

# The effect of adding borax on the Oxy-Acetylene Welding (OAW) process on tensile strength of ST42 steel

Moh. Jufri<sup>a</sup>, Heni Hendaryati<sup>b</sup>, Nur Subeki<sup>c</sup>, Mita Putri Bambang Pramojo<sup>d</sup>, Baiq Firyal S S<sup>e</sup>

<sup>a,b,c,d,e</sup> Jurusan Teknik Mesin, Fakultas Teknik, Universitas Muhammadiyah Malang

Jl. Raya Tlogomas No. 246 Tegalondo, Lowokwaru, Malang, Jawa Timur, Indonesia, 65144

e-mail: [jufri@umm.ac.id](mailto:jufri@umm.ac.id)

## Abstract

The welding process aims at joining materials, especially metals or thermoplastic for certain purposes. It melts the materials in the joining process. In some cases, such material is difficult to be joined with the welding process. Therefore, an appropriate flux is needed in this process. The effect of adding borax in the welding process of OAW is the focus of this research. The research was conducted using the experimental method of adding 1 gram, 3 grams, and 5 grams of borax to the brass and ST42 steel welding process. Borax was added to aid the adhesion process between brass and steel as both have different properties. This research results in the highest elongation value in 1 gram of borax addition; the elongation is 3.9935 cm. Meanwhile, adding 1 gram of borax also affects the welding joints' ultimate tensile strength (UTS). It results in the highest UTS value of 9.961779 kN/mm<sup>2</sup> among the other weight variations of borax addition. It indicates that the borax addition with proper weight in the welding process affects the joints. Moreover, the borax addition in the welding process influences the elongation values, ultimate tensile strength, and modulus of elasticity of the welding joints.

**Keywords:** borax; microstructure; Oxy-Acetylene Welding; ST42; tensile test

## 1. INTRODUCTION

Welding is an important method in the steel construction industry and machine manufacturing. It connects two types of metal materials. In the industrial era, welding techniques have become common for connecting rods in steel building construction and machines (1–3). Welding is the main choice in the industry because of its strength. In general, there are several types of welding, such as SMAW, GTAW, GMAW, and OAW. Of the many types of welding, acetylene gas welding or OAW is one of the most widely used in the industrial world for low-carbon steel. The materials being joined can be of the same type or different types (4). This dissimilar welding can be more complicated than similar welding because of the various thermal cycles experienced by each metal (5,6).

Oxy-acetylene welding is a manual process in which the joint surfaces are heated until they melt by an acetylene gas flame produced from the combustion of C<sub>2</sub>H<sub>2</sub> with oxygen (7,8). This process can be done using filler metal and does not involve pressure. In addition to being used for welding, oxy-acetylene welding is also useful for preheating, brazing, cutting, and hard-facing. This technique can be applied in a variety of situations, including production, fieldwork, and repair (9–11). The results are very satisfactory when used to weld carbon steel, especially on thin sheet metal and thin-walled pipes. Although almost all types of ferrous and non-ferrous metals can be welded with this method, either with or without the use of additional materials (12).

Borax has a wide range of applications in various sectors, from manufacturing to agriculture (2,13–16). This compound acts as a raw material in the manufacture of enamel for conductor wires, ceramic glazes, fiberglass base materials, fluxes in metallurgical

processes, fertilizers, and as a fireproof material. In addition, borax is also a flux material used in welding and metal melting processes. The combination of borax and ammonium chloride is often used as a flux in welding steel and iron, helping to lower the melting point of iron oxide compounds (scale) and separating these compounds from the iron surface.

In some cases, using flux in the Oxy-acetylene welding process is important to improve metal properties, increase the degree of liquidity of the molten metal, and prevent gas dissolution to avoid oxidation of the molten metal (1). The composition of this flux usually includes a mixture of borax, glass powder, boric acid, and sodium phosphate, which can be varied according to the type of metal to be welded. Adjusting this composition is the key to achieving optimal and quality welding results.

Tensile strength of OAW welding results with the addition of borax to ST37 steel (17). The results of the study identified that the tensile strength of the specimen using borax had a greater tensile strength value compared to without using borax. In addition, the tensile strain is analyzed on the addition of borax. The results of the specimen test were obtained for specimens using borax higher than those without using borax.

Oxy-acetylene welding (OAW) welding uses various types of filler materials (18–21), one of which is brass, an alloy of copper and zinc. The use of filler materials in Oxy-Acetylene Welding (OAW) is related to heat management. The heating process of the material is carried out carefully to achieve strong joints and optimal structures. The filler pressing time is used to focus on certain aspects of the welding process that can affect the microstructure of the material. Therefore, research is needed to understand the impact of using various types of fillers in Oxy-Acetylene Welding (OAW) welding. This study aimed to evaluate the effect of fillers on Oxy-Acetylene Welding (OAW) weld joints through tensile testing and analysis of tensile strength, microstructure, and microstructure characteristics.

