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Effect of Temperature on Tensile Strength of Polypropylene Plate Material Using Hot Gas Welding (HGW) Method

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ABSTRACT

This study focuses on plastic welding, a technique that employs polypropylene plastic material in 3600-litre reservoir applications. The liquid pressure within it causes hydrostatic pressure in the reservoir. The pressure in the reservoir is approximately 0.01 N/mm2. This study aimed to determine how frequently polypropylene joints leak or sustain damage as a result of welding. Hot gas welding (HGW) with a v-groove connection type is employed (v-grove). Specimens of polypropylene were prepared in accordance with ASTM D638-I. In this study, the input parameters were chosen by varying the welding position and the machine's setting temperature. The results indicated that the required welding temperature for 5 mm-thick polypropylene plastic ranged between 220 and 280 degrees Celsius. In the tensile test on samples S1, S2, and S3, the average decrease in tensile strength of the three test objects was 13.84 N/mm2, 15.98 N/mm2, and 15.21 N/mm2, respectively.

***Keywords**: Hydrostatic pressure, Plastic welding, Polypropylene , Tensile strength, Welding temperature.*

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1. INTRODUCTION

Plastics belong to a class of polymers that have unique properties. Plastic comes from the word "plastikos," which means easy to shape. A polymer is a material consisting of molecular units called monomers. A homopolymer is one in which the monomers are the same. A copolymer is formed when the monomers are different. Plastics can be thermoplastic or thermoset in general [1] [2]. The first type of plastic is a material that can be welded. Thermoplastic is a type of plastic that can be processed by the heating process and can recycle. In contrast, thermoset plastic is a type of plastic that, when subjected to certain conditions, cannot be reprinted [3].

Welding is commonly performed on ferrous and nonferrous steel materials. Welding on steel types was performed by [4][5][6][7], whereas welding applications on nonferrous materials was performed by [8][9][10]. Welding research with plastic materials is still uncommon. The inefficiency of the hot gas welding process is that the gas temperature is higher than the melting point temperature of the polymer being welded [11]. Another issue is the appearance of polymer substrate degradation. The operator determines the quality of welds on plastic materials and is governed by the EN 13067 standard [12]. According to ISO 472, plastic welding is the process of joining softened material surfaces, typically with the aid of heat (except solvent welding). The welding of thermoplastics is done in three stages: surface preparation, heat and pressure application, and cooling [13].

Several plastic studies using polypropylene materials were carried out by [14]. The research was performed utilizing the friction stir welding (FSW) technique. This is accomplished through the application of technology created by the manufacturing sector as a result of its numerous contributions involving the welding of lightweight materials such as aluminum and magnesium. The process has recently incorporated thermoplastics [15].

The study's goal was to look into the quality of the welds. Utilized were three distinct pin geometries: cylindrical, square, and conical. Different rotational and tool traversal speeds were selected. Also investigated is the effect of shoulder circumference. The tensile strength of the weld has been measured and correlated to the pin profile. The results show that square pins have the potential to produce high-quality welds. It has been found that process parameters have a substantial effect on the tensile strength of welded joints.

Several studies on polypropylene-based plastics were conducted by [16]. The research was performed using the friction stir welding (FSW) technique. The possibility is a result of the manufacturing industry's technological advancements, which involve lightweight welding materials such as aluminum and magnesium for use to incorporate thermoplastics. Three different tools with cylindrical, square, and conical pin shapes were used to check the quality of the welds. For the experiment, three distinct rotational and tool traverse speeds were selected. Researchers have examined the impact of shoulder diameter. The tensile strength of the weld has been measured and correlated with the profile of the pin. The results obtained demonstrate the capability of square pins to produce high-quality welds. Weld tensile strength is significantly affected by process parameters [16].

In contrast to the aforementioned studies, 5 mm thick polypropylene sheet material was used for plastic welding research. Using the hot gas welding (HGW) technique, the weld is created. This study was conducted to determine the impact of temperature variations on the tensile strength of polypropylene sheet material. The chosen welding connection technique for polypropylene material is a single V-weld groove at an angle of 60 °. The digital universal testing machine (UTM) standard is used for the tensile test according to ASTM D 638

2. METODOLOGY

This research employed an experimental approach. Using a combination of literature reviews, field research, and testing, this study collects data. The process flowchart for this research is depicted in **Figure 1**.

