COMPARISON OF THE PROPERTIES AT ATIG AND TIG WELDED JOINTS WELDED ON THE X5CrNi18-10 STAINLESS STEEL

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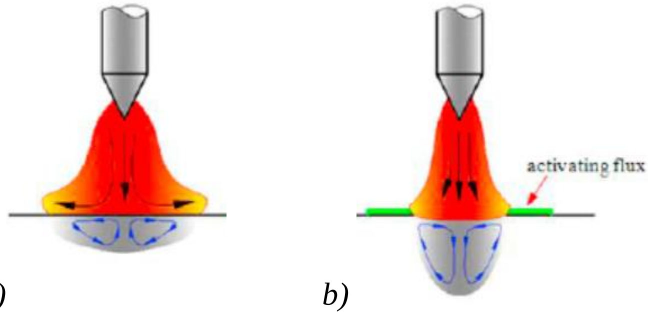
Abstract
Comparison of TIG and ATIG welding processes were investigated in this article on the 5 mm thick X5CrNiMo18-10 stainless steel. Two different active welding fluxes were used for ATIG welding. In first step, the influence of the TIG and ATIG processes on the weldability of the steel were studied by using different welding parameters, where geometries of weld joints were analysed in detail. In second step, mechanical properties of the weld joints, such as tensile tests and bending tests were determined and compared.
Investigation revealed that reveal that ATIG welding process enable better penetration than classical TIG process and at lower welding parameters is easily to achieve fully penetration. This influence on lower heat input during welding what resulted in better mechanical properties welded by ATIG welding process.

1 INTRODUCTION

Reliability of welded joints is one of the basic parameter in achieving good integrity of welded construction as a whole, like pressure vessels, tanks, cranes, metal bridges, etc. Because of the significant share of welding works during its manufacture, the selection of the optimal welding technology is crucial phase in the process of product's manufacturing. Therefore, the special attention needs to be devoted to weld joints, where the most important in such construction building are selecting the right welding process, appropriate welding technology and at the end inspection during and after welding.

One of possibility in area of TIG welding process, which is continuously developing all the time, represents the use of new generation of activating fluxes during TIG welding. In such cases, the TIG process is named ATIG welding process (Activation of electric arc in TIG process) Such active fluxes are highly dispersed mixture which contains necessary micro-amounts of electro-negative and surface active elements, which under the shield of the inert gas in welding allows development of the physical-chemical reactions. This increase the surface tension of the weld molten weld pool what resulted in changing of the rotation of melted material in the weld pool. This is called Marangoni effect of liquid melted metal flow in weld pool which is schematically shown in Figure 1.



a) *b)*

Figure 1. Schematic preview of the Marangoni effect of liquid melted metal flow in weld joint; a) TIG welding process, b) ATIG welding process

These facts and reactions enhance the increased ability of penetration of the arc, what reduces the heat affected zone (HAZ) width and improve the structure of the weld metal. Because of the increasing of crystallization rate due to the molten metal and micro-alloying from the active flux, chopping of the weld metal grains is appeared, what resulted in more fine and disoriented weld material microstructure [1-4].

In this investigation two different active fluxes were used and ATIG welding process which was compared to classical TIG process. Special attention was devoted to influence on the weld geometry and on mechanical properties which were analysed in detail in this article.

2 MATERIAL

Stainless steel s X5CrNi18-10 (304) was used for this investigation. Thickness of the material was 5 mm. The chemical composition of the stainless steel X5CrNi18-10 is presented in Table 1 and its mechanical properties are given in Table 2.

Table 1. Chemical composition of the stainless steel X5CrNi18-10 (weight %)

C	Si	Mn	P	S	Cr	Ni	N
0.026	0.34	1.28	0.029	0.001	18.17	8.05	0.063

Table 2. Mechanical properties of the stainless steel X5CrNi18-10

$R_{p0.2}$ / MPa	R_m / MPa	A5 / %	Hardness / HB
316	657	57,1	88

3 EXPERIMENTAL PROCEDURE

The ATIG welding process and the TIG welding process were used in this investigation. Two different active fluxes were used for ATIG welding. First one was white coloured ATIG active flux - QuickTIG produced by Slovenian JUVAR company. The second one was green coloured ATIG flux - BC-31 produced by Paton Institute in Ukraine. The first active flux was further in this article designated by letter B and the second one by letter Z.

Weldment plates 300 x 150 x 5 mm form stainless steel X5CrNi18-10 were prepared before welding. The I-shaped shaped groove is used on the each of them for welding. Geometry of the weldment before welding is shown in Figure 2.

Program of the investigation with weld joints welded by different welding parameters, active fluxes and welding processes is listed in Table 3.

Table 3. Program of the weldments for TIG and ATIG welding process

TIG	*I* / A	Flux	ATIG	*I* / A	Flux	ATIG	*I* / A	Flux
TIG-A1	80		ATIG-B1	80		ATIG-Z1	80	
TIG-A2	100		ATIG-B1	100		ATIG-Z1	100	
TIG-A3	120	Without	ATIG-B1	120	QuickTIG	ATIG-Z1	120	BC-31
TIG-A4	140		ATIG-B1	140		ATIG-Z1	140	
TIG-A5	150		ATIG-B1	150		ATIG-Z1	150	

