quantity of Becauseferrite is present, they are ductile and strong, and they retain their characteristics at high temperatures [9].Austenitic steels, for instance, are completely non-magnetic [7]. In the modern world, austenitic steels are more efficient than other types of steel.There are many more grades available, including 316L, 316LN, 304L, and 317LN [8].It is used in cryogenic as well as high temperatures.When austenite is worked at temperatures below zero,concentration varies, as does the precipitation conductivity of carbides.As a result, the characteristics must be analyzedeven in below-freezing weather. Cryogenic transfer lines, such as tubes and thin-walled shells, and cryogenic control valves working at 1.9 K are therefore examples of cryogenic uses [10].When combinedbuilt ASS316L samples are inspected, they show a heterogeneous microstructure, as well as disturbances and divisions [11].When friction welding two samples, ASS316L and 1045 MCS,together, the hardness and forging pressure increase significantly [12]When boron is added .

2 Behaviour of the material

2.1 Material

Because ASS 316L is extensively utilised this research assesses and contrasts the mechanical properties of ASS 316L in applications requiring both high and low temperatures, including those found in ships, aircraft, nuclear power plants, offshore buildings, and LNG carriers.Utilising an electric discharge machine (EDM) with a wire-cut attachment,the specifications were cut from cold-rolled ASS 316L sheetthat was 0.6 mm thick in order to get a very high level of polish and accuracy.Tensile testing in successionarecarried out in both negative and increased temperatures.Table 1 displays the spectrometer's analysis of the ASS 316L alloy's chemical composition as received.As seen in Fig. First, the specimens are chopped in three orientations (see to Fig. 2).

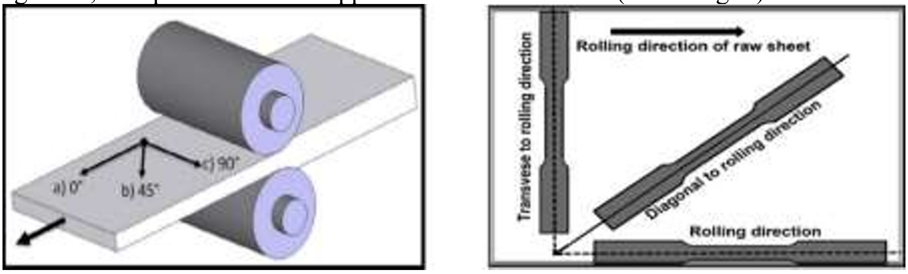
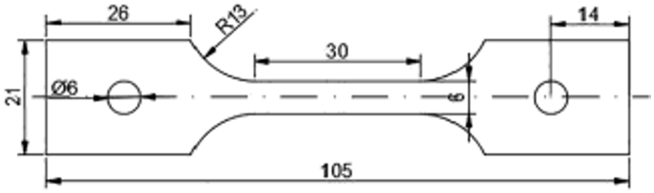


Fig. 1 shows the specimen'sdirectionalitywith regard in the direction of rolling.



(All dimensions are in mm)

Fig 2. The specimen'sgeometricaccording to ASTM standard E8-M standards.

2.2 Warm disfigurementbehaviour

Typical real stress vs true strain charts are obtained from a range of temperatures using uniaxial isothermal tensile testing, as shown in Figures 5-7. It is shown that the temperature of deformation has a direct correlation with flow stress.As the temperature rises during warm deformation, the flow stress drastically reduces, as seen in Fig. 5.The flow stress first peaks, then steadily decreases to almost a constant stress, and then experiences a downturn.Because of this, the proportion of elongation rises noticeably as temperature rises.These curves usually arise from the interplay between dynamic recrystallization and dynamic recovery.Dynamic softening is caused by deformation at higher temperatures.by enhancing Grain boundary motion and dynamic recrystallization nucleation rate.Because greater temperatures can enhance the mobility of grain boundaries, which is beneficial for abundant dynamic nucleation of recrystallization, flow stresses are significantly reduced as temperatures rise.As a result, dynamic recrystallization behaviour can be noticeably enhanced at relatively lower temperatures.Fig. 6 further shows the impact of elongation rate at the specific increased temperature of 825 °C.Faster strain rates are thought to reduce the percentage of elongation at a certain temperature because the grains have less time to deform at higher strain rates and notably increase in overall strength [23].Stated differently, the strength and flexibility of the conductdemonstrates a high dependence on temperature and the rate of deformation.Fig. 7 illustrates the planar isotropy of the material; however the test results show no contrast in three distinct orientations. This might be because the fortifying hastens disperse randomly.