## 2. METHODS

This research uses an experimental method to mix the filler in an OAW welding system. The filler is brass copper, which will be combined with sodium tetraborate (borax) during welding. In this study, variations in filler mixtures will be tested by conducting three experiments for each subject.

For the first subject, the welding of ST 42 steel joints was carried out without borax addition, with air as the cooling medium. In the second subject, the welding of the joints will be carried out by adding borax to the filler, with variations of 1 g, 3 g, and 5 g. Each variation of borax volume will be tested three times.

After the welding process is complete, the final result will be tested using a tensile test. The tensile test data will then be analyzed and presented in graphical form. This analysis aims to understand the effect of adding borax on the tensile strength of welded joints on ST 42 steel, as well as to determine the optimal volume of borax that can increase tensile strength without sacrificing other material properties.

## 3. RESULTS AND DISCUSSION

### 3.1 Findings

This chapter presents the processing of research data that will be discussed according to the data obtained. From the results of the joints after the OAW process and according to the variation of the borax weight on the ST 42 material, the following data was obtained:

Table 1. Data of tensile test

Borax weight (g)	Specimen	Max Force (kN)	Break Force (kN)
0	1	5,99041	5,32308
	2	5,5666	5,22249
	3	5,92208	5,77121
1	1	10,1718	-
	2	10,5556	10,2783
	3	9,21178	3,21717
3	1	10,7551	7,48825

Borax weight (g)	Specimen	Max Force (kN)	Break Force (kN)
	2	9,09514	2,31495
	3	8,18429	5,11150
	1	7,51405	6,27694
5	2	6,72994	3,51877
	3	8,43554	5,08003

Table 1 shows that the specimen with a 1 g borax mixture obtained the largest tensile load value (max force), 10.5556 kN, and the specimen without a borax mixture obtained the smallest tensile load value.

### 3.2 Data analysis

Borax in OAW is used as a flux to improve cleanliness and bonding in welding products, prevent oxidation, and minimize defects. Therefore, it indirectly increases the tensile strength of the steel. It improves the formation into a stronger and more durable weld.

The tensile test results show the various values of Max Force (kN) and Break Force (kN) in the OAW process of ST42 steel, and the values change with varying amounts of borax. The data calculation results show how borax content may affect the tensile properties. Formulas calculate the influence of borax on tensile stress.

$$\Delta L = L_i - L_o \quad (1)$$

The deformation calculation related to elongation and compression is used under a force or stress. The equation finds the change due to stretching, compression, or another form of deformation.

Meanwhile, the calculation for stress is conducted by dividing the force applied to a material by the area over which the force is applied. It quantifies the internal resistance of a material to deformation.

$$\sigma = \frac{F}{A} \quad (2)$$

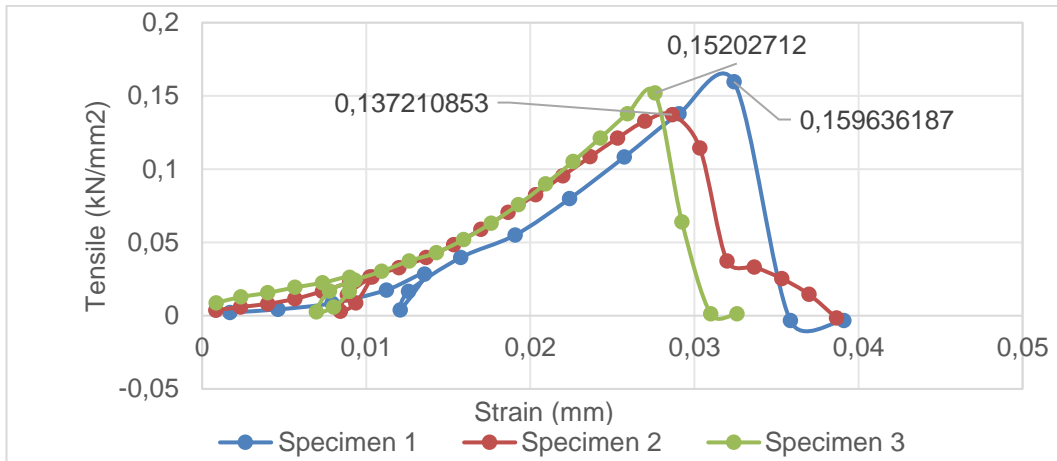
The measure of deformation or the amount of displacement per unit length due to an applied force uses the strain formula.

$$\varepsilon = \frac{\Delta L}{L_o} \quad (3)$$

The modulus of elasticity is calculated after calculating the strain of ST42 welded with OAW and borax flux. This measures the stiffness of ST42 and quantifies its ability to resist tensile or compressive stress.

$$E = \frac{\sigma}{\varepsilon} \quad (4)$$

After calculating the elongation, stress, and modulus of elasticity, the results show that borax has a role in the OAW process of ST42. The results of the calculation are depicted in the graphs.