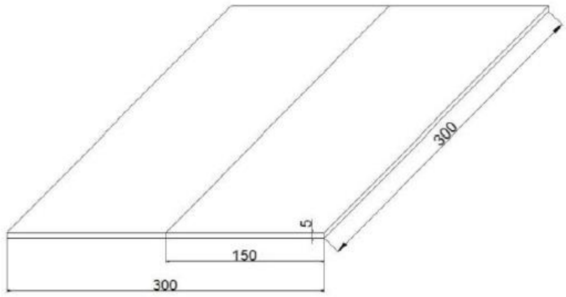
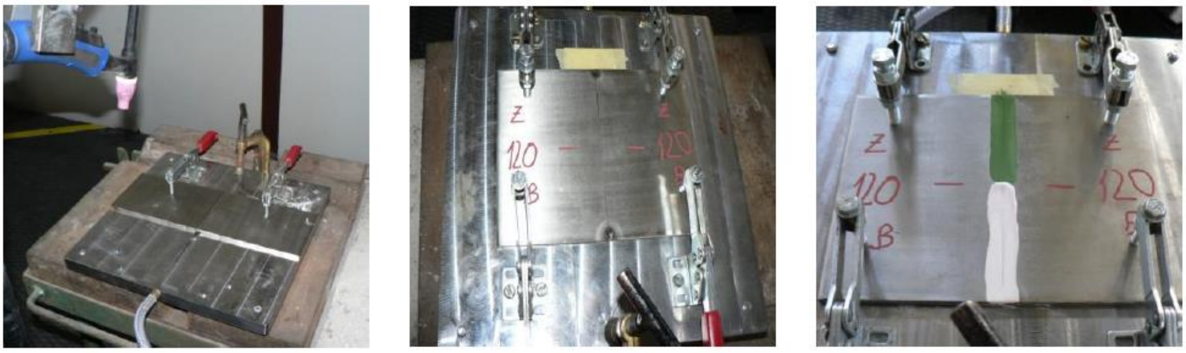


Figure 2. Geometry of the weldment for TIG and ATIG welding

Robot ACMA XR701 and Fronius TIG Magic Wave Fuzzy 2000 equipment were used for welding where welds were protected by forming gas argon from the root side of the weldment. The geometry of the weldment before welding is shown in Figure 2. Preparation of the weldments before welding for TIG and ATIG welding process is shown in Figure 3. Appearance of the weldment directly before welding, during and after welding is represented in Figure 4.



a) b) c)

Figure 3. Clamped weldments before welding; a) TIG process, b) ATIG process – attaching of the weld plates by clamps (c) ATIG process weldment with active fluxes B and Z

a) b) c) d)

Figure 4. Weldment during robot ATIG welding process (welded by welding current 100 A); a) before welding, b) during welding, c) after welding - face side, d) after welding - root side

Welding parameters for each individual weld joint are presented in Tables 4 to 6, where in Table 4 are measured welding parameters for the classical TIG process without active flux. Table 5 shows welding parameters for ATIG process where active flux B (QuickTIG) was used, while in Table 6 are the welding parameters for ATIG welding where the active flux Z (BC-31) were used.

Table 4. Welding parameters for TIG welding

Designation of the Weld joint	*I* [A]	*U* [V]	*v* [cm/min]	*Q* [kJ/cm]
TIG-1	80	9.3	9.1	2.94
TIG-2	100	9.4	9.1	3.72
TIG-3	120	10.0	9.1	4.75
TIG-4	140	10.5	9.1	5.82
TIG-5	150	11.3	9.1	6.71

Table 5. Welding parameters for ATIG welding with active welding flux B (QuickTIG)

Designation of the weld joint	*I* [A]	*U* [V]	*v* [cm/min]	*Q* [kJ/cm]
ATIG-B1	80	10.0	9.1	3.16
ATIG-B2	100	10.7	9.1	4.23
ATIG-B3	120	11.2	9.1	5.32
ATIG-B4	140	11.6	9.1	6.42
ATIG-B5	150	11.4	9.1	6.76

Table 6. Welding parameters for ATIG welding with active welding flux Z (BC-31)

Designation of the weld joint	*I* [A]	*U* [V]	*v* [cm/min]	*Q* [kJ/cm]
ATIG-Z1	80	10.9	9.1	3.45
ATIG-Z2	100	11.5	9.1	4.55
ATIG-Z3	120	12.2	9.1	5.79
ATIG-Z4	140	12.5	9.1	6.92
ATIG-Z5	150	12.3	9.1	7.30

4 RESULTS AND DISCUSSION

Macro-section of the weld joints, which had had the same welding current during welding, were prepared by putting them into plastic mass and grinding on the water resistant grinding paper with different granulation (from 100 to 1000). At the end the macro sections were polished and etched by Ralph’s reagent for 15 to 20 seconds. Macro sections which had been welded by different welding current are shown for welding current 80 A and 100 A in Figure 5, for welding current 120 A and 140 A in Figure 6 and finally for welding current 150 A in Figure 7 [5].

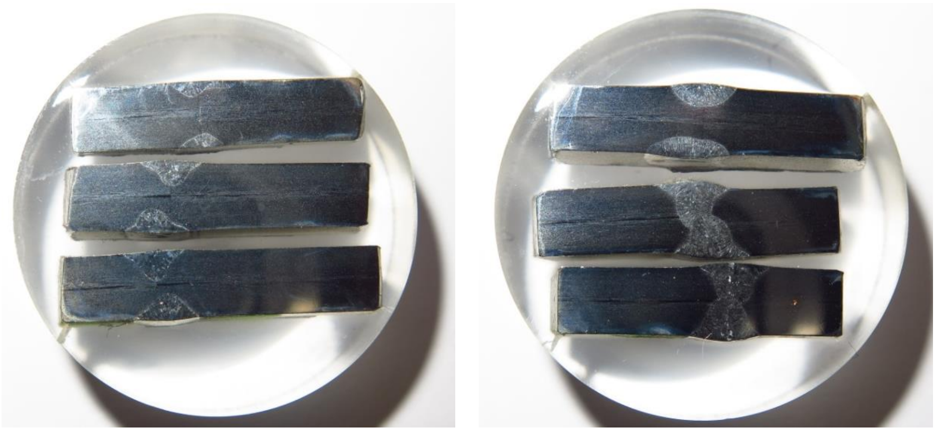


Figure 5. Macro-sections of weld joints welded by current 80 A; (a) TIG-1, (b) ATIG-B1, (c) ATIG-Z1 and macro-sections of weld joints welded by curr. 100 A; (a) TIG-2, (b) ATIG-B2, (c) ATIG-Z2