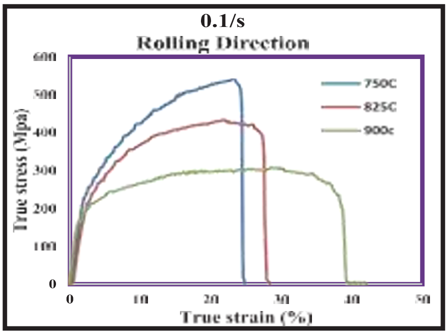


Fig.5.At various temperatures, genuine strain vs true stress

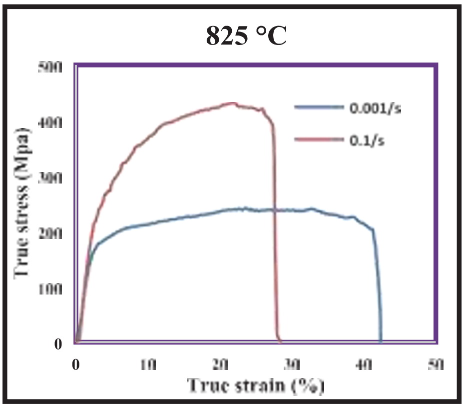


Fig.6. Genuinestraincurvesatvariousstrain rates corresponding to genuinestress

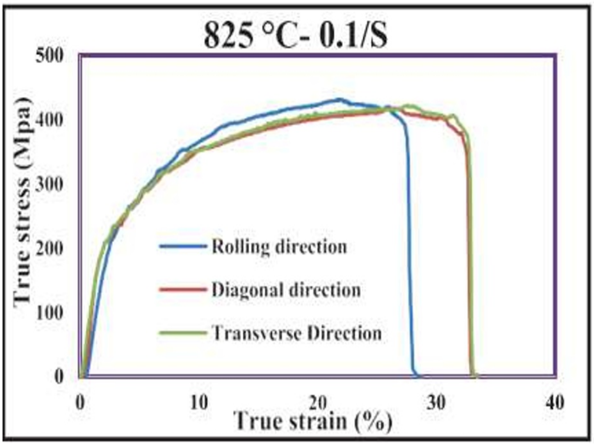


Fig.7.Genuinestrain vs genuinestress atvariousorientations

2.3 Sub-Zero deformation behaviour

When compared to warm temperatures, ASS 316L's behaviour is less variable in negative temperatures.As anticipated, the genuine stress is determined to have a With a little variation in its genuine strain values, the values range from 897.1 Mpa at 0 °C at the lowest to 1065.32 Mpa at 50 °C at the highest, as demonstrated inFigure 9.temps below zero typically result in a significant drop lowers its flexibility at negative temperatures due to a rise in slip system stress and an increase in the austenitic phase's SFE (stacking fault energy), which makes cross-slip challenging and confines dislocations to their original form. Similar to this, tough cross slips will result in greater strain hardening exponents and higher flow stresses.At negative temperatures, all specimens exhibit the secondary hardening behaviour, one of the main features.Additionally, there appears to be reports of a yield plateau occurrence.Additionally, it can be deduced from Fig. 9 that a little drop in the sheet's ultimate strength and a minimal rise in its yield strength were seen with an increase in cross-head velocity. Work hardening often results via the creation and migration inside the crystal structure of the substance, of dislocations.Thus, this method may be used to reinforce a variety of ductile materials.