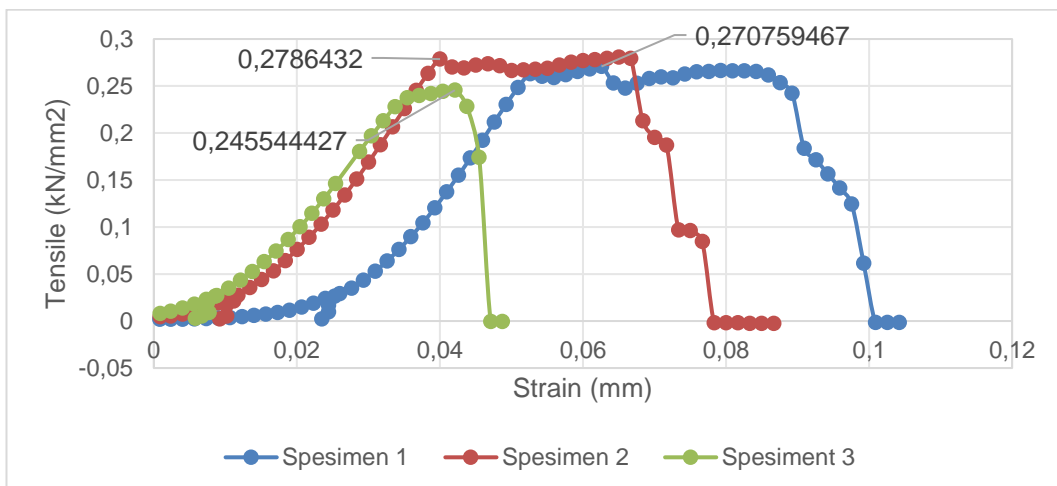


Graph 1. Tensile-strain without borax

Graph 1 represents the mechanical testing of three specimens welded without borax. It depicts the tensile-strain behavior of three specimens. The differences in the curves reflect variations in their mechanical properties. The three specimens show an initial region where the stress increases linearly with strain. It indicates elastic deformation, where the material returns to its original shape if the load is removed. The curves reach a peak tensile stress, which means at the point of ultimate strength, beyond which the stress decreases as strain increases. This marks the onset of plastic deformation and eventual failure of the material.

The peaks for the specimens are labeled with their respective maximum tensile stresses, where specimen 3 results in 0.1372 kN/mm<sup>2</sup>, specimen 2 results in 0.1520 kN/mm<sup>2</sup>, and specimen 1 is 0.1596 kN/mm<sup>2</sup>. These values represent the ultimate tensile strength for each specimen. Therefore, the graph shows that specimen 1 exhibits the highest ultimate tensile strength with the average value of tensile strain is 0.0436 kN/mm<sup>2</sup>, while specimen 3 has the lowest and its average value is 0.0457 kN/mm<sup>2</sup>.

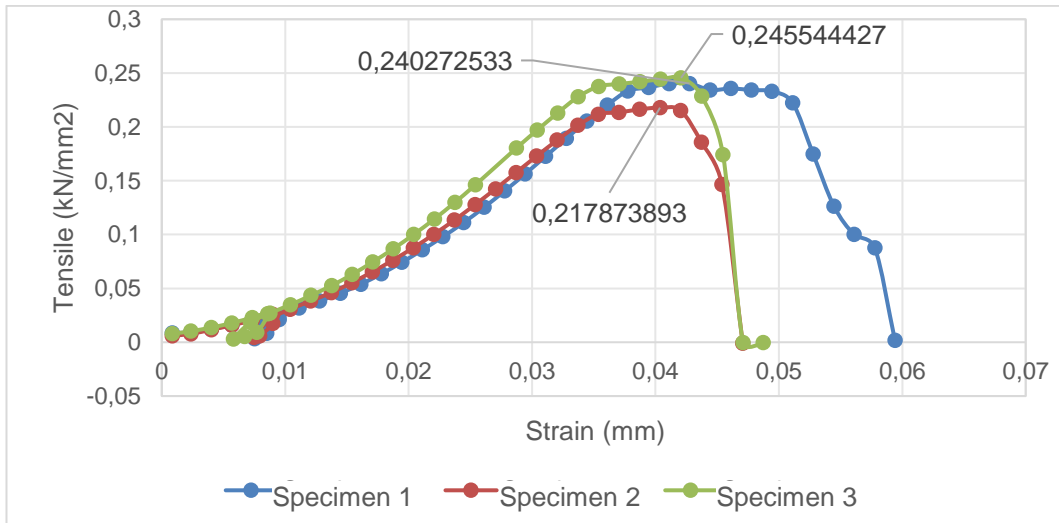
The comparison between the three specimens shows that specimen 1 shows an inclined slope in the elastic region, indicating potentially higher stiffness compared to the others. Specimen 3 shows a slight decline curve with lower stress, which implies weaker material properties or greater ductility. Moreover, specimen 2 lies between the other two in terms of both tensile strength and strain behavior.