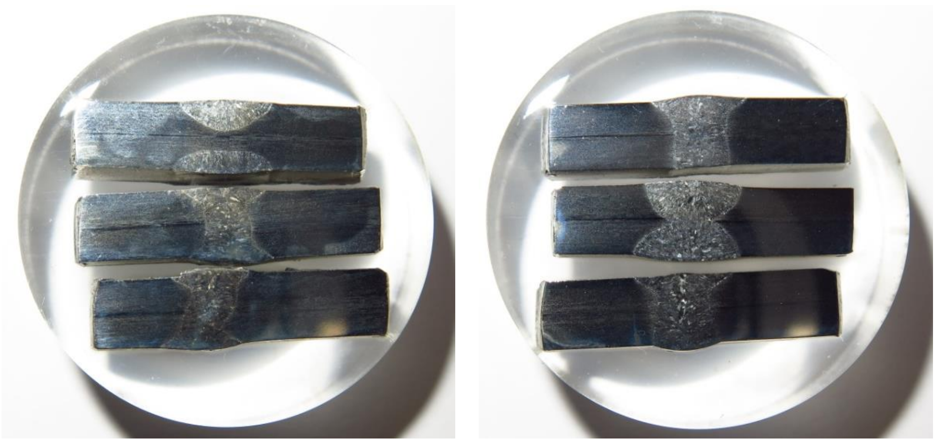


Figure 6. Macro-sections of weld joints welded by current 120 A; a) TIG-3, b) ATIG-B3, c) ATIG-Z3 and macro-sections of weld joints welded by current140 A; a) ATIG-B4, b) TIG-4, c) ATIG-Z4

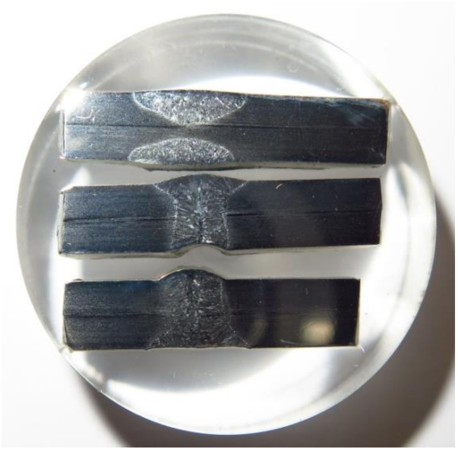


Figure 7. Macro-sections of weld joints welded by current 150 A; a) TIG-5, b) ATIG-B5, c) ATIG-Z5

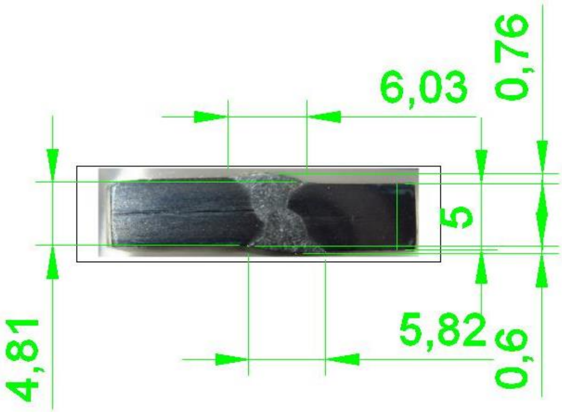


Figure 8. Sample of measured dimensions in weld joint ATIG-B2

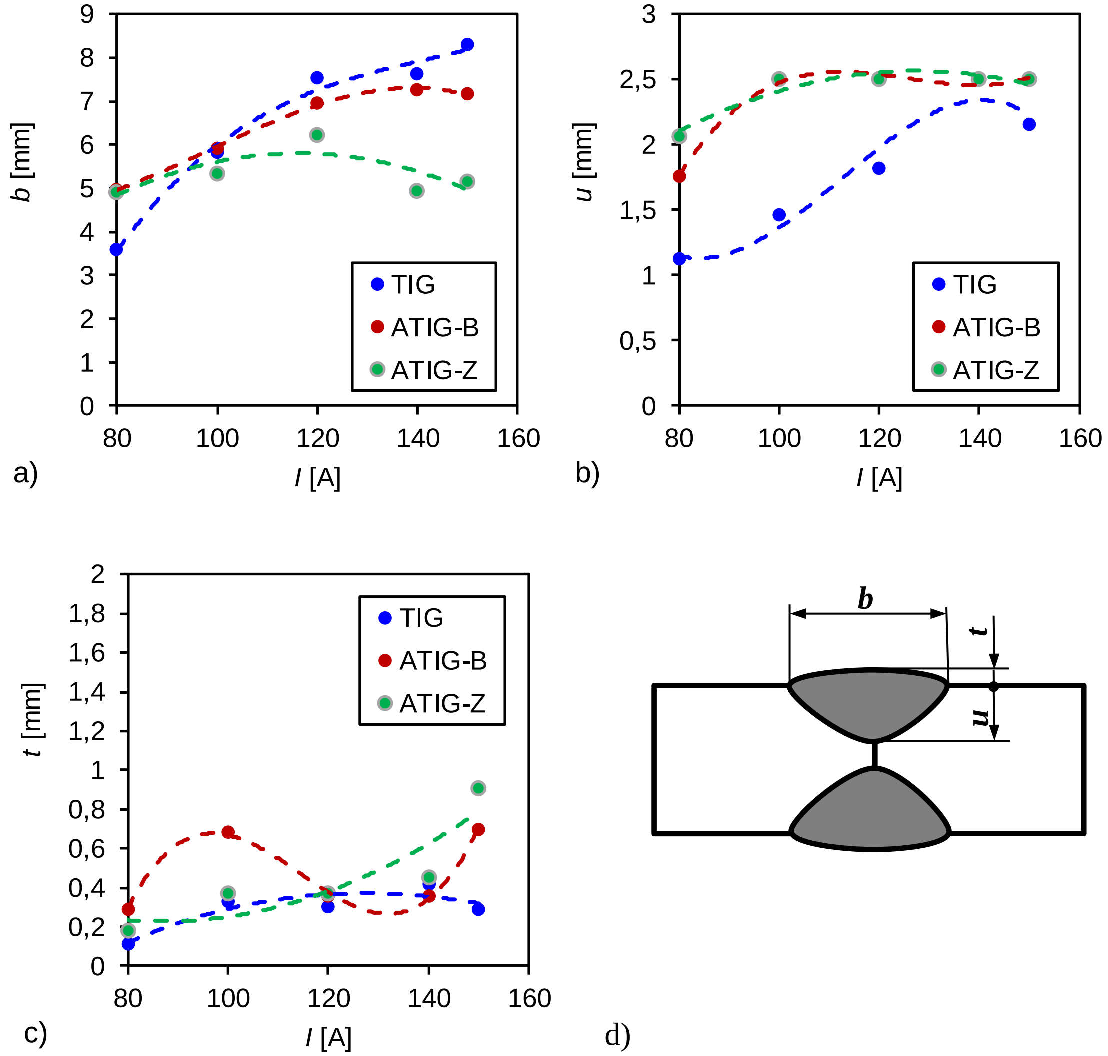


Figure 9. Influence of the welding parameters on a) weld face wideness, b) weld face height, c) penetration depth [5]