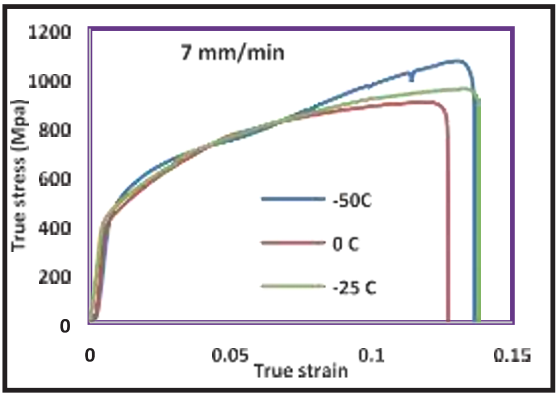


Fig. 8. At varied sub-zero temperatures, ASS 316L characteristics.

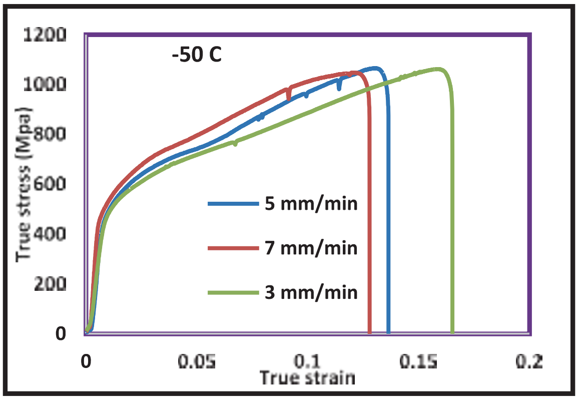


Fig.9. Experimentalfindingsatdifferenttemperaturesand deformation speeds.

3 Conclusion

The impact of The impact of orientation, temperature, and deformation speed on the responses of cold-rolled ASS 316L sheetthatis 0.6 mm thick are measured in an attempt to compare the way ASS 316L behavesmechanicallyatvarioustemperatures. Thefollowing conclusions canbereported:

- ✓ ASS 316L's strength and plasticitybehaviourshow substantialdependenceon strain rate and temperatureduringdeformationatextremetemperatures, whereaslittle change isseenwithregard to variousorientations.
- ✓ As the deformationtemperaturesrise, anotable increase in the percentageelongationand a considerable drop in the flow stress are seen.
- ✓ Whendeformationoccursatnegativetemperatures, the ultimatetensilestrengthdecreases and the yieldstrengthincreasesalongwith an increase in crossheadvelocity.
- ✓ It appearsthat a yield plateau phenomenaoccurs, and strainhardeningis a processthatpredominates in below-freezingtemperatures.