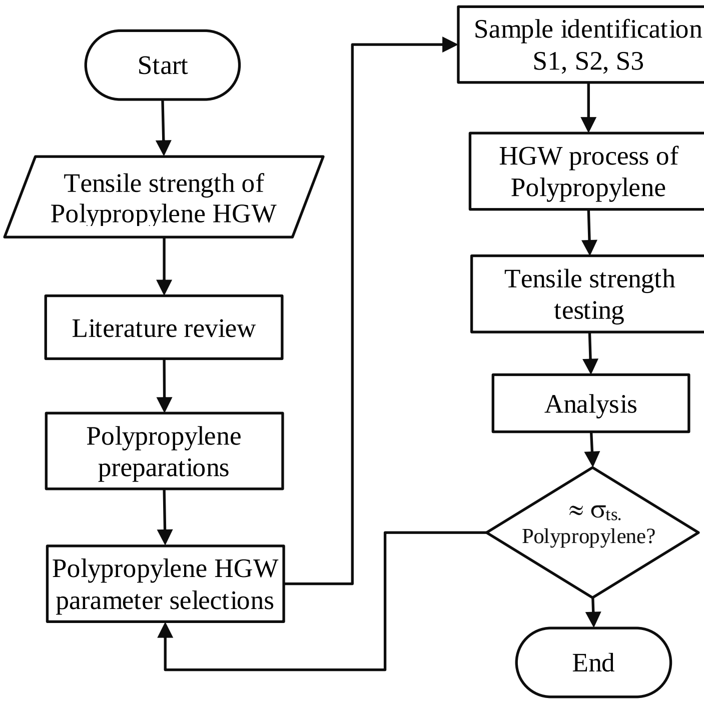

Figure 1. The research flowchart methodology.

2.1. Plastic polypropylene

Polypropylene plastic is frequently employed in producing motor engine covers for pump motors, chemical bath covers, and laboratory equipment, among other items. The tensile strength of polypropylene is approximately 34 MPa, and its modulus of elasticity is 2,000 MPa [17]. Preparation of test samples according to the ASTM D638 standard for tensile testing [18]. Following the HGW procedure, tensile and breaking strain tests were performed to determine the strength of the polypropylene plastic welded joint. The sample preparations for this research is depicted in **Figure 2**.

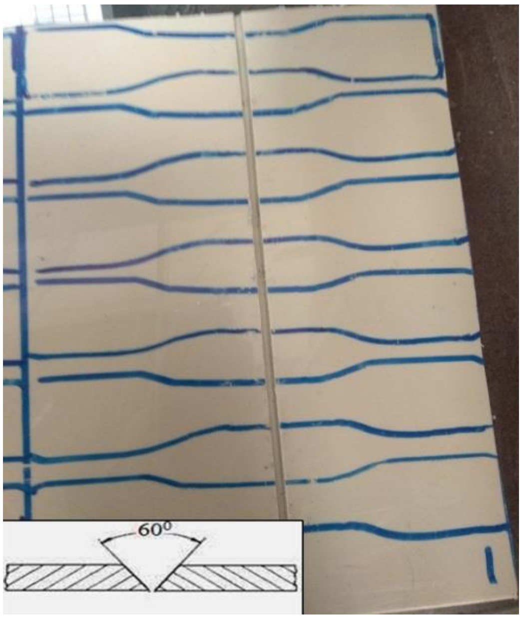

Figure 2. Test sample of polypropylene material

2.2. Test the sample preparation process.

In order to conduct testing for this study, the following steps must be taken to create specimen shapes and weld polypropylene plastic materials:

a. Create a sketch on paper in accordance with ASTM D638 [18]. Preparation and sketching of polypropylene plastic material on a polypropylene plastic plate.
b. The process of cutting plastic with a jigsaw and making an angle so that seams can be welded.
c. Attach the speed welding nozzle to the machine and adjust the welding temperature.
d. Identification of S2, S2, and S3 test samples on a polypropylene plate. Each HGW test parameter is comprised of three test samples.
e. Prepare the polypropylene welding wire and clean it with a thinner-moistened cloth..
f. Weld in accordance with the parameters listed in **Table 1**
g. Conduct the test using a calibrated tensile testing machine.

Figure 3 illustrates the polypropylene tensile test specimen for every test specimen parameter.

Table 1. The Temperature setting experimental

Sample no.	Temperature setting		Sample code
	Min.	Max	
1	33^{0}C	140^{0}C	S1
2	140^{0}C	220^{0}C	S2
3	220^{0}C	280^{0}C	S3

2.3. The tensile strength test

For the purpose of determining the results of the welding strength in this study, a tensile testing machine was required. In the tensile test specimen standard ASTM D 638: Standard test method for tensile properties of plastics. The tensile test uses a calibrated tensile strength tester (RTF) machine. The tensile testing machine can measure with an accuracy of 0.05 kg up to 500 kg. The tensile testing machine is set at 50 mm/min speed. The tensile testing process is presented in **Figure 4**. The resulting test data is in Newton (N) so that the tensile strength value (N/mm^2) is obtained by dividing the force F (N) by the area of the miner *A* (mm^2). The calculation of the tensile strength is expressed in Equation 1[19][20].