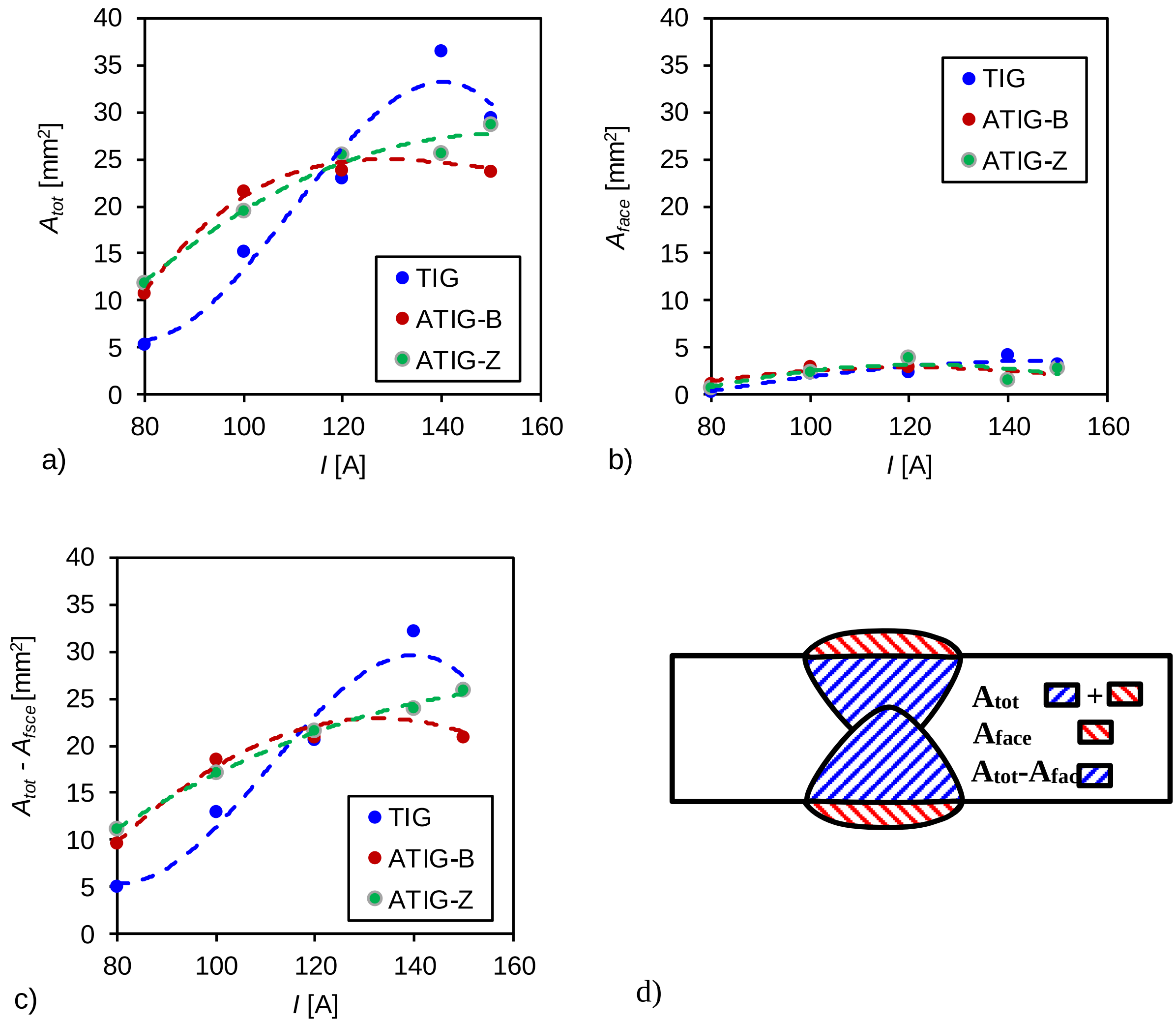


Figure 10. Melted area in weld metal material; a) total weld metal area, b) weld face area, c) weld metal area without weld face area, designation of the measured areas in weld metal [5]

Tensile tests were done for the all of weld joints, by using tensile specimens which geometry is shown in Figure 10.

