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Effect of Sulfur and Chlorine on the Mechanical Properties of Welded Steel

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ABSTRACT
This study investigates how sulfur and chlorine affect welded steel by examining its mechanical properties. In a welded environment, these components are available, which impacts the strength of the welded joint. The study aims to construct a steel specimen that has been welded and drenched in various concentrations (5 types) of sulfur and chlorine content for 5 days. Two types of mechanical tests, such as tensile and flexural, have been carried out. The source of the Sulfur is chlorine ammonium sulfate and sodium chloride. In flexural strength, sulfur always performs better than chlorine, while the opposite scenario is in flexural modulus. Sulfur content shows a better performance of 0.3% in flexural analysis. In tensile modulus, chlorine content shows better results in tensile modulus and tensile strength. In tensile analysis, 0.1% chlorine content has better tensile modulus and better tensile strength. To improve long-term structural dependability, this study intends to give significant insights into how welded steel might degrade when exposed to Sulfur and chlorine. These results may assist enhance welding procedures and advise better material selections.

Keywords: Welded Steel, Sulfur, Chlorine, Tensile modulus, Mechanical properties.

1.0 Introduction:
Mechanical components have typically been attached using rivet joints, fasteners, etc. These days, many different welding procedures are available, leading to the widespread use of welding as a fabrication process to unite materials of various compositions, forms, and sizes. Welding is a crucial joining procedure due to its high joint efficiency, low fabrication costs, ease of setup, and flexibility [1]. Welded joints are finding applications in critical components where failures are catastrophes. Hence, inspection methods and adherence to acceptable standards are increasing. Welding involves a wide range of variables such as time, temperature, electrode, pulse frequency, power input and welding speed that influence the eventual properties of the weld metal [2]. Steel welding is not always simple. Choosing welding parameters appropriately for a particular operation is necessary to produce a high-quality weld. As a result, the majority of the "guess work" that welders frequently do to determine the welding parameters for a particular operation can be eliminated when the control system is used in arc welding [3]. However, the sulphide inclusions responsible for the enhanced machinability may have detrimental effects on the anisotropy of properties, which may impair the in-service performance of the component. The extent of this deterioration in properties is dependent on the volume fraction, size, shape and distribution of non-metallic inclusion [4]. Aggressive disinfectants and highly chlorinated water can quickly corrode steel pipes and harm their protective layers, causing galvanized steel to rust and the zinc coating to dissolve. It is crucial to choose a particular kind of stainless steel that provides better corrosion resistance than ordinary stainless steel in order to avoid this [5]. Numerous analyses that support the results have been conducted. Analysis has been done on the impact of Sulfur and oxygen on high austenitic stainless steel weld penetration as well as the microstructure of that penetration [6]. Using 10 mm plates spaced 3 mm apart, the effects of welding parameters on the mechanical characteristics of low carbon steel arc welded joints have been examined. The study illustrates the link between properties such as hardness, tensile strength, impact toughness and welding parameters such as electrode diameter, speed, and voltage [1]. The study investigates how welding parameters affect the microstructure and mechanical characteristics of AA7039 aluminum alloy friction stir welded joints. Furthermore, fracture surfaces of broken tensile specimens were examined using scanning electron microscopes in order to conduct failure analysis and comprehend the influence of microstructure on failure patterns [7]. The study looks into the mechanical joining of Grade 316L stainless steel parts made by laser welding and powder bed fusion. It analyzes the microstructure and stress-strain response, showing that laser welding can make large-scale components that can be produced using additive manufacturing techniques [8]. Kumar et al. [9] observed that the same optimum combination (i.e., A2B1C2D2) in notch tensile strength. In this paper, the metallographic analysis reveals a fine grain structure at the weld centre, which results in higher mechanical properties. Squillace et al. [10] investigated the influence of welding speed and laser power on the macroscopic geometry, microstructure, monotonic tensile and fatigue properties of LBW butt joints in Ti–6Al–4V. Two welding regimes are observed in dependence of the specific heat input. This paper plotted graph welding speed vs root underfill, welding speed vs face underfill, specific heat vs root under fill and welding speed vs face underfill. It also discusses the microstructure of the welded joints. A few studies have found that sulfur and chlorine content in welded steel has a less significant effect if the content is around 0.026 to 0.05 % by weight. However, the increase of this

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content will affect the weldability by reducing the ductility and hardness, increasing the susceptibility of steel to hot cracking during welding, reduce the resistance of corrosion. To check the effect of Sulfur and chlorine at comparatively higher level in welded steel, this topic is interesting to study.