$$\sigma = \frac{F}{A} \qquad (1)$$

(a) (b) (c)

Figure 3. Tensile test samples: (a) S1-parameter 1, (b) S2-parameter 2, and (c) S3-parameter 3

3. RESULT AND DISCUSSION

3.1. The tensile strength Analysis

The purpose of the discussion of the results of the strength of the polypropylene plastic welding joint using the HGW method is to determine the tensile strength and breaking strain at the welding joint with variations in welding temperature beginning with S1, S2, and S3. Using equation 1, the magnitude of the tensile strength value is calculated. The average tensile test results for hot-gas-welded polypropylene material S1, S2, and S3 are 13.84 N/mm2, 15.98 N/mm^2, and 15.21 N/mm^2 for test samples S1, S2, and S3, respectively. The data regarding tensile strength is shown in Table 2.

Figure 4. Demonstrates the results of the tensile test for HGW polypropylene.

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Table 2. Tensile strength test data

Test No	Sample 1				Sample 2				Sample 3			
	Length (mm)	Thic. (mm)	Load Test (N)	TS (N/mm^2)	Length (mm)	Thic. (mm)	Load Test (N)	TS (N/mm^2)	Length (mm)	Thic. (mm)	Load Test (N)	TS (N/mm^2)
1	17.05	4.93	1138.8	13.55	14.45	4.88	1180.8	16.75	18.06	4.88	1296.9	14.72
2	17.43	4.75	1321.7	15.96	15.16	4.89	1206.2	16.27	18.02	4.9	1290.6	14.62
3	16.93	4.88	990.94	11.99	16.06	4.89	1172.4	14.93	16.76	4.88	1332.8	16.3

Figure 5 illustrates sample test data for each welding process temperature setting.

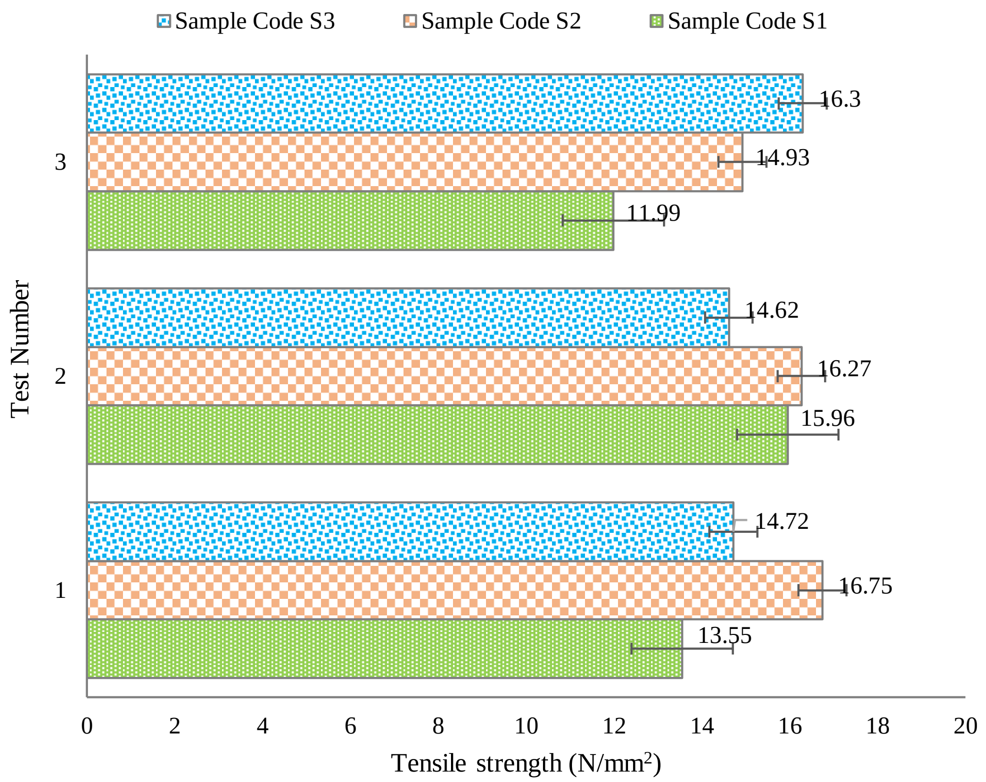

Figure 5. Tensile strength values for each sample and test number

Figure 5 demonstrates that welding polypropylene sheets with the HGW method at temperatures between 140 and 220 °C respectively resulted in a consistent, stable tensile strength value compared to temperatures below 140 °C temperature and above 220 °C temperature The above occurs because the melting point of polypropylene sheet material is approximately 165 ºC [17]. The deficiency of the connection influences the instability of the tensile strength test results in the welding process using the parameters of sample 1. This condition is consistent with the explanation provided by previous research studies [21] [22]

3.2. The elongations analysis

The objective of the discussion of the elongation test results of polypropylene plastic welding with the HGW method is to determine the elongation value of welding joints with variations in welding temperature beginning with S1, S2, and S3[23]. The results of calculating the tensile strength value are found using equation 1. The average tensile test results of hot-gas-welded polypropylene S1, S2, and S3 specimens are 4.4%, 5.2%, and 4.6%, respectively. **Figure 6** depicts data regarding tensile strength.