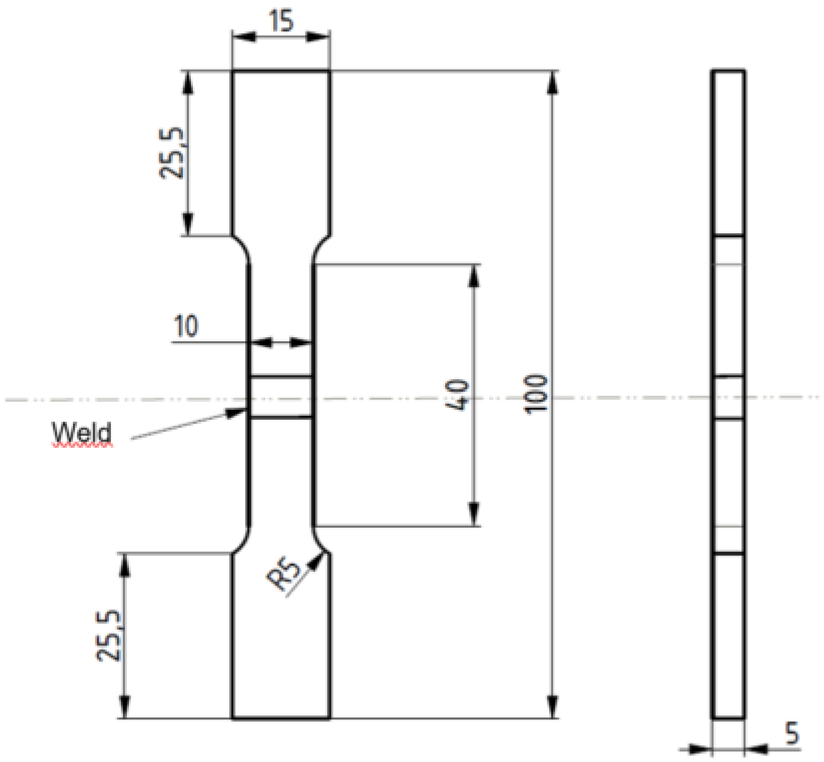


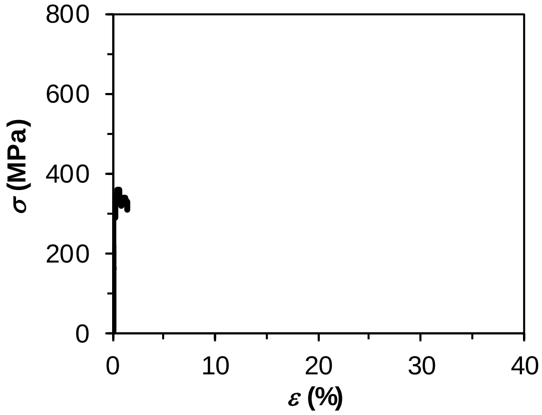
Figure 11. Geometry of tensile specimens.

The curves of the tensile tests for the all weld joints are presented in Figures 11 to 13.

Results of tensile tests on welded joints welded by classical TIG process with different welding currents are presented in Figure 11. Only weld joint TIG-A4 welded by 140 A achieved full penetration through whole thickness, while other weld joints did not achieve penetration through whole thickness. This is reason why in weld joints TIG-A1, TIG-A2 and TIG-A3 influence on of the tensile test results for classical TIG welding are lower, but in contrast at the weld joint TIG-A5 weld is almost fully penetrated and this did not influence on tensile results at all.

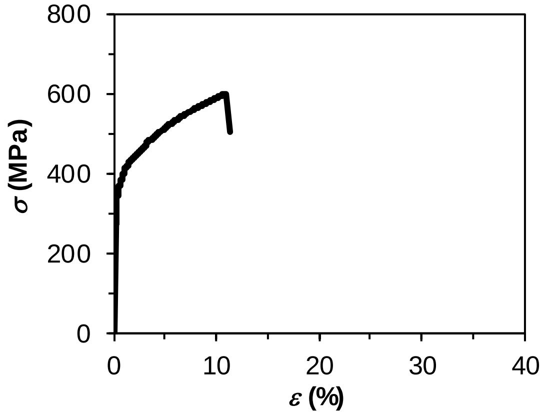
Results of tensile tests welded by the ATIG process with QuickTIG active flux B are listed in Figure 12. The ATIG-B1 weld joint was not fully penetrated during welding, what influenced on tensile test results, other weld joints are fully penetrated.

Finally, results of tensile test welded by ATIG process with BC-31 active flux Z are shown in Figure 13. The ATIG-Z1 weld joint was not fully penetrated during welding, what influenced on tensile test results, while the other weld joints were fully penetrated and tensile tests were correct without any influence.



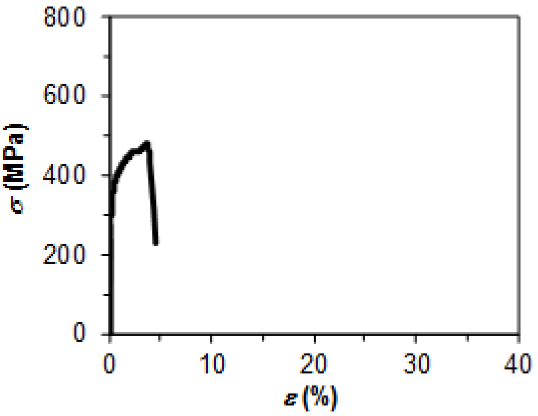
a) TIG-A1 (I = 80A)

Not welded through whole thickness.



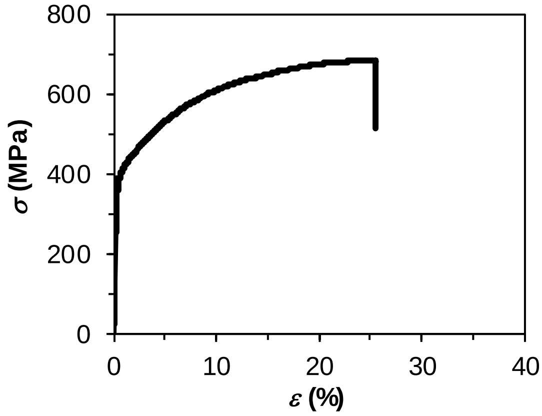
b) TIG-A2 (I = 100A)

Not welded through whole thickness.

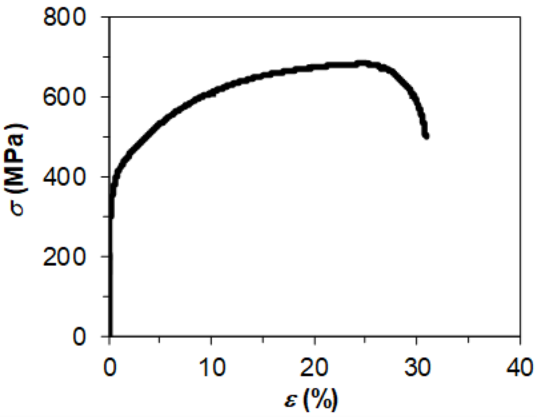


c) TIG-A3 (I = 120A)

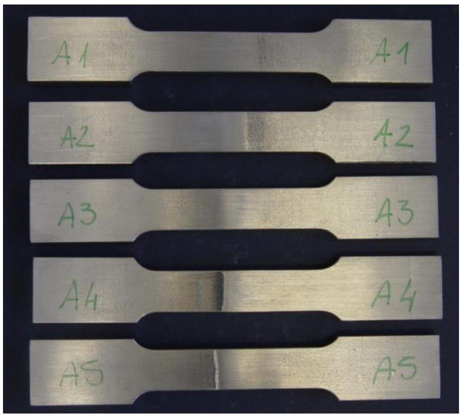
Not welded through whole thickness.