Graph 2. Tensile-strain with 1 g borax

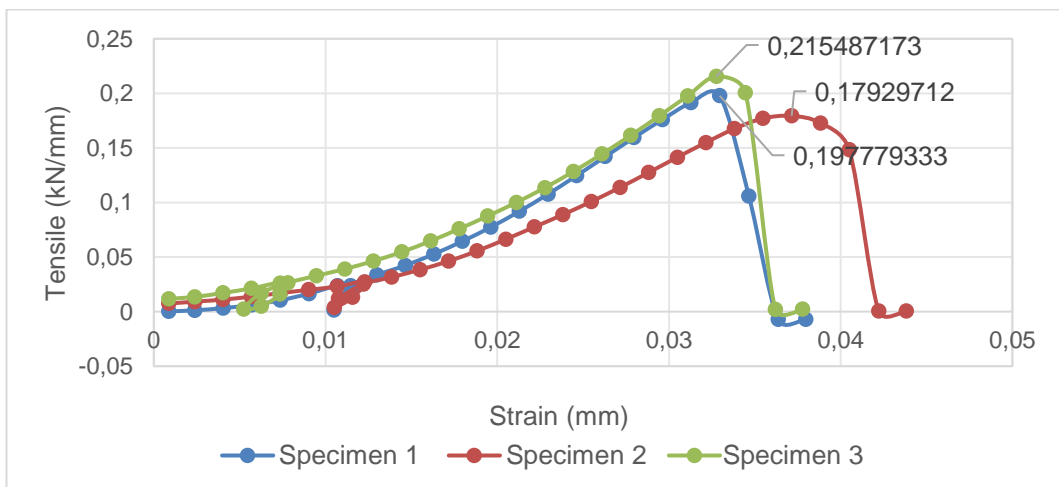
The results of mechanical testing and calculation of ST42 welding with 1 g of borax show a different appearance of the graph without borax. Graph 2 shows that specimen 1 has the highest ultimate tensile strength, which means its peak stress of 0.2786 kN/mm<sup>2</sup> and the

largest strain capacity. The stress continues to decrease gradually after the peak, it shows a more ductile behavior with extended deformation before failure. The average value of specimen 1 tensile-stress is 0.1337 kN/mm<sup>2</sup>. Meanwhile, specimen 2 reaches an ultimate tensile strength of 0.2707 kN/mm<sup>2</sup>, which is slightly lower than specimen 1. The stress drops after the peaks and it shows a brittle-like failure mode. The average value of specimen 2 tensile-stress is 0.1374 kN/mm<sup>2</sup>. For the shortest strain capacity, it is obtained by specimen 3. The curve of the graph shows the lowest tensile strength of this specimen. It is 0.2455 kN/mm<sup>2</sup>. The decline in stress is sharp after the peak. It indicates the brittle failure of the specimen during the testing. The curve also presents the least deformation of specimen 3 before failure. The average value of specimen 3 tensile stress is 0.101 kN/mm<sup>2</sup>.



Graph 3. Tensile-stress with 3 g borax

Graph 3 has slight differences in the ultimate stress, ductility, and elastic region. In this graph, which presents the test results of welded ST42 specimens with 3 g of borax, specimen 1 reaches a maximum tensile stress of approximately 0.2403 kN/mm<sup>2</sup>. It means the largest average strain value of 0.1116 kN/mm<sup>2</sup>. Yet, the stress declines gradually after the peak. It shows more ductility and uniform deformation before failure. Meanwhile, specimen 2 reaches a maximum tensile stress of 0.2179 kN/mm<sup>2</sup>, which is lower than both specimen 1 and specimen 3. The average value of strain is moderate and it is 0.953 kN/mm<sup>2</sup>. After the stress reaches the peak, it drops sharply which shows the brittle failure of the specimen. Furthermore, the graph also shows the highest ultimate tensile stress of specimen 3 which reaches 0.2455 kN/mm<sup>2</sup>. Its average value of the tensile stress is 0.067 kN/mm<sup>2</sup>. It shows that it has a shorter strain value than specimen 1.