Figure 6 demonstrates that the elongations of polypropylene sheets using the HGW method at temperatures between 140 and 220 °C resulted in a consistently stable tensile strength value when compared to temperatures below 140 °C and above 220 °C. This occurs because the melting point of polypropylene sheet material is approximately 165 ℃ [17]. The incompleteness of the connection influences the instability of the tensile strength test results in the welding process using the parameters of sample 1. This condition is consistent with the explanation provided by previous research studies [24].

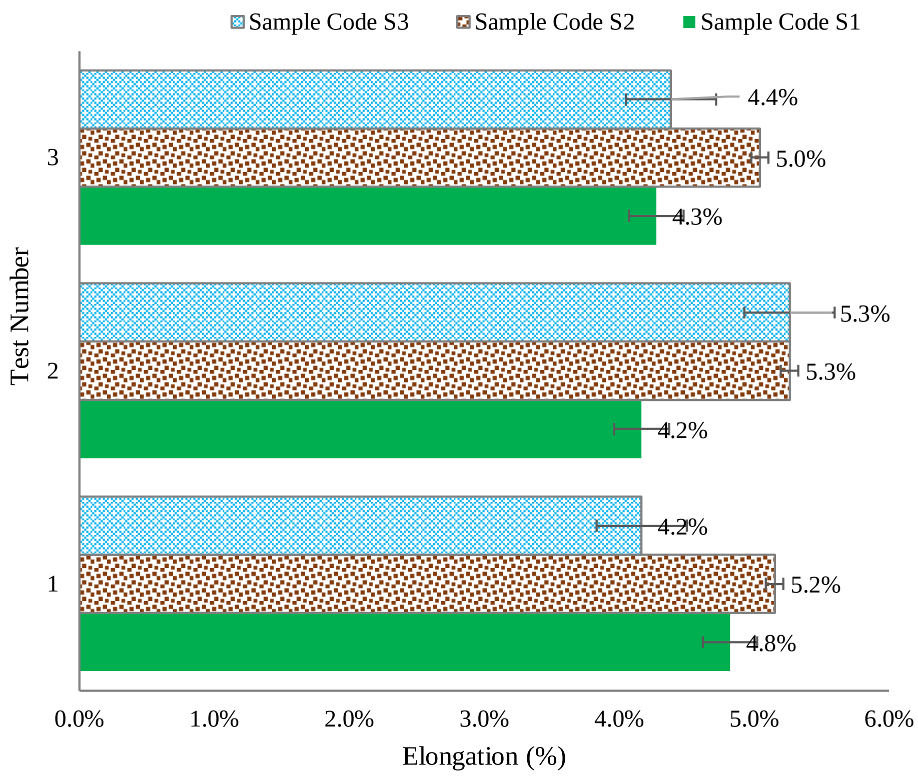

Figure 6. The elongations values for each sample and test number

4. CONCLUSIONS

The following is a summary of the findings of the research on plastic welding of polypropylene sheet materials:

a. The average tensile strength values for the S1, S2, and S3 test samples were 13.84 N/mm2, 15.98 N/mm^2, and 15.21 N/mm^2, respectively, as determined by the polypropylene welding test results. This data illustrates the influence of polypropylene plastic welding temperature settings on the tensile strength of the resulting welds.
b. The average elongation values of the S1, S2, and S3 polypropylene welding test samples were 4.4%, 5.2%, and 4.6%, respectively, based on the average tensile test results. This data illustrates the effect of setting the welding temperature for polypropylene plastic on the resulting tensile strength.
c. The optimal temperature range for welding sheets of 5 mm thick polypropylene plastic is between 140 and 220 °C. This occurs as a result of the polypropylene sheet material's melting point occurring at approximately 165 ° C.

AUTHOR'S DECLARATION

Authors' contributions and responsibilities

The authors contributed significantly to the conception and design of the study. The authors were responsible for data analysis, results interpretation, and discussion. The authors read the final manuscript and gave their approval.

Availability of data and materials

The authors have made all data available.

Competing interests

The authors declare that they have no competing interests.

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