d) TIG-A4 (I = 140A)

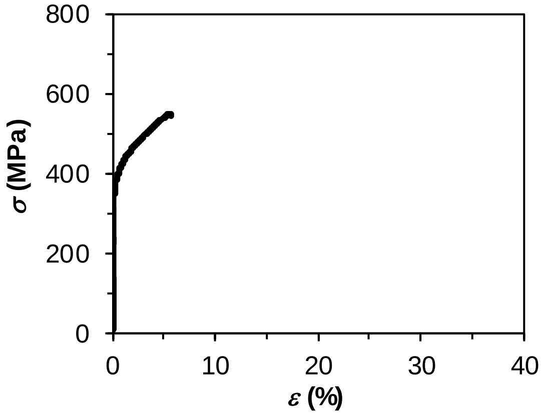


e) TIG-A5 (I = 150A)



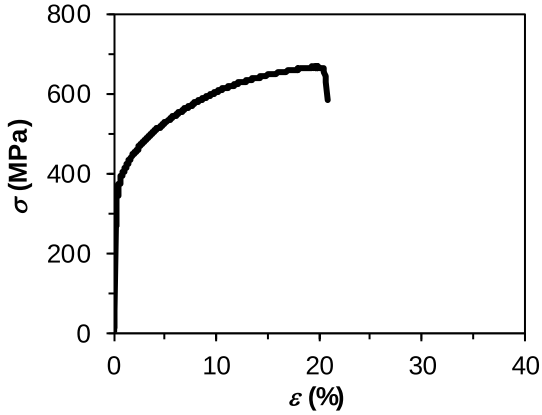
f) TIG-A's tensile specimens before test

Figure 12. Results of tensile tests for classical TIG-A weld joints [5]



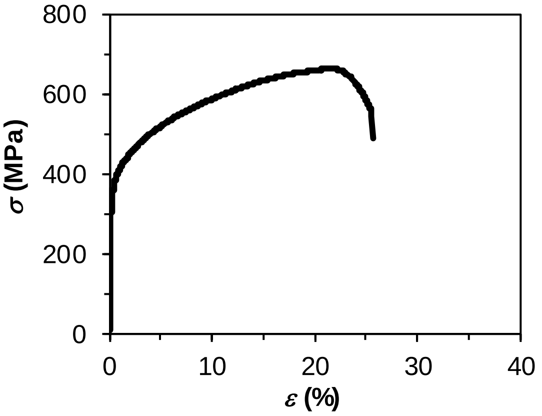
a) ATIG-B1 (I = 80A)

Not welded through whole thickness.

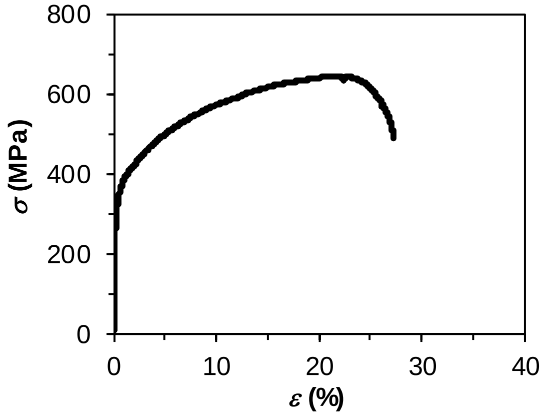


b) ATIG-B2 (I = 100A)

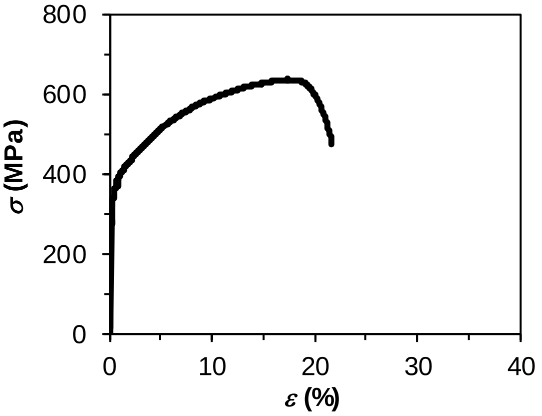
Not welded through whole thickness.



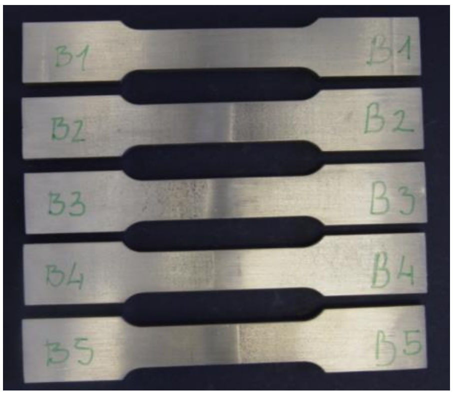
c) ATIG-B3 (*I* = 120A)



d) ATIG-B4 (*I* = 140A)

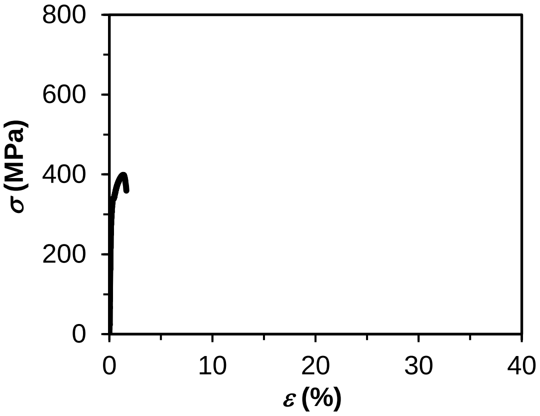


e) ATIG-B5 (*I* = 150A)