Graph 4. Tensile-stress with 5 g borax

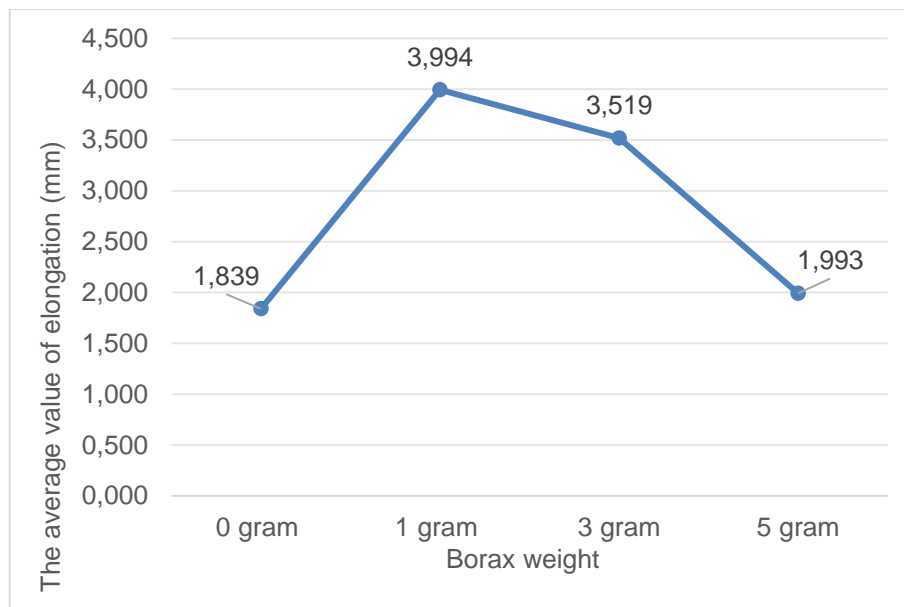
This graph illustrates the tensile stress-strain behavior of specimen 1, specimen 2, and specimen 3 under applied loading. The stress-strain correlation provides insights into the mechanical properties of the specimens, including their strength, ductility, and failure characteristics. The curves show an initial linear elastic region, followed by yielding, and eventually failure at peak stress. Each specimen displays unique peak tensile strength and strain capacity, highlighting differences in material behavior under identical testing conditions.

The three specimens show a similar linear elastic region up to 0.01 mm strain, where the correlation between stress and strain is linear. It represents elastic deformation. The initial slope indicates the stiffness or Young's modulus of the material. These three specimens have the same stiffness because of their nearly identical elastic slopes. They begin to yield and encounter plastic deformation after the elastic region. The stress increases continuously but slower until reaching a peak or ultimate tensile strength. Specimen 3 has the highest ultimate tensile strength of 0.2155 kN/mm<sup>2</sup>, indicating it has better load-bearing capacity before failure because of adding borax flux in the welding process. It has a 0.0715 kN/mm<sup>2</sup> average value of tensile stress. Meanwhile, specimen 2 has the lowest ultimate tensile strength among the three. The value is 0.1793 kN/mm<sup>2</sup>.

### 3.3 Discussion

#### 3.3.1 Elongation

Variation in borax concentration influences the material flexibility and its tensile properties. It is depicted in the graph that there is a correlation between borax weight and the average elongation of specimens.



Graph 5. Elongation value

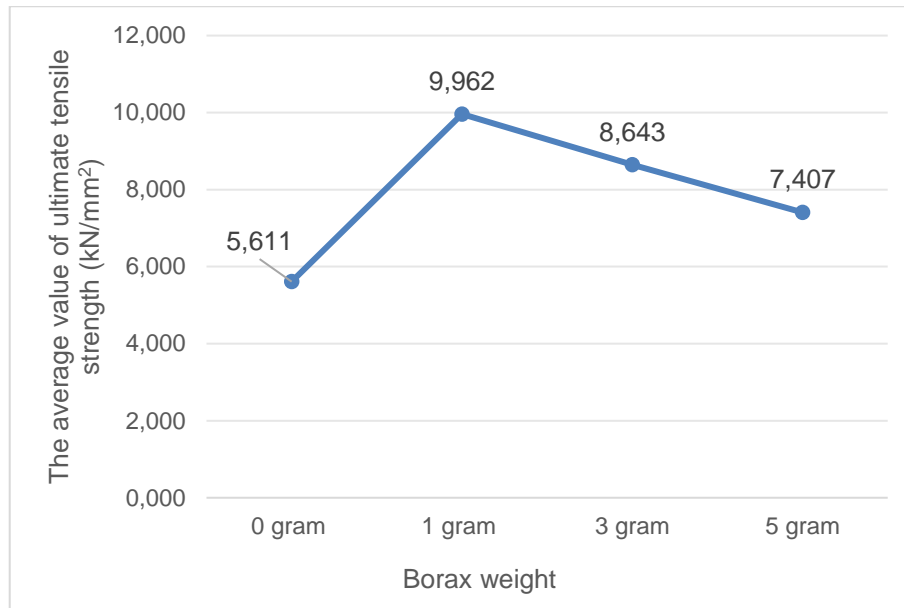
Graph 5 shows the correlation between borax weight and the average elongation of the specimens. It presents the effects of borax on the material's ability to stretch or deform under tensile forces.

