Experimental Research of Tensile Strength Variation of Welded Joints on MMA, MIG and WIG Welding Methods

Sandor Ravai-Nagy[1,*], Ioan Pasca[2], Catalin Darius Crisan[3]

Abstract: *The welding process have a high weight in a lot of industry fields. The quality requirement of welded joint with different methods of welding is very important. For this reason it is necessary to identify the optimum value of input parameters, not only individual value of each parameter but the optimum combination between them. The correct choice of the applied welding method is a challenge in terms of quality and costs. A lot of welding methods are available, each of them ensure different conditions by point of mechanical and chemical properties of welded assembly. The tensile strength analysis of welded joint is one of the most important parameter in order to establish the quality of welding. Its analysis, for the most used welding methods like MMA, MIG and WIG methods, is necessary with experimental methods. Also, the influence of filler metal upon tensile strength of welded joint must me researched.*

Keywords: *Welding, tensile strength, welded joint, filler metal*

1 INTRODUCTION

In modern times a lot of parts from metal fabrication, steel industries, automotive, aerospace, agriculture and other, are produced by using different types of arc welding. This degree of use imposes flexibility and efficiency from welding process. Depending on the required application, the following methods can be used: MMA (manual metal arc), MIG (metal inert gas), MAG (metal active gas), TIG (tungsten inert gas), WIG (wolfram inert gas), FCAW (flux cored arc welding), SAW (submerged arc welding), FW (friction welding), FSW (friction stir welding), FSSW (friction stir spot welding), and EW (explosive welding).

The diversity of welding methods and the particularity of each of the methods in terms of parameters it requires a lot of research and to respect the rules from the standard in order to obtained good results and even to optimize the process.

Some parameters like current, voltage, wire diameter, gas flow type and rate, torch angle can influence the welding process, characterized by some researchers as a complex one (Kumar et al., 2019).

The advantages presented by MMA method, using the electrode in different conditions regarding steel grade, position and place of welding, gives him the reputation of the most universal welding method (Penkala et al., 2014).

Among the advantages of MMA method are also the quality of joints, wide choice of additional materials, highest flexibility and low investment costs. But the method present also some disadvantages because the efficiency is lower and the quality of joint can be affected by a lot of porosity.

The increasingly demanding requirements of different industry area regarding cost-effective, the welding speed and welding quality, requires to use a stable welding process. The MIG welding method is having a growing popularity in industrial aplications because of high-quality of joint (Accar et al., 2023). This method has the possibility of mechanization and automation and to weld in all positions and the burning performance is good.

One of the disadvantages of WIG process is the appearance of impurities because reaching the optimal values of the parameters is a continuous challenge. The desired quality of welding is the result of using strict conditions regarding the work environment, the optimal combination of the parameters values and the training of the welders (Kumar et al., 2019).

The WIG method has a continuous research process noted by evolution and improvement of welding device performance doubled by identification of some automation methods that ensure productivity growth and high quality of welded assembly. The tendency to reduce the share of manual use of the WIG method in favor of automation is a requirement of the industrial environment in order to increase the performance of the process (Burca et al., 2016). Compared with MMA and MIG method the speed of this method is lower but the quality of joint is higher.

A large number of studies are oriented towards optimization of parameters of different method and particularly for specific application or to compare the efficiency and quality using two or more welding methods.

Even if the specialized literature and common standards indicated the optimum value of each parameters for particularly conditions of welding, the experimental practice indicate that is necessary to combine different values in order to obtained the best results in terms of quality and costs (Obura et al., 2023).

The type and structure of material in welding joint have a great influence upon mechanical properties of weld (Singh et al, 2019). Due to the large-scale use of welded assemblies it is important to establish the mechanical properties in order to ensure the proper functioning of the welded structures (Ramazani et al.,2014), (Krella et al., 2020).

In MIG welding of low carbon steel the tensile strength of specimens from welded joints was higher than low carbon steel base material (Nurdin et al., 2021).

2 MATERIALS, EQUIPMENT AND METHODS

2.1. Materials

The choice of material base must be made in correlation with availability and technical requirement of welded structure (Dixit et. al., 2016).