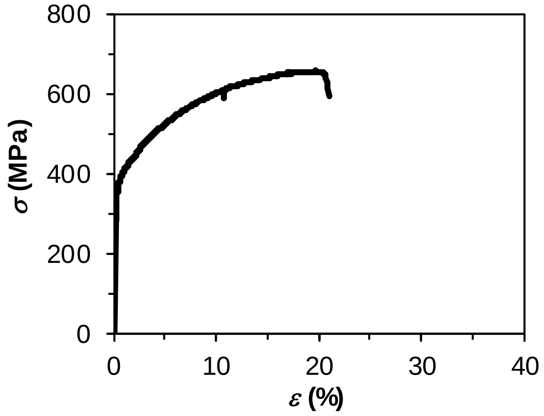


f) ATIG-B’s tensile specimens before test

Figure 13. Results of tensile tests ATIG-B weld joints [5]

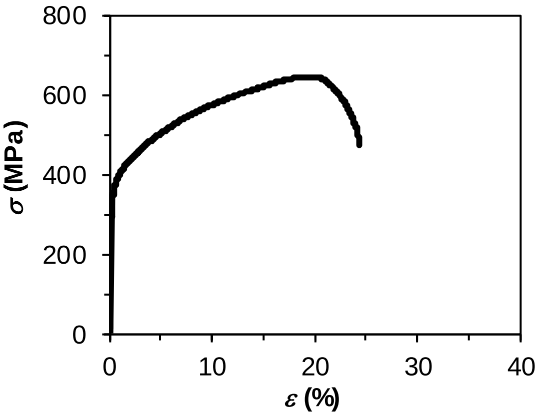


a) ATIG-B1 (*I* = 80A)
Not welded through whole thickness.

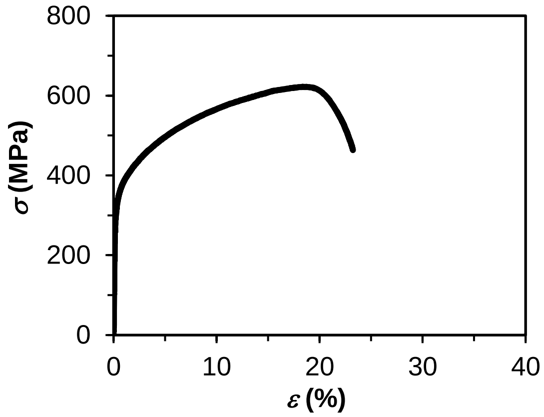


b) ATIG-B2 (*I* = 100A)

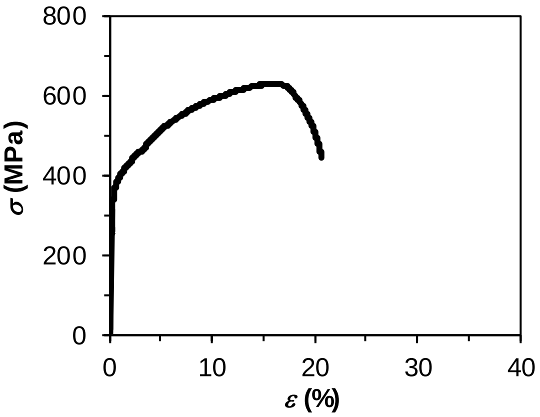
Not welded through whole thickness.



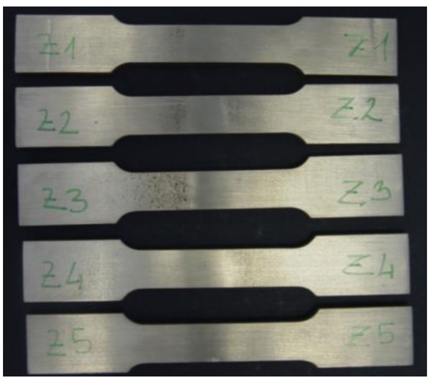
c) ATIG-B3 (*I* = 120A)



d) ATIG-B4 (*I* = 140A)



e) ATIG-B5 (I = 150A)



f) ATIG-Z’s tensile specimens before test

Figure 14. Results of tensile tests ATIG-z weld joints [5]

By analysing individual tensile test results, the general influence of welding current on tensile strength and on elongation were determined, Figure 14, but we have to mentioned that the same welding speed was used during welding what is archived by robot welding.

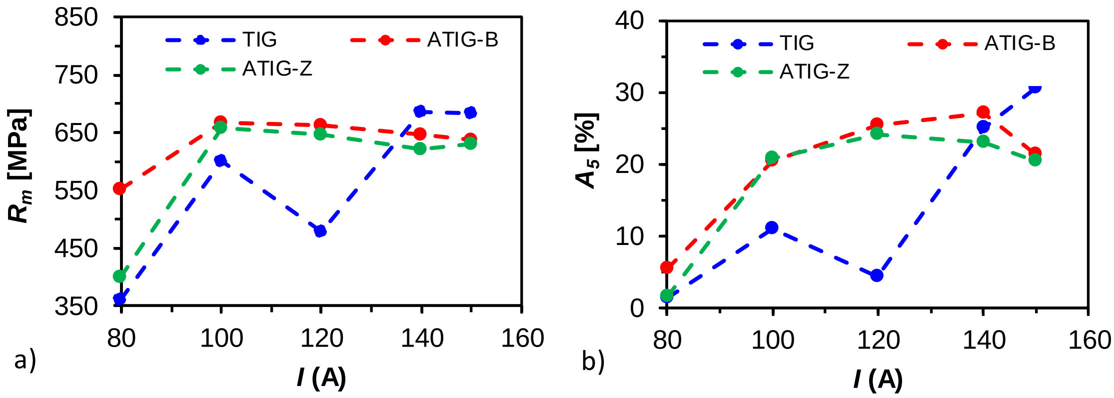
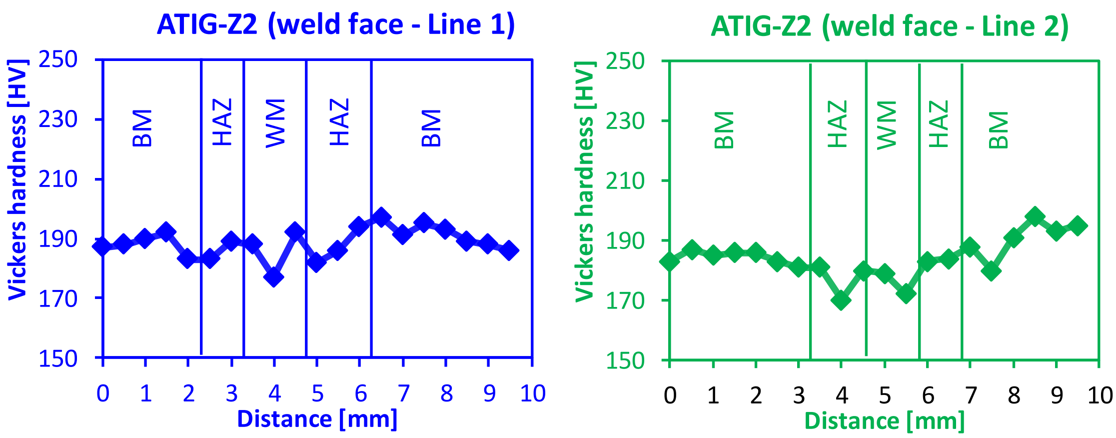