The graph shows the trend of borax weight and average elongation correlation. As borax weight increases from 0 grams to 1 gram, the average elongation increases significantly, reaching the maximum value of 3.994 mm at 1 gram. With more than 1 gram of borax, the elongation starts to decrease. It declines to 3.519 mm at 3 grams and further reduces to 1.993 mm at 5 grams. 1 gram of borax addition in the OAW process of ST42 enhances its elongation. It is possibly due to improved bonding, flexibility, or plasticity imparted by borax at this level. The graph shows that the optimal borax weight for maximizing elongation is 1 gram, as this condition yields the highest elongation of the material.

As the flux in OAW for ST42 steel, borax acts as a plasticizer or modifier up to a certain concentration. It improves flexibility and elongation. However, excessive borax might interfere with the material's structure or introduce brittleness leading to a reduction in elongation.

### 3.3.2 Ultimate Tensile Strength (UTS)

Optimizing borax concentration in the OAW of ST42 is important for maximizing the tensile strength. At low concentrations, borax enhances the material UTS. However, it leads to a decline in performance at excessive amounts. It is likely due to adverse structural effects.



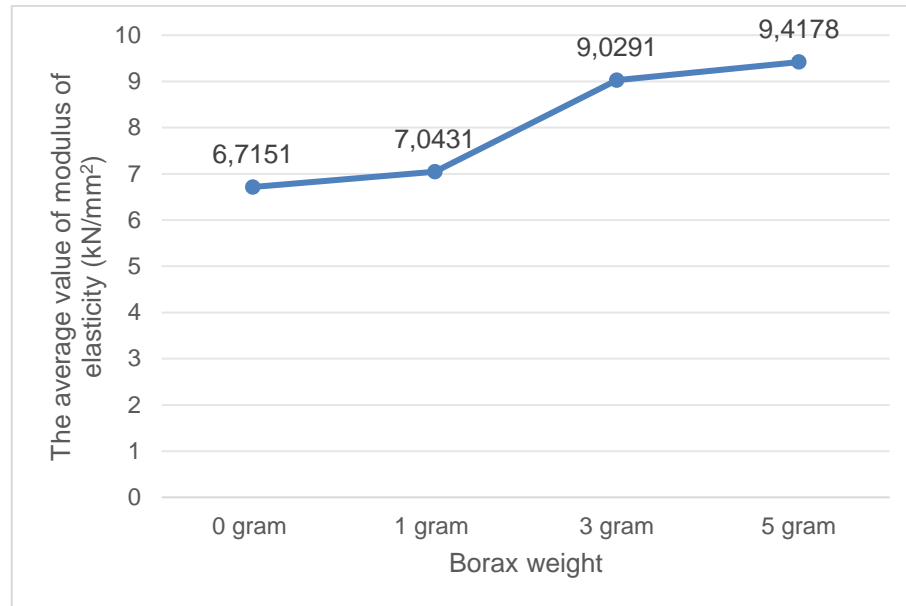
Graph 6. Ultimate Tensile Strength

Graph 6 illustrates the correlation between borax weight and the average value of ultimate tensile strength (UTS) in specimens. The UTS represents the maximum stress the specimens can withstand before breaking. The data shows a clear trend where the tensile strength increases with borax addition in the welding process up to a certain point. It gradually declines as borax concentration increases. This behavior shows the role of borax in modifying the material's mechanical properties and its potential limitations at higher concentrations of borax.

At 0 grams of borax, the material has an initial UTS of approximately 5.611 kN/mm<sup>2</sup>. UTS value significantly improves reaching a peak of 9.962 kN/mm<sup>2</sup>, when 1 gram of borax is added. The increasing value can be attributed to borax improving the structure of the material. The improvement possibly occurs in the stronger inter-particle bonding or the good performance of borax flux as a stabilizing additive. Maximum UTS at 1 gram indicates the optimal concentration of borax for the specimens. However, UTS drops to 8.643 kN/mm<sup>2</sup> with 3 grams of borax addition at OAW, and it further declines to 7.407 kN/mm<sup>2</sup> at 5 grams of borax concentrations. The decrease indicates that excessive borax might disrupt the material's structural integrity, potentially causing agglomeration, weakening of bonds, or increased brittleness. Therefore, the result of this research shows better mechanical properties of ST42 welding with 1 gram of borax concentration and brass filler.

