Comparative Study of Tensile Strength of SS316L Shaft with and without Welding

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Abstract: To assure security, dependability, and ideal performance in a range of applications, engineering and material science heavily rely on measuring the strength of materials. Tensile, compressive, shear, and fatigue strength are a few examples of characteristics that make up a material's strength. Steel is a versatile alloy whose outstanding strength and endurance have revolutionized manufacturing, construction, and transportation. Although steel has many uses, it needs protective coatings since it is prone to corrosion. Modern high-strength steels are made to maintain mechanical qualities while being lighter thanks to recent improvements. The importance of comprehending material behavior is emphasized in this study in order to choose appropriate materials, improve performance, and guarantee durable products. The popular stainless steel SS316L's tensile behavior is also examined in the study, which also includes numerous research findings on the behavior of steel, structural integrity, and fatigue performance.
Keywords: Material strength, SS316L steel, mechanical properties, corrosion, advanced high-strength steels

I. INTRODUCTION

Evaluating a material's strength is a crucial part of engineering and material science. When building structures, making components, or developing new materials, it is crucial to comprehend and evaluate a material's strength characteristics to ensure safety, dependability, and optimal performance. "Material strength" refers to a material's ability to withstand external forces without breaking down, deforming, or experiencing long-term injury. Tensile strength, compressive strength, shear strength, and fatigue strength are only a few of the qualities it covers [1]. Iron plus a moderate amount of carbon make up the majority of the versatile and common alloy known as steel. Depending on the desired qualities, other alloying elements may also be added. It is well known for its extraordinary strength, long lifespan, and broad range of applications in a variety of sectors. The invention of steel transformed the fields of construction, manufacturing, and transportation, profoundly influencing the modern world.

Applications for steel are incredibly varied. Due to its excellent strength-to-weight ratio, it is the basic building material and is used to construct buildings, bridges, and skyscrapers. It creates the framework of automobiles and offers essential safety features in the automotive sector. Steel is utilized for tools, machinery, and equipment in manufacturing because of its superior mechanical qualities. Steel is used to build renewable energy structures, power producing equipment, and pipelines in the energy sector.

Steel presents a number of difficulties, including its propensity for corrosion. To prevent this, different kinds of steel are covered in protective layers like zinc (galvanized steel) or chromium (stainless steel) to provide extra protection. The steel's resistance to environmental deterioration is improved by these coatings.

Advanced high-strength steels have been developed as a result of recent improvements in metallurgy and manufacturing methods. These steels are made with the intention of lightening constructions while preserving or even improving their mechanical qualities. Brittle -carbides are thought to be the cause of low-density -TRIP steels' propensity for breaking during both hot and cold rolling. By enhancing fine-grain strengthening and refining -ferrite grains, warm rolling serves a dual purpose. More precipitate nucleation sites are created throughout this refining process, which in turn encourages stronger precipitation. Lamellar -carbides can also be dissolved and spheroidized more easily when rolling at a heated temperature.

Importance of Material Behavior

- Strength and Load-Bearing Capacity: Evaluating a material's strength and load-bearing capacity necessitates understanding its response to mechanical forces. Materials with high strength and superior load-carrying capabilities can support heavy loads, resist deformation, and withstand pressures without failure. A solid grasp of material behavior aids engineers in selecting optimal materials for diverse applications.
- Durability and Fatigue Resistance: Throughout their operational life, materials endure cyclic loading, vibrations, and repetitive stresses. Predicting a material's durability relies on comprehending its behavior, particularly concerning fatigue resistance. This understanding empowers designers to create products that endure repeated loading without failure or degradation.
- Environmental Compatibility: Different materials tolerate environmental factors like moisture, chemicals, UV radiation, or temperature changes to varying extents. Choosing materials compatible with the working

environment minimizes degradation, corrosion, or deterioration. Understanding material behavior guides this selection process.

- Material Selection and Optimization: Engineers leverage material behavior to select the most suitable materials for specific applications. By considering attributes like strength, stiffness, thermal expansion, and chemical resistance, engineers optimize material selection to meet performance requirements and prevent potential failures or limitations.

