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Influence of welding parameters on carbon steel welded structures

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Abstract. The present work examines the influence of welding parameters on the mechanical properties of 10 mm carbon steel plates using MMA welding process. The variables investigated are welding current, voltage, welding speed and type of filler material. The samples underwent ISO 9606 standard tests such as tensile, impact and hardness testing. The obtained results are indicating that welding parameters significantly impact the mechanical properties of the welded samples.

1.Introduction

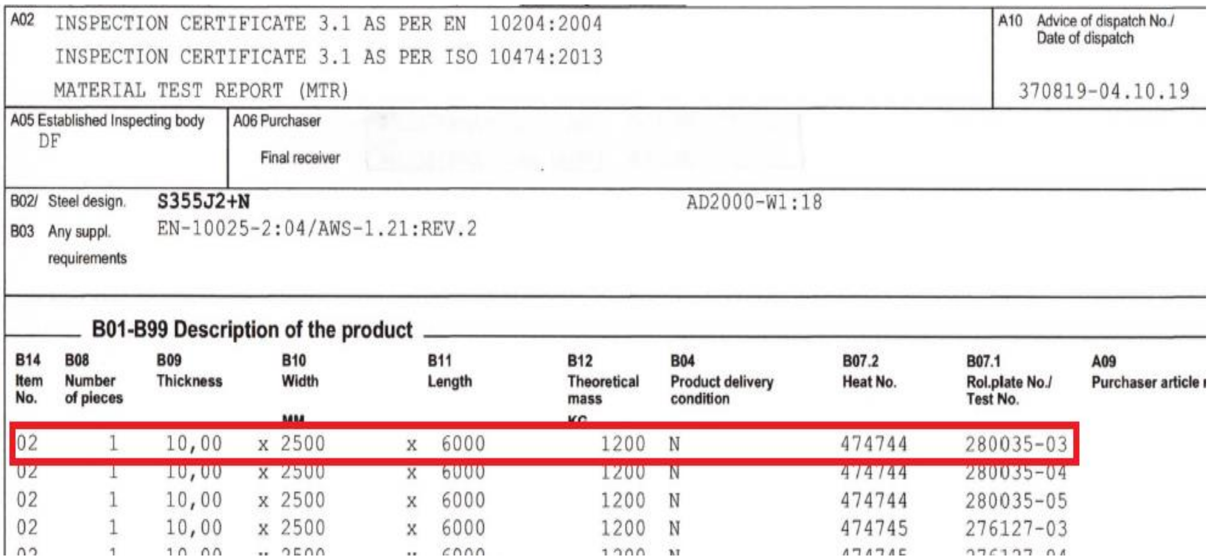
Steel stands as a pivotal engineering material in the maritime industry and not only, it is used in a variety of applications such as automotive, domestic appliance, civil construction and military industry. It boasts an extensive range of mechanical propertiees, rendering it economically reliable for various purposes.

Traditionally, in the past, mechanical components have relied on fasteners, rivet joints for material joining. Nowadays, the streamline manufacturing, reduce weight and enhance mechanical properties, welding becomes prevalent. Described in a variety of standards such as ISO 9606, ISO 15614, a plethora of welding techniques are available, which facilitates the fabrication process by joining materials of various dimensions, chemical composition and shapes. Welding will offer a high joint efficiency, flexibility and cost-effectivness if chosen right for the need. However, this joining technology is today and indispensable method.

Welded joints are now integral to critical components, necessitating stringent inspection methods and adherence to established standards to mitigate huge failures. The ISO standards outline minimum weld quality, determined through tests on welded specimens containing discontinuities. Welding encompasses numerous variables – time, temperature, electrode, power and speed., that will influence the weld quality. Welding steel presents challenges, requiring meticulous selection of welding parameters to obtain a satisfactory weld quality.
This research is focused on the impact of welding variables on the mechanical properties on carbon steel joints and tries to elucidate how individual variables affect the mechanical carachteristics of the welded samples.

2.Selection of material and methods.

For the testing, it was chosen the most easy to find base material, S355J2+N, manufactured in accordance