### 3.3.3 Modulus of elasticity

The correlation between the additional borax concentration in the OAW of ST42 and the average value of the modulus of elasticity is shown in the graph. It reveals a consistent upward trend and indicates that increasing borax concentration enhances the stiffness of the specimens. It proves that borax acts as a reinforcing agent and it improves the resistance of specimens to elastic deformation.



Graph 7. Modulus of Elasticity

Graph 7 exhibits that without borax, the specimens reach the modulus of elasticity of 6.7152 kN/mm<sup>2</sup>. This value represents the baseline stiffness of the specimens in their untreated state. Adding 1 gram of borax increases modulus to 7.0431 kN/mm<sup>2</sup>. It indicates a slight improvement in stiffness. This change may result from borax interacting with the material microstructure. It also enhances its ability to resist elastic deformation. Moreover, adding 5 grams of borax leads the modulus to reach its maximum value of 9.4178 kN/mm<sup>2</sup>. It is the highest stiffness observed. It presents that those higher concentrations of borax continuously enhance the material's structural rigidity, although the rate of improvement diminishes more than the lower concentrations.

#### 4. CONCLUSION

The result of tensile stress-strain analysis represents that adding borax in OAW of ST42 steel influences the mechanical properties of the specimens in different ways. It includes its elongation, ultimate tensile strength, and modulus of elasticity.

Adding borax concentration in OAW of ST42, the elongation value of the specimens reaches the maximum at 1 gram of borax weight. The value of the elongation is 3.994 mm. This value implies that at this concentration, the material exhibits better ductility. However, a higher borax weight results in a decline in elongation. It indicates reduced flexibility and an increase in brittleness.

Variation of borax concentrations in OAW of ST42 steel indicates that the ultimate tensile strength peaks at 1 gram of borax. The value is 9.962 kN/mm<sup>2</sup>. It implies the increase of the material's capacity to bear maximum stress due to the borax concentration. Above this point, the tensile strength decreases as the borax weight increases to 3 and 5 grams. Therefore, excessive borax concentration is inappropriate for the material's structure.

The modulus of elasticity consistently increases with borax weight in OAW of ST42. The maximum value reaches 9.4178 kN/mm<sup>2</sup> with 1 gram borax concentration in OAW. This value implies the stiffer and more resistant specimens to deformation under elastic conditions. However, the tensile strength and elongation are reduced.

The implications of this research signify the difference between the borax weight of 1 gram and higher for OAW of ST42. 1 gram of borax in this welding process and this material provides the highest tensile strength and elongation. It is appropriate for balancing strength, flexibility, and stiffness. Meanwhile, the higher borax concentrations improve modulus of elasticity, but compromise ductility and ultimate strength.

These findings found that borax can be used as a flux for OAW of ST42 with brass filler to modify the mechanical properties of the material based on specific application

requirements. However, excessive amounts of borax can lead to diminishing returns reducing the material's effectiveness in load-bearing or flexible applications.