References

1. Kalluri, Anil, SatyanarayanaKosaraju, and SwadeshKumar Singh. "Effect of sub-zerotreatment on tensilebehavior of ASS 316L." *AIP ConferenceProceedings*. Vol. 2283. No. 1. AIP Publishing, 2020.
2. Kosaraju, Satyanarayana, et al. "Evaluation and characterisation of ASS316L atsub-zerotemperature." *Advances in Materials and Processing Technologies* 6.2 (2020): 365-375.
3. Baloji, Dharavath, Kalluri Anil, K. Satyanarayana, SwadeshKumar Singh, and M. T. Naik. "Evaluation and optimization of materialproperties of ASS316L atsub-zerotemperatureusingtaguchirobust design." *MaterialsToday: Proceedings* 18 (2019): 4475-4481.
4. Kosaraju, S., Kalluri, A., Singh, S. K., &ul Haq, A. (2019, November). Evaluation and Characterization of ASS316L atsub-zerotemperature. In *ASME International Mechanical Engineering Congress and Exposition* (Vol. 59490, p. V012T10A034). American Society of MechanicalEngineers.
5. Harshini, Dharanikota, et al. "Comparative study on mechanicalbehavior of ASS 316L for low and hightemperature applications." *MaterialsToday: Proceedings* 19 (2019): 767-771.
6. Hussaini, Syed Mujahed, et al. "Development of experimental and theoreticalforminglimitdiagrams for warm forming of austeniticstainlesssteel 316." *Journal of ManufacturingProcesses* 18 (2015): 151-158.
7. Hussaini, Syed Mujahed, et al. "Development of experimental and theoretical forming limit diagrams for warm forming of austenitic stainless steel 316." *Journal of Manufacturing Processes* 18 (2015): 151-158.
8. Desu, RaghuramKarthik, et al. "Mechanical properties of Austenitic Stainless Steel 304L and 316L at elevated temperatures." *Journal of Materials Research and Technology* 5.1 (2016): 13-20.
9. Gupta, AmitKumar, V. K. Anirudh, and SwadeshKumar Singh. "Constitutive models to predict flow stress in AusteniticStainlessSteel 316 atelevatedtemperatures." *Materials& Design* 43 (2013): 410-418.
10. Prabhakaran A, Bensely A, Nagarajan G, Mohanlal D. Effect of cryogenic treatment on impact strength of casecarburized steel-En353. Proceedings of IMEC2004 international mechanical engineering conference; 2004. p. 1–5.
11. Johan Singh P, Guha B. Fatigue life improvement of AISI 304L cruciform welded joints by cryogenictreatment. Eng Fail Anal 2003;10:1–12.
12. S. Dineshkumar, ShrinidhySriram, R Surendran, V. Dhinakaran "Experimental Investigation of TensileProperties of Ti-6Al-4V alloy at Elevated Temperature" International Journal of Recent Technology andEngineering 8, no.1S2 (2019): 103-107.
13. Failure analysis and prevention, in Metals Handbook, 9th Ed., Vol. 11, American Society for Metals, MetalsPark, OH, p. 111 (1986).
14. Hussaini, S.M., Krishna, G., Gupta, A.K. and Singh, S.K., 2015. Development of experimental and theoreticalforming limit diagrams for warm formingof austenitic stainless steel 316. Journal of Manufacturing Processes,18,pp.151-158.
15. Song, R.B., Xiang, J.Y. and Hou, D.P., 2011. Characteristics of mechanical properties and microstructure for 316L austenitic stainless steel. Journal of iron and steel research, international, 18(11),pp.53-59.
16. Desu, R.K., Krishnamurthy, H.N., Balu, A.,Gupta,A.K. and Singh, S.K., 2016. Mechanical properties ofAustenitic Stainless Steel 304L and 316L at elevated temperatures. Journal of Materials Research andTechnology, 5(1), pp.13-20.

17. Karthik, V., Murugan, S., Parameswaran, P., Venkiteswaran,C.N.,Gopal,K.A.,Muralidharan,N.G., Saroja, S.andKasiviswanathan, K.V., 2011. Austenitic stainless steels for fast reactors-irradiationexperiments, propertyevaluation and microstructural studies. Energy Procedia, 7,pp.257-263.
18. Elsariti, S.M., 2013. Behaviour of stress corrosion crackingofausteniticstainlesssteelsinsodiumchloridesolutions. Procedia Engineering, 53,pp.650-654.
19. Banabic D. Sheet metal forming process constitutive modeling and numerical simulations. Berlin/Heidelberg: Springer-Verlag; 2010.
20. Kuroda M, Tvergaard V. Forming limit diagrams for anisotropic metal sheets with different yield criteria. Int J Solids Struct 2000;37:5037–59.
21. Geiger M, Merklein M. Determination of forming limit diagrams – a new analysis method for characterization of materials formability. Ann CIRP 2003;52:1–6.
22. Chen J, Zhou X. A new curve fitting method for forming limit experimental data.J Mater SciTechnol 2005;21:521–5.
23. Keeler SP. Determination of forming limits in automotive stampings. In: SAE mid-year meeting. 1965.