Figure 15. Influence of welding current on a) tensile strength and b) elongation [5]

Vickers hardness were measured on the all weld joints in three lines, Figures 14. First line was measured 1 mm below of the weld face from upper side (line 1), second line was measured 1 mm below of the weld face from lower side (line 2) and finally the third line was measured in the weld root. For example, the hardness measurement results for ATIG-Z2 weld joint are shown and analysed in Figure 14.



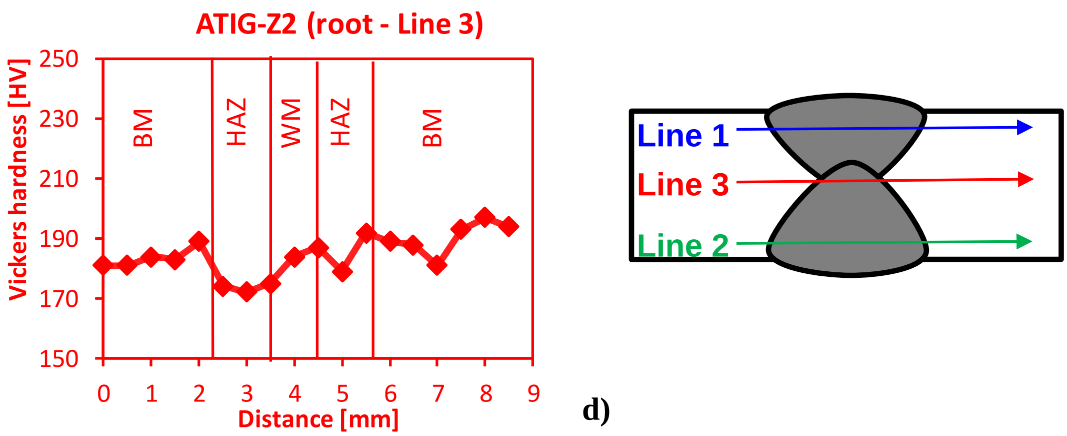


Figure 16. Results of hardness measurement for ATIG-Z2 weld joint

Averaged hardness in the weld metals and the maximal hardness in HAZs are presented in Figure 15 for the all weld joints. The weld joints welded by higher welding current had lower hardness, except the weld joints welded with welding current 150 A. Weld joints which were not fully penetrated through thickness has higher hardness because the cooling rate was higher due to non-melted material between two welding passes from the both side of the weld plate. Particularly, this trend shows the weld joint TIG-A3 (welded by 120 A) which not fully penetrated through thickness during welding, where the hardness in HAZ is the highest.

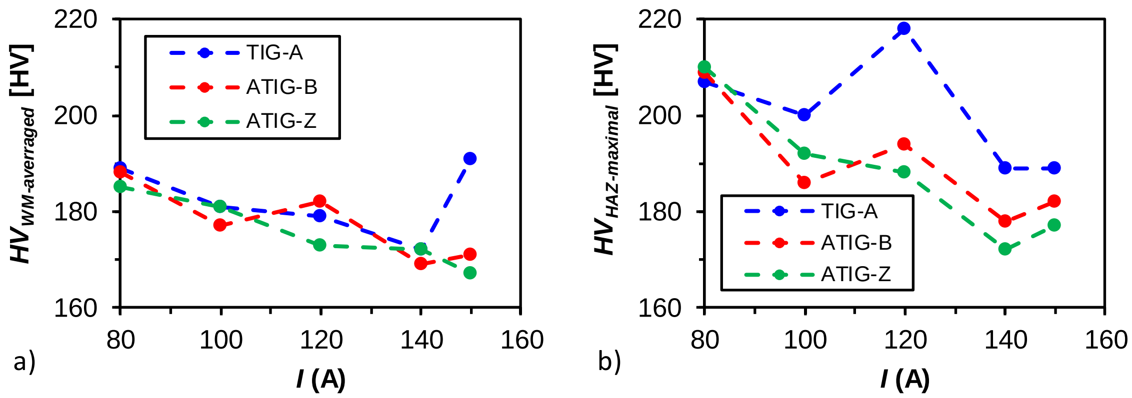


Figure 17. Results of hardness measurements; a) Averaged hardness in the weld metals, b) Maximal hardness in HAZs [5].

5 CONCLUSIONS

Classical TIG process and ATIG process, were successfully used for welding X5CrNi18-8 stainless with different welding parameters where the welding current were variated from 80 A to 150 A. Two different active flux were used tor ATIG welding, QuickTIG (B) and BC-31 (Z).

Due to higher surfaces tension at ATIG welding process caused by active flux the rotation of the melted material in weld pool is from side of the weld pool to centre of the weld pool and the penetration is better. In contrast with classical TIG welding where rotation of the melted material in weld pool is from the weld pool centre to side of weld pool and therefore the penetration is lower but weld pool is more wide what influenced on the shape of weld joint geometry.

Above mentioned fact and the welding parameters themselves influence also on the properties of the weld joint like that tensile strength, elongation and hardness. At the ATIG process welded by lower welding current is easily achieved the higher strength and better elongation in comparison to classical TIG process. Hardness is usually lower in the ATIG welding process especially maximal hardness in HAZ.

Comparison between two ATIG welding processes where different active fluxes were used revealed small differences between them in properties and in weld geometry. In some cases, seem to be better the QuickTIG active flux but the difference is small.

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