The S235JR non-alloy structural steel material, in conformity with EN 10025-2, was used in experiment. The chemical composition (table 1), mechanical properties of S235JR (table 2) and related standards indicate that this material present good weldability.

Table 1. Chemical properties of S235JR

Material	C %	Si %	Mn%	P %	S %
St-37	0.11	0.024	0.56	0.007	0.01

Table 2. Mechanical properties of S235JR

Material	Tensile stenght [N/mm^2]	Elongation A5 %	Yield strenght [N/mm^2]
S235JR	340-470	26	235

The shape of sheets plate used for welding was rectangle with dimensions 95x160 mm and thickness 7.5 mm. The welding slot was machined according EN ISO 9692-1:2003 international welding standard with practice V-groove with a milling machine FUS 32.

For MMA welding was used the electrod with following code: ESB 50 EN ISO 2560-A Ø3.5x450 mm, without gas protection.

On MIG welding the wire with diameter Ø1.2 mm, from Magmaweld, type MG1 with code 21001EJAM2 (EN ISO 14341-A) was used, with gas protection of Argon 4.8.

In welding on plates with WIG welding method, was used wire from Kronweld producer with diameter Ø1.6 mm, code SG2 for non-alloy steel, with Argon 4.8 protection gas, according with EN ISO 636-A.

The chemical properties of each type for used additional material, are presented in table 3 and mechanical properties of filler metal in table 4.

Table 3. Chemical properties of additional material

Welding Method	Wire type	C %	Si %	Mn %	P %
MMA	ESB 50	0.07	0.35	1.45	-
MIG	MG1	0.07	0.7	1.25	-
WIG	SG2	0.08	0.9	1.5	<0.02

Table 4. Mechanical properties of additional material

Welding Method	Wire type	Tensile stenght [N/mm^2]	Elongation A5 %	Yield strenght [N/mm2]
MMA	ESB 50	560	29	470
MIG	MG1	470	30	400
WIG	SG2	≥500	>22	>460

In order to reduce the error that can be generated by human operation, in welding process was used the standard WPS procedures and certified welder. The skills of the welder can influence the strength of welding result by position, torch angle or speed of welding.

2.2. Equipment and methods

For each welding method, different equipment (table 5) with specific characteristics was used.

Table 5. Welding equipment

Welding Method	Equipment
MMA	Fronius Trans Pocket 2500
MIG	Fronius Trans Steel 4000 Pulse
WIG	Fronius Magic Wave 4000

For measurement of tensile strength of specimens the LBG TC-100 kN tensile testing machine was used (Fig.1).

Fig. 1. LBG TC-100 kN type tensile testing machine

3 EXPERIMENTAL WORK AND CONDITIONS

Because of the large number of parameters involved, obtaining the valid welded samples is a sensitive issue. The most important parameters, mention in paper (Kumar & Singh, 2019), are: current, voltage, gas flow type and rate, torch angle, plate thickness, filler metal.

Most of research indicated that the parametric ranges for current value in MMA welding are indicated between 120 to 160 Amp. The experimental comparison between strength of MS-MS, SS-SS and MS-SS joint, indicate that the highest strength with 140 Amp was obtained in SS-SS joint. From the point of view of remaining energy the lowest value was obtain at 120 Amp by the MS-SS joint (Dixit et al., 2016).

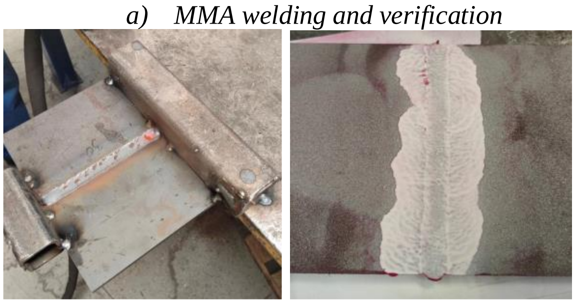
Counting this indication from different researches, the parameters values used in our experiment are presented in table 6 for each welding method used. In order to ensure good condition for current transition the specimen was welded by working table, also another additional material was used at the end of the specimens.