The study of quality and material behavior is crucial to both engineering and material science. Quality materials have an impact on the performance, dependability, safety, and customer satisfaction of engineered goods. Understanding material behavior helps in material selection, product design, and optimization by assuring that materials can withstand expected loads, conditions, and service scenarios. By considering both quality and material behavior, engineers may design trustworthy and durable products that meet industry standards, customer expectations, and performance specifications. Popular stainless steel known as SS316L is renowned for its outstanding mechanical properties, flexibility, and corrosion resistance. It is critical for engineers and manufacturers to comprehend the properties and applications of SS316L in order to take advantage of its benefits in a variety of products and structures. The austenitic family of stainless steels includes SS316L, a low carbon variant of grade 316 stainless steel. It typically contains less than 0.03% carbon, 16–18% chromium, 10–14% nickel, and 2-3% molybdenum. In certain circumstances, a lower carbon concentration enhances weldability and reduces corrosion and sensitization sensitivity.

II. LITERATURE REVIEW

Experimental methods were used in a study by **W Li et al. [1]** to examine the mechanical behavior of HRBSC in low-cycle fatigue with buckling while taking into account variables like strain amplitude, strain rate, and nominal diameter. A core of HRB400E ribbed carbon steel is enclosed in 316L stainless steel in HRBSC, a revolutionary stainless steel clad rebar. Based on test results, the research discusses ways for assessing ultimate strength, strength decline, and fatigue life. By highlighting advantageous material features, the study confirms HRBSC's applicability as a load-bearing rebar for seismic-resistant constructions. According to the research, the clad ratio affects the elastic modulus of HRBSC. While nominal diameter and strain rate have only a small impact on ultimate strength and the degradation of strength under low-cycle fatigue, strain amplitude clearly dominates these effects. The results of the study demonstrate that increasing nominal diameter improves fatigue life, whereas greater strain rates have an adverse effect on the low-cycle fatigue mechanism and shorten the fatigue life of HRBSC, particularly at low strain amplitudes.

The effect of post-treatments on the fatigue properties of 316L stainless steel created by laser powder bed fusion was studied in the study by **C Elangeswaran et al. [2].** Through optimum processing conditions and vertical orientation of tiny fatigue specimens, the study sought to achieve low porosities and constrained dispersion. At a nominal load ratio of 1, the fatigue performance of two material states—namely, as-built and stress-relieved—was assessed. For testing, samples were either surface-machined or left untreated. Detailed microstructure and fractographic investigation evaluated the effects of the main fatigue factors. The results showed that as compared to 316L stainless steel manufactured normally, both machined samples with and without stress relief heat treatment had superior fatigue behavior.

Z Liu et. al. [3] explored the modification of austenitic stainless steel surfaces using low-temperature gaseous carburization. Fully reversed axial fatigue experiments were conducted on specimens with varying residual case depths to investigate the impact of low-temperature gaseous carburization on AISI 316L's fatigue behavior. After low-temperature gaseous carburization, AISI 316L's fatigue performance exhibited significant improvement, with a 15% greater endurance limit achieved. The enhancement in fatigue performance was somewhat reduced when electro polishing removed the exterior brittle portion of the carburized case. Fractography revealed that fatigue cracks consistently initiated on the surface for untreated specimens. However, the initiation sites for carburized specimens varied with applied stress levels. Compressive residual stresses in the case caused initiation sites to shift towards the sub-surface, with initiation site depth increasing with lower applied stress levels. A quantitative analysis of fatigue behavior formed the basis for a life prediction model, accurately estimating AISI 316L steel's fatigue life after low-temperature carburization.

R Sivasubramani et. al. [4] conducted an examination of material and property aspects of duplex stainless steel due to the influence of various solid-state welding techniques used in connecting DSS structures. The study involved exploring options like girth friction welding and friction stir welding, among others. The research aimed to assess the impact of solid-state welding on DSS and its significance. This analysis aids researchers in evaluating the value and challenges of DSS welding. The study evaluated Basquin constants and assessed fatigue strength, notch sensitivity factor, and fatigue notch factor for dissimilar joints. The connection between microhardness, microstructure, and fatigue strength was examined, and tensile properties of the joints were also analyzed.