2.0: Materials and Methodology:

2.1 Materials: Mild steel, which has a low carbon content (0.05% to 0.25%), was used for the welding procedure. For the purpose of the study, five kg of mild steel measuring five inches by two inches were gathered. A grinding machine was used in a machine shop to cut the metal. Sulfur and chlorine were added as chemicals along with the mild steel; the Sulfur was supplied by ammonium sulfate and the chlorine by sodium chloride. Next, the proportions of Sulfur and chlorine in these compounds were computed.

2.2 Sample preparation: First, mild steel was collected and shaped according to ASTM standards. A grinding machine was used to cut the specimens, with 62 samples prepared—31 for bending tests and 31 for tensile tests. The specimens were then submerged in a chemical solution containing Sulfur and chlorine, where ammonium sulfate provided Sulfur and sodium chloride provided chlorine. Concentrations of Sulfur and chlorine varied at 0.02%, 0.1%, 0.3%, 0.5%, and 0.7%. The specimens were left in the solution for 5 days. After this period, they were ready for testing, which was carried out using a UTM machine.

Metals can be joined together via arc welding, a type of fusion welding. An electric arc produced by an AC or DC power source can reach high temperatures, which is so hot that it melts the metal connecting two work components.

The voltage of the power supply = 179 V

A consumable electrode was used to create an arc between the metals. Mild steel is used for the welded steel. Mild steel is steel with a lower percentage of carbon (0.05% to 0.25%). The amount of mild steel is collected for the research is 5 kg. Specification of the mild steel is 5 inches by 2.5 inches. Then the metal is cut in the machine shop by grinding machine. After mild steel, sulphur and chlorine have been used as chemicals. Ammonium Sulfate has been used as the source of Sulfur, and Sodium Chloride has been used as the source of chlorine. Then calculated, the percentage of Sulfur and chlorine from the chemical

.

Table 1: Amount of Sulfur in Ammonium Sulfate

% of Sulfur(S)	Amount of ($(NH_4)_2SO_4$)
0.02 % S	0.41g
0.1% S	2.06 g
0.3% S	6.19 g
0.5% S	10.32 g
0.7% S	14.45 g

Table 2: Amount of Cl in NaCl

% of Chlorine	Amount of NaCl
0.02% Cl	0.16 g
0.1% Cl	0.82 g
0.3% Cl	2.46 g
0.5% Cl	4.11 g
0.7% Cl	5.76 g

2.3 Testing:

Flexural: Figure 1 is the specimen for the bending test. They are prepared for the bending test five days after the chemical solution. The Specific standard for mild steel for the bending test is ASTM E190-92.

Figure 1: Sample for the Bending test

Tensile: Figure 2 shows the specimen for the tensile testing. The specific standard for mild steel is ASTM E8-13. A specific dimension is required for the tensile testing.

Figure 2: Sample for the tensile test

Figure 3: Tensile test on UTM (Universal Testing Machine)

3.0 Result and Discussion: Chlorine shows more brittleness than Sulfur in the variation of concentration. In every concentration, the modulus of Sulfur is always greater than that of chlorine. The maximum modulus is achieved in 0.10% Cl, which is 122.93 GPa. Comparing with ultimate strength, in most of the cases, Sulfur shows maximum strength**.** However, chorine shows less stress than sulphur, at

0.10% and 0.70%. This can happen because of a chemical reaction with the metal. The maximum strength is 0.30%S, which is 378.71 MPa.