Table 6. Experimental conditions

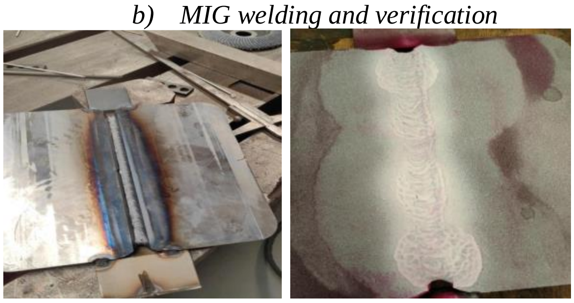
Parameter	MMA method	MIG method	WIG method
Current (A)	130	170	100
Voltage (V)	26	20.5	15.7
Welding speed (m/min)	0.121	0.26	0.099
Gas type	-	Argon 4.8	Argon 4.8

After welding process was finished, the specimen was tested with non-destructive method in order to identify the presence of the porosities and errors (fig. 2).

a) MMA welding and verification



b) MIG welding and verification



c) WIG welding and verification

Fig. 2. Experimental work and non-destructive verification method

After this step, was prepared the shape of specimens and dimensions according to SR EN ISO 6892-1:2020 (fig. 3).

4 EXPERIMENTAL RESULTS

In order to obtained pure information of weld quality both method non-destructive and destructive was practice.

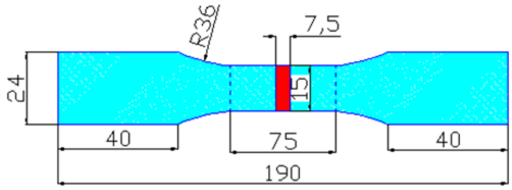
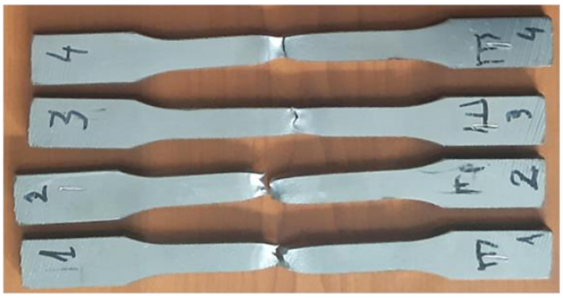


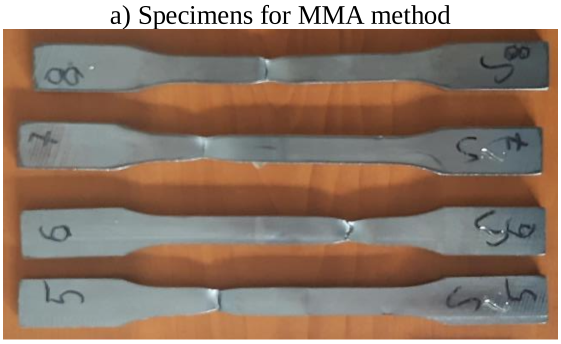
Fig.3. Shape and Dimensions of Test Specimens According to SR EN ISO 6892-1:2020

After non-destructive testing method in MIG welding specimens some defects was observed in first 20 mm, in consequence first and last 25 mm of welding was removed. The specimens were taken from the zone without errors. In MMA and WIG methods this errors was not detected.

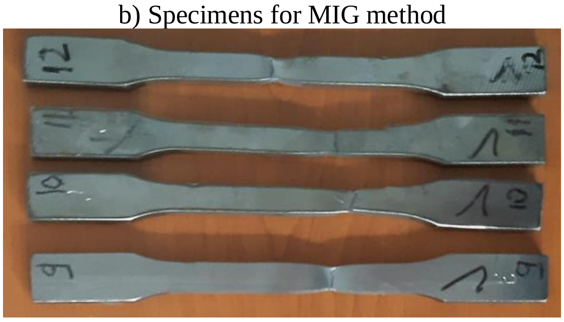
The configuration of specimen, after unfolding of destructive method are presented in figure 4.a for MMA method, figure 4.b for MIG method and figure 4.c for WIG method.



a) Specimens for MMA method



b) Specimens for MIG method



c) Specimens for WIG method

Fig.4. Specimens after destructive method

The results, regarding tensile strength that reflected the mechanical properties, for each welding method, are centralized in tables 7, 8 and 9. Also, for each destructive experiment, the graphs of tensile strength results are present in figure 5,6 and 7.