J Limbert et. al. [5] addressed the issue of premature deterioration in reinforced concrete structures caused by chloride-induced corrosion of steel reinforcing bars. Stainless steel reinforcement offers a promising solution due to its resistance to chloride corrosion and independence from concrete alkalinity or cover. The study aimed to replicate stress-strain responses of reinforcement and concrete using constitutive material models for investigating nonlinear behavior. The research introduced a novel exploration into the stress-strain behavior of stainless steel reinforcement bars, considering inelastic buckling. Experimental and numerical methods were used to study this phenomenon. Tension and compression tests were conducted on stainless steel bars of different grades and slenderness ratios. Numerical simulations informed the development of a compressive stress-strain constitutive model tailored for stainless steel reinforcement.

In the study by **P Wood et. al. [6],** the fatigue performance of selectively laser-melted (SLM) stainless steel (SS) 316L was investigated. The research delved into the influence of build orientation and post-fabrication methods, such as stress relief, machining, and shot peening. Horizontal construction and machining of SS 316L test pieces exhibited superior fatigue behavior compared to vertically constructed pieces. Stress relief had minimal impact on the fatigue behavior of certain test pieces. Comparative analysis revealed that horizontally constructed samples had better fatigue behavior than their counterparts with poor ductility. Shot peening improved fatigue performance of specific test specimens. The study provided insights into process parameters, microstructure, and mechanical properties of SLM-produced SS 316L, shedding light on fracture patterns and anisotropic behavior in SLM-printed components. It offered valuable information on factors influencing fatigue behavior in laser-manufactured steel alloys.

D Liu et. al. [7] utilized an ultrasonic surface rolling process to fabricate a gradient structure layer on 17-4PH specimens. The study revealed that the fretting fatigue (FF) life benefits from the gradient nano-crystalline structure, "fish scale-like" surface topography, and residual compressive stress, as indicated by the separation-factor methods. The remaining compressive stress facilitates crack closure and reduces the applied tensile stress. Post the FF experiment, nano-grains expanded, and dislocation density decreased, enhancing the material's ability to withstand external strain and mitigate stress accumulation. The distinctive "fish scale-like" texture minimized contact area between the specimen surface and fretting pad, thereby reducing surface damage.

F Dai et. al. [8] investigated the impact of laser shock peening (LSP) on 316 stainless steel's performance in terms of residual stress, micro-hardness, and resistance to rolling contact fatigue (RCF). The study found that LSP significantly enhances the RCF performance of 316 stainless steel. The primary contributor is LSP's ability to induce large amplitude compressive residual stress in the surface layer. The increase in residual compressive stress changes the wear process on the RCF surface, shifting from delamination to micro-plastic deformation. The RCF behavior of LSP-treated 316 stainless steel responds positively to contact stress.

L Chen et. al. [9] conducted low-cycle fatigue tests on Austenitic stainless steel S30408, a material known for its low yield point and high elongation properties. The study subjected the material to cyclic loading with a maximum strain amplitude of 5%. The investigation focused on the stress-strain behavior of the stainless steel material under cyclic loads. Parameters related to the strain-fatigue life relationship and cyclic-plastic constitutive model utilized in finite element analysis (FEA) simulations were considered. Results indicated a nonlinear stress-strain curve lacking a yield plateau, demonstrating a high strength yield ratio and ductility. Prominent shuttle-shaped hysteresis loops symmetrically centered on the origin indicated substantial energy dissipation capability. The study's findings contribute valuable data for the seismic design of civil structures involving Austenitic stainless steel S30408.

YX Liu et. al. [10] delved into the fatigue behavior of ultrafine structured rolling process (USRP) samples, investigating factors like marten site phase transformation (MPT), residual compressive stress, and grain nanoscale layers (GNS). MPT during USRP and cyclic loading significantly influenced fatigue behaviors, impeding surface crack initiation and propagation through residual compressive stress and GNS layers. In high cycle fatigue (HCF) tests, the formation of a hard-brittle marten site phase via USRP enhanced material strength and strain energy absorption during crack propagation, leading to improved HCF life. Conversely, in low cycle fatigue (LCF) tests, the presence of a hard-brittle marten site phase reduced GNS layer ductility and accelerated fracture formation under higher strain amplitudes, resulting in reduced LCF life. This study provides a pioneering exploration of fatigue behaviors in duplex stainless steel featuring a grain nanoscale structure**.**