## REFERENCES

1. Kumar K, Kalita H, Zindani D, Davim JP. Welding. In 2019. p. 65–81.
2. Baghel A, Sharma C, Rathee S, Srivastava M. Influence of activated flux on microstructural and mechanical properties of AISI 1018 during MIG welding. *Mater Today Proc.* 2021;47:6947–52. doi: <https://doi.org/10.1016/j.matpr.2021.05.210>
3. Singh RP, Kumar S, Dubey S, Singh A. A review on working and applications of oxy-acetylene gas welding. *Mater Today Proc.* 2021;38:34–9. doi: <https://doi.org/10.1016/j.matpr.2020.05.521>
4. Nagy M, Behúlová M, Pérez MR. Microstructural and mechanical properties of dissimilar Al-Ti joints prepared by GTAW welding-brazing. *IOP Conf Ser Mater Sci Eng.* 2019 Jan 4;465:012006. doi: [10.1088/1757-899X/465/1/012006](https://doi.org/10.1088/1757-899X/465/1/012006)
5. Ogbonna OS, Akinlabi SA, Madushele N, Fatoba OS, Akinlabi ET. Grey-based taguchi method for multi-weld quality optimization of gas metal arc dissimilar joining of mild steel and 316 stainless steel. *Results in Engineering.* 2023;17:100963. doi: <https://doi.org/10.1016/j.rineng.2023.100963>
6. Wang H, Klarić Š, Havrlišan S. Influence of activating fluxes on metallurgical characterizations in welding process for steels - A review. *METALURGIJA.* 2024;63(2).
7. Silva GLS, Campos JCC, Silva CL da, Carlos IRR, Siqueira AM de O, Brito RF, et al. Flame temperature analysis in the oxycut process using acetylene gas: a numerical study. *The Journal of Engineering and Exact Sciences.* 2020 Oct 20;6(4):0555–63. doi: <https://doi.org/10.18540/jcecvl6iss4pp0555-0563>
8. Atak O, McDermott R, Langston J, Koo JH. PRELIMINARY ANALYSIS OF THE EXPERIMENTAL STUDY OF ABLATIVE MATERIALS EXPOSED TO OXY-ACETYLENE TEST BED WITH MODELING. *International Journal of Energetic Materials and Chemical Propulsion.* 2020;19(3):239–52. doi: [10.1615/IntJEnergeticMaterialsChemProp.2020030350](https://doi.org/10.1615/IntJEnergeticMaterialsChemProp.2020030350)
9. Rout A, Deepak BBVL, Biswal BB. Advances in weld seam tracking techniques for robotic welding: A review. *Robot Comput Integr Manuf.* 2019 Apr;56:12–37. doi: <https://doi.org/10.1016/j.rcim.2018.08.003>
10. Wang B, Hu SJ, Sun L, Freiheit T. Intelligent welding system technologies: State-of-the-art review and perspectives. *J Manuf Syst.* 2020 Jul;56:373–91. doi: <https://doi.org/10.1016/j.jmsy.2020.06.020>
11. Attah J, Mohammed L, Nyamful A, Donkor P, Asamoah A, Zainudeen MN, et al. Oxy-hydrogen gas as a sustainable fuel for the welding industry: Alternative for oxy-acetylene gas. *Cleaner Energy Systems.* 2024 Dec;9:100160. doi: <https://doi.org/10.1016/j.cles.2024.100160>
12. Civjan SA, Guihan T, Peterman K. Testing of oxyacetylene weld strength. *J Constr Steel Res.* 2020 May;168:105921. doi: <https://doi.org/10.1016/j.jcsr.2019.105921>
13. Orhan R, Aydoğmuş E, Topuz S, Arslanoğlu H. Investigation of thermo-mechanical characteristics of borax reinforced polyester composites. *Journal of Building Engineering.* 2021 Oct;42:103051. doi: <https://doi.org/10.1016/j.jobe.2021.103051>
14. Cetin MH, Kabave Kilincarslan S. Effects of cutting fluids with nano-silver and borax additives on milling performance of aluminium alloys. *J Manuf Process.* 2020 Feb;50:170–82. doi: <https://doi.org/10.1016/j.jmapro.2019.12.042>
15. Al Shlowiy A. Tracking Saudi EFL Students' Reflections of Online Learning During Coronavirus: Different Rounds. *Front Educ (Lausanne).* 2021 Dec 20;6. doi: [10.3389/educ.2021.770786](https://doi.org/10.3389/educ.2021.770786)
16. Ding Y, Xu G, Liu A, Liu P, Zhang L, Fan Z, et al. Influence of borax on the structure and tribological properties of aluminum alloy plasma electrolytic fluorination film layer. *Surf Coat Technol.* 2024 Aug;490:131175. doi: <https://doi.org/10.1016/j.surfcoat.2024.131175>
17. Bagas Ariya Dipangga, Prantasi Harmi Tjahjanti. Study of Tensile Strength Test of Oxi-Asetylene Welding with the Addition of Borax to St 37 Steel. *Procedia of Engineering and Life Science.* 2021 Mar 28;1(1). doi: <https://doi.org/10.21070/pels.v1i1.828>

18. Mochamad Yusuf Afandi, Dwisetiono. Comparison of Welding Results Using Oxy Acetylene Welding (OAW) and Gas Metal Arc Welding (GMAW) on Brass Leaf Propeller Repair. JOURNAL OF MECHANICAL ENGINEERING MANUFACTURES MATERIALS AND ENERGY. 2024 Nov 15;8(2):109–18. doi: [10.31289/jmemme.v8i2.10256](https://doi.org/10.31289/jmemme.v8i2.10256)
19. H. R. Alinaghian, Vanini SAS, Vaghefi SMM. Evaluation of microstructure and hardness in repair with OAW method in copper DHP moulds. Journal of Welding Science and Technology. 2020;6(1).
20. Fadelan, Winardi Y, Putra WT, Anangga TP. The Effect of Welding Current on Shear Test and Microstructure TIG Brazing of Cemented Carbide and Steel. Journal of Physics: Conference Series. 2024 Apr 1;2739(1):012041. doi: [10.1088/1742-6596/2739/1/012041](https://doi.org/10.1088/1742-6596/2739/1/012041)
21. Modi OP, Deshmukh N, Mondal DP, Jha AK, Yegneswaran AH, Khaira HK. Effect of interlamellar spacing on the mechanical properties of 0.65 % C steel. 2001;46:347–52. doi: [https://doi.org/10.1016/S1044-5803\(00\)00113-3](https://doi.org/10.1016/S1044-5803(00)00113-3)