Table 7. Experimental results for MMA specimens

Nr	A [mm]	B [mm]	Section area [mm²]	Force F [kN]	Tensile strenght [N/mm²]
1	7.4	14.8	109.52	63.419	579.1
2	7.4	14.8	109.52	61.836	564.6
3	7.4	14.8	109.52	61.355	560.2
4	7.4	14.9	110.26	61.553	558.3

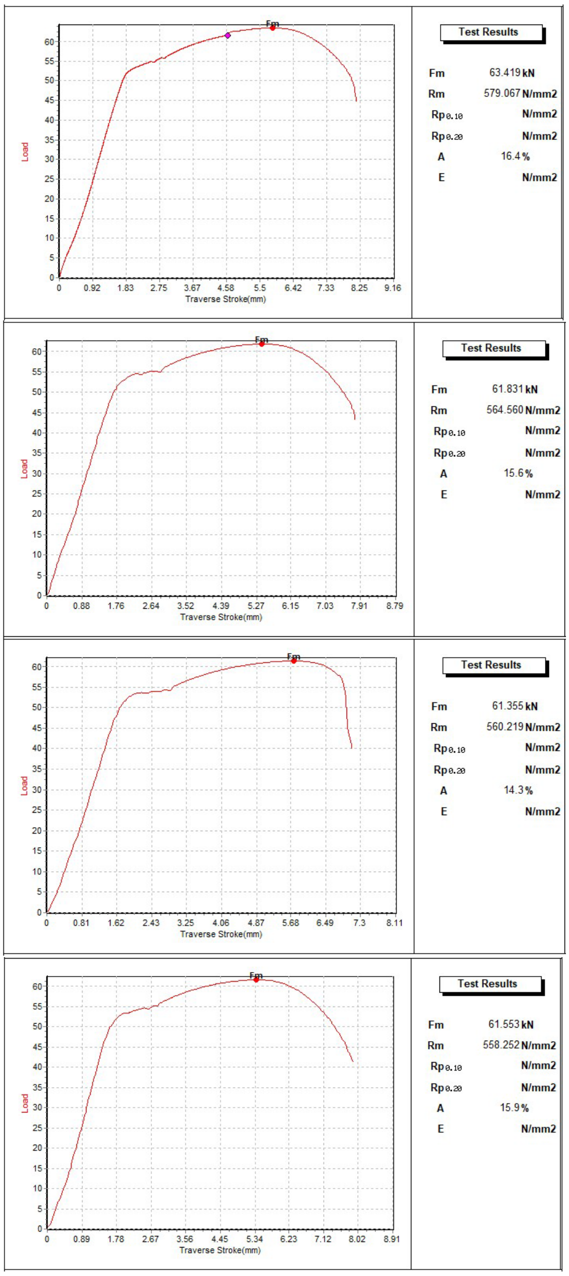


Fig.5. Tensile strength for MMA specimens

Table 8. Experimental results for MIG specimens

Nr	A [mm]	B [mm]	Section area [mm²]	Force F [kN]	Tensile strenght [N/mm²]
1	7.37	14.77	108.885	58.195	534.6
2	7.4	14.85	109.89	60.859	553.8
3	7.35	14.8	108.78	62.862	577.9
4	7.35	14.85	109.147	64.138	587.6