III. Experimental Procedure and Result Obtained

The purpose of testing specimens with welding and without welding is to evaluate and compare the mechanical properties, performance, and behavior in both scenario. The geometrical description of the tensile test specimen is shown in figure. The total specimen length of 250 mm, gauge length 70mm, diameter of gauge length is 8 mm; gripping length and diameter are 75mm and 12mm. To check the strength of welded rod of the SS316l two piece (75 mm each) have been welded and then prepare the tensile test specimen in order to investigate the yield stress, Ultimate stress, Nominal braking stress, percentage elongation as shown in figure1

Figure 1. Tensile Test Raw Welded Specimen

Figure 2. Tensile Test Raw Without Welding Specimen

Mathematical Calculation

$$Yield\ Stress = \frac{Yield\ point}{Initial\ area}$$

$$Ultimate\ Stress = \frac{Ultimate\ load}{Initial\ area}$$

$$Breaking\ Stress = \frac{Breaking\ load}{Initial\ area}$$

$$Elongation\ in\ length = \frac{Final\ length - initial\ length}{initial\ length} \times 100$$

$$Reduction\ in\ area = \frac{initial\ area - neck\ area}{initial\ length} \times 100$$

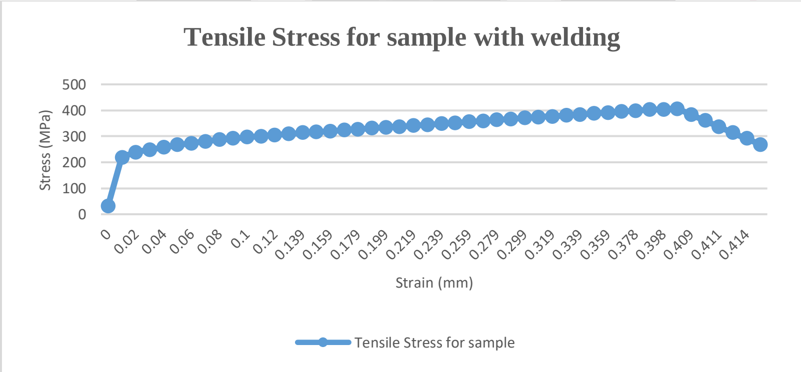

Figure 3. Tensile Stress for sample with welding

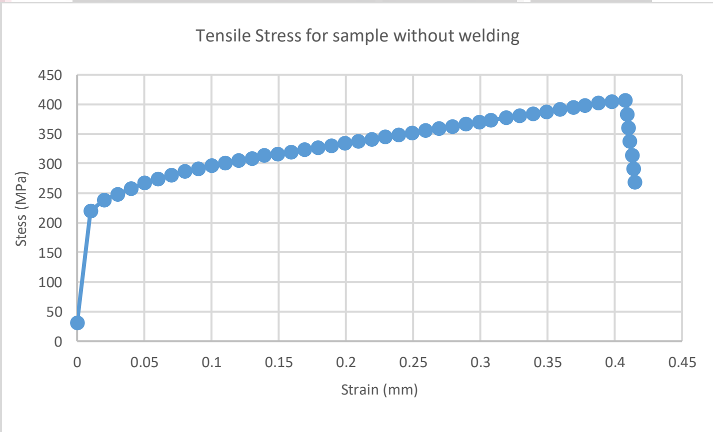

Figure 4. Tensile Stress for sample without welding

IV CONCLUSION

this research paper underscores the critical role of evaluating material strength in engineering and material science, highlighting its impact on safety, performance, and product durability. Steel's widespread applications, particularly in construction, automotive, manufacturing, and energy sectors, underscore its importance. While corrosion poses a challenge, protective coatings mitigate its effects. The rise of advanced high-strength steels showcases industry innovation. The experiment compares mechanical properties of welded and non-welded SS316L specimens, with tensile tests providing essential data on various attributes. In conclusion, understanding material behavior empowers engineers to make informed choices, optimize designs, and ensure product reliability. The paper emphasizes ongoing material science research's importance in driving innovation and addressing industry challenges.

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