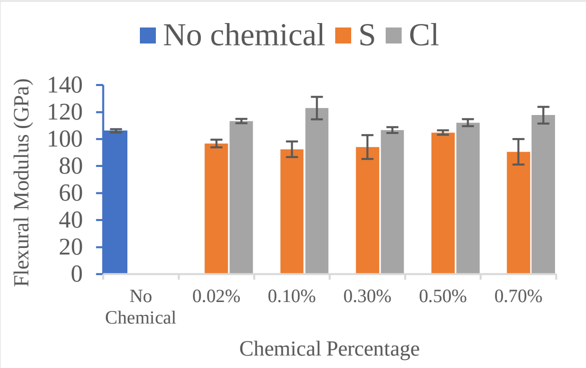

Figure 4: Flexural Modulus

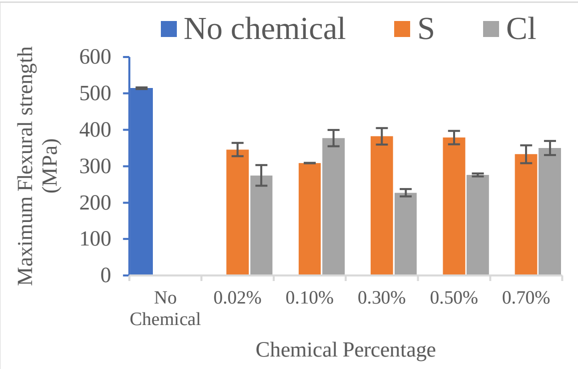

Figure 5: Maximum Flexural Strength

In Figure 5, the tensile modulus of chlorine increased to a certain level, which was 0.1%, and again decreased. The material for sulfur content composition also followed the same trends.

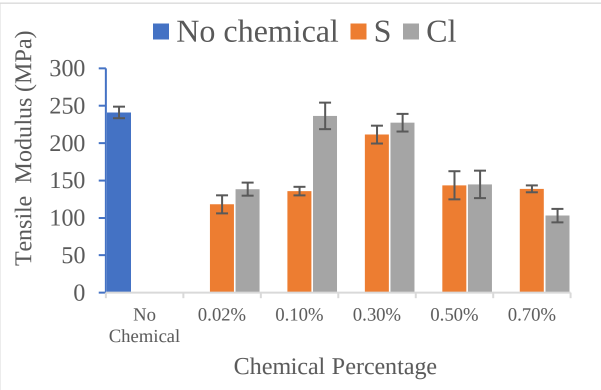

Figure 6: Tensile Modulus

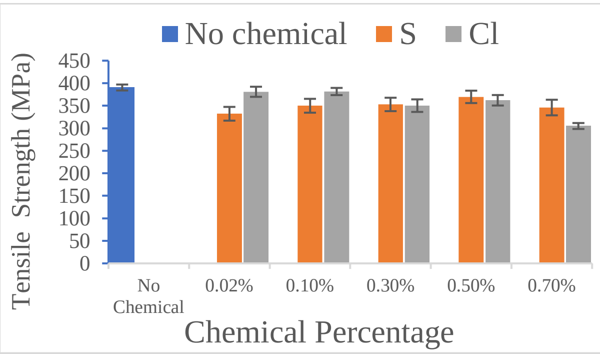

Figure 7: Maximum Tensile Strength

To compare the two contents, the chlorine composition has a modulus of elasticity different from that of sulphur. So, there is a possibility of cracking down easily in the welded joint with chlorine content. In Figure 6, chlorine and Sulfur show nearly equal maximum strength. However, in some cases, chlorine shows better maximum strength than sulfur. The maximum tensile modulus is 236.42 MPa in 0.10% Cl content, which is the same as the flexural modulus percentage. The maximum tensile strength has also been found to be 0.10% Cl.

4.0 Conclusion:

The conclusion of the effect of Sulfur and chlorine content on the mechanical properties of the welded steel is as follows:

Sulphur Content:

- Augmenting the content percentage will increase the modulus of a certain content and again decrease after that. So, a certain portion has the possibility to crackdown maximum because of increasing modulus.
- In the analysis of maximum stress and modulus, both tensile and flexural properties are possible crackdown in the percentage of 0.3% S. In 0.3%S content, it always shows moderated results in both tensile and flexural analysis.

Chorine Content:

- It follows the same trend except maximum stress in flexural analysis, like sulphur content. This can happen because of chemical composition or surface treatment faultiness.
- The overall analysis shows that chlorine has a possible crackdown in the content of 0.1%Cl.

To conclude, Cl has more influence in the welded joint compared to S. Chlorine shows more hard types of material properties than Sulfur.

5.0 Future recommendation:

- Increasing the number of days to keep the sample in the solution mixture. More property changes will be noticed.
- Advanced weldment techniques and post-weld treatment analysis should be applied for better analysis.

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