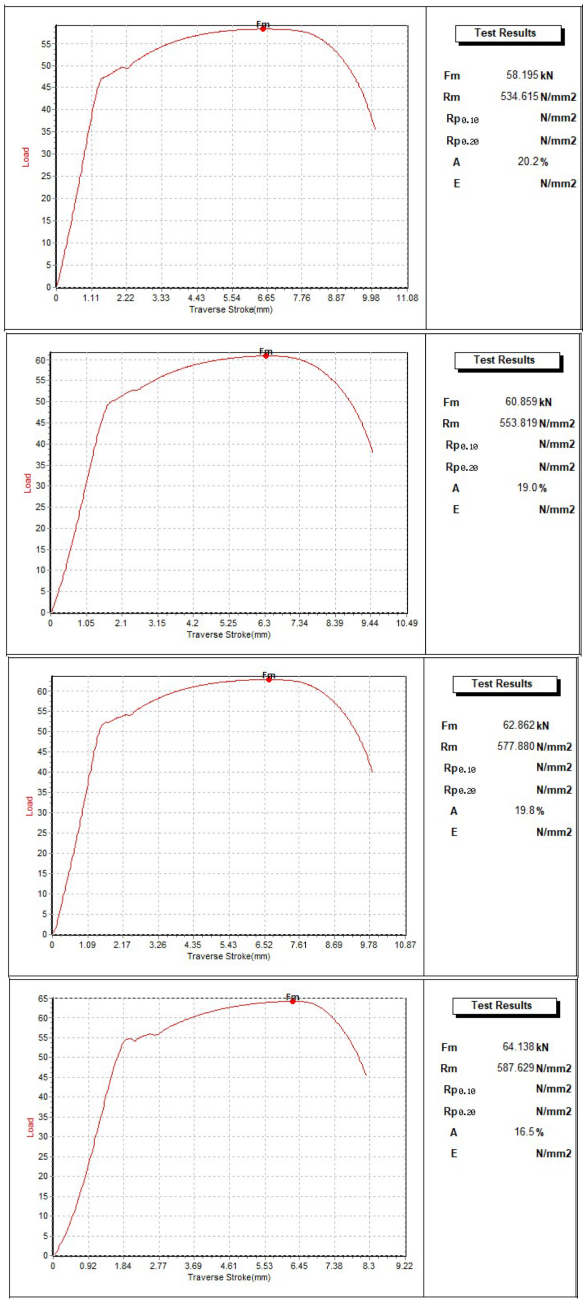


Fig.6. Tensile strength for MIG specimens

Table 9. Experimental results for WIG specimens

Nr	A [mm]	B [mm]	Section area [mm²]	Force F [kN]	Tensile strenght [N/mm²]
1	7.4	14.9	110.26	56.567	513
2	7.35	14.2	104.37	55.211	529
3	7.45	13.4	99.83	53.489	535.8
4	7.37	14.77	108.85	55.841	527.3

5 EXPERIMENTAL DATA ANALYSIS

The analysis was oriented in order to evaluate the quality of weld in relation with tensile strength properties.

For low carbon steel specimen (Nurdin et al., 2021) without welding indicated that tensile strength value is 439.04 [N/mm^2]. In this case by comparison of tensile strength between base material and welded specimens obtained by MMA, MIG or WIG methods, we can conclude that tensile strength is higher on specimens. These results indicate that the filler metal and welding process lead to a higher tensile strength of welded joint.

