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COMPARISON OF AIR AND WATER-AIR PLASMA CUTTING OF SHEET SHIPBUILDING STEEL

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To perform submerged arc welding of carbon steel sheet edges immediately after plasma cutting, it is necessary to improve the formation of these edges. Such improvements include reducing edge roughness and non-perpendicularity, as well as minimizing their gas saturation, particularly with nitrogen. It has been established that the degree of non-perpendicularity is not stable under the same operating conditions and depends on the shape of the plasma column. Poor mechanical processing of the nozzle, misalignment of the nozzle and electrode cathode insert can cause the plasma jet to deviate from a cylindrical shape, resulting in variable cut profiles along the coordinate axes. Therefore, special attention must be paid to nozzle processing and cleanliness.

Experiments showed that adding 0.028–0.11 L/min of water to the plasma improved the quality of the cut edges. This improvement was manifested in a significant (by an order of magnitude or more) reduction in gas saturation of the edges, their roughness, and non-perpendicularity [1]. The cut surface had a silvery appearance and low edge surface roughness Rz. With water addition, Rz = 0.020–0.010 mm; when cutting in pure air, Rz = 0.12–0.09 mm. Thus, adding water reduces roughness by 6–9 times and meets the first class according to ISO 9013:2017 "Thermal cutting — Classification of thermal cuts — Geometrical product specification and quality tolerances."

Based on the results of gas phase composition modeling, water vapor concentrations in the plasma of approximately 10–20% were selected. According to the distribution of water supplied to the plasma torch nozzle, these concentrations correspond to a total water flow into the nozzle's internal channels of 0.023–0.11 L/min, or 0.082–0.4 L/min into the nozzle. The effect of such additions on the perpendicularity of the cut edges was investigated.

It was found that adding 0.028–0.11 L/min of water to the plasma stream (5.6–19.2% vapor in the plasma) reduces the non-perpendicularity of the cut edges from 2.3–2.5 mm to ≤ 1.0 mm, corresponding to Class 2 according to ISO 9013:2017 "Thermal cutting — Classification of thermal cuts — Geometrical product specification and quality tolerances" for thicknesses of 5–12 mm.

Two factors contribute to the reduction of cut edge non-perpendicularity: the formation of gas mixtures containing hydrogen, which increases the electric field intensity of the arc, and the constriction of the plasma arc [2]. The arc voltage increases by 25–30 V at a constant current. Arc constriction enhances its energy characteristics and promotes penetration of the anode spot through the metal thickness, as evidenced by the increased width of the cut at the lower edge. Non-perpendicularity of cut edges for different thicknesses is reduced by 2.3–2.5 times.

The non-perpendicularity of cut edges increases with increasing metal thickness and cutting speed, which is related to the position of the anode spot within the cut cavity.

In plasma cutting, it is impractical to reduce non-perpendicularity by lowering the cutting speed, as this would lead to an increased cut width, distortions in the cut parts, and reduced productivity. The primary approach to minimizing non-perpendicularity is to select cutting conditions that ensure the lowest possible non-perpendicularity while maintaining high productivity.

Changing the total water flow to the plasma torch nozzle ((1.67–3.3) × 10^{-3} L/s for cutting in an oxygen + water plasma-forming medium and (1.67–4.67) × 10^{-3} L/s for cutting in an air + water medium) practically did not affect the non-perpendicularity of the cut edges. Increasing the flow of the plasma-forming gas without changing the water flow reduces the edge non-perpendicularity: for the air + water medium from 1.3 to 0.83, and for the oxygen + water medium from 1.5 to 0.65. The data on cut edge non-perpendicularity depending on the plasma-forming gas flow are presented in Table 1.

Increasing the cutting speed leads to an increase in cut edge non-perpendicularity from 0.5 to 1.1 mm for the air + water plasma-forming medium and from 0.4 to 0.9 mm for the oxygen + water medium. The resulting dependence of edge non-perpendicularity on cutting speed, based on the cutting of five 250 × 50 mm parts, is presented in Table 2.

Table 1

Dependence of edge non-perpendicularity on the plasma-forming medium consumption when cutting 5 mm thick carbon steel

No	Plasma-forming medium	Plasma-forming medium flow rate, l/s	Water consumption, x10^{-3} l/s	Cutting speed, mm/s	Cutting width, mm		Non-perpendicularity value, mm
					at the top	at the bottom	
1	Air + water	0,83	4,6...5,6	50,0	6,3-6,5 6,3	3,6-3,8 3,7	1,2-1,45 1,3
2		1,33			5,8-6,3 6,0	4,0-4,2 4,0	0,8-1,15 1,0
3		2,0			5,5-5,85 5,7	3,65-4,0 3,95	0,75-1,1 0,83
4	Oxygen + water	0,83	3,0...3,6		5,9-6,3 6,1	2,8-3,1 3,0	1,4-1,75 1,5
5		1,33			5,9-6,25 6,0	3,95-4,4 4,16	0,75-1,15 0,92
6		2,0			5,0-5,8 5,5	4,0-4,3 4,2	0,5-0,75 0,65

Table 2

Dependence of edge non-perpendicularity on cutting speed of 5 mm thick carbon steel

No	Plasma-forming medium	Plasma-forming medium flow rate, l/s	Water consumption, x10^{-3} l/s	Cutting speed, mm/s	The magnitude of non-perpendicularity in the edges, mm		Average value of non-perpendicularity, mm
					right	left	
1	Air + water	1,3...1,5	4,6...5,6	33,3	0,35-0,6 0,44	0,45-0,8 0,56	0,4-0,7 0,5
2				50,0	0,7-1,2 0,83	0,92-1,6 1,07	0,8-1,3 0,95
3				66,7	0,72-1,2 0,95	1,0-1,44 1,24	0,85-1,3 1,1

Continuation of table 2

No	Plasma-forming medium	Plasma-forming medium flow rate, l/s	Water consumption, x10^{-3} l/s	Cutting speed, mm/s	The magnitude of non-perpendicularity in the edges, mm		Average value of non-perpendicularity, mm
					right	left	
4	Oxygen + water	1,5...1,6	3,0...3,3	33,3	0,3-0,45 0,35	0,4...0,55 0,45	0,35-0,5 0,4
5				50,0	0,4-0,74 0,6	0,56-0,8 0,7	0,5-0,8 0,65
6				66,7	0,6-1,25 0,8	0,8.-1,25 1,00	0,7-1,15 0,9

Conclusion: It was found that adding 0.028–0.11 L/min of water to the air plasma stream (5.6–19.2% vapor in the plasma) reduces the non-perpendicularity of the cut edges from 2.3–2.5 mm to ≤ 1.0 mm for thicknesses of 5–12 mm.

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