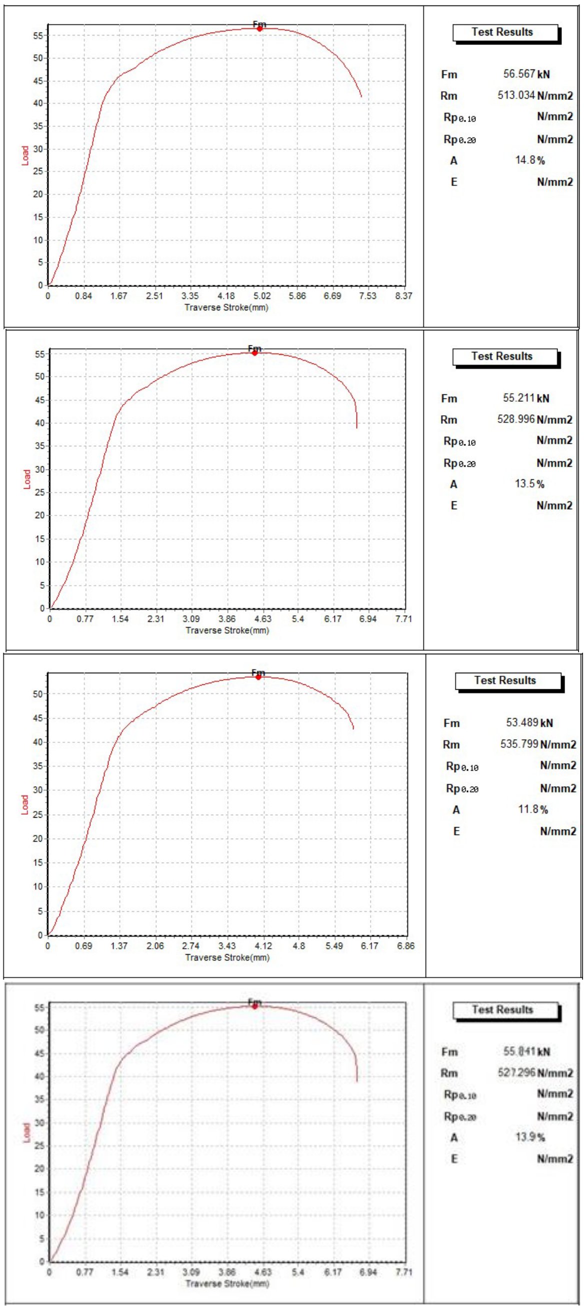


Fig.7. Tensile strength for WIG specimens

The average values of force and tensile strength for each method of welding are presented in table 10.

The biggest value of force an tensile strength have result for MMA welding joint with value of 62.02 kN and 565.55 N/mm^2. The smallest value was obtained for WIG welded joint respectively 55.277 kN and 526.275

Table 10. Average values of tensile strenght

Nr	Welding method	Average value of force F [kN]	Average value of tensile strength [N/mm^2]
1	MMA	62.04	565.55
2	MIG	61.51	563.475
3	WIG	55.277	526.275

6 CONCLUSIONS

By point of welding speed it is obvious that WIG method is slowest in comparison with MMA or MIG welding method. Also, the cost of this method is high, but the quality of welded joint is more accurate, according with non-destructive verification. About analysis of tensile strength, WIG welding method lead to smaller value, what it reflect that the welded joint present a higher flexibility, even if the content of allowing elements of the additional material is higher. The smaller value of tensile strength of 513 N/mm^2 was obtained by using WIG welding method and the higher value of 587 N/mm^2 was obtained by using MIG welding method. By using the MMA and MIG welding methods, average value can be obtain by point of tensile strength, with small costs but with low quality of welded joint.

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Authors addresses

[1]Sandor RAVAI-NAGY, Lecturer Ph.D. Eng., Technical University of Cluj-Napoca, Faculty of Engineering, e-mail: sandor.ravai@imtech.utcluj.ro, V. Babes, Str. 62A, 430083, Baia Mare, Romania.
University of Nyíregyháza, Institute of Technical and Agricultural Sciences, e-mail: nagy.sandor@nye.hu, Sóstói Str. 31/b, 4400, Nyíregyháza, Hungary,
[2]Ioan PASCA, Ph.D. Eng., S.C. Electro Sistem SRL, e-mail: pascaing@yahoo.com, 8 Martie, Str. 4B, 430406, Baia Mare, Romania.
[3]Cătălin Darius CRIȘAN, Eng., Technical University of Cluj-Napoca, Faculty of Engineering, e-mail: dariuscrisan102@gmail.com, V. Babes, Str. 62A, 430083, Baia Mare, Romania.

Contact person

[*] Sandor RAVAI-NAGY, Lecturer Ph.D. Eng., Technical University of Cluj-Napoca, Faculty of Engineering, e-mail: sandor.ravai@imtech.utcluj.ro, V.Babes, Str. 62A, 430083, Baia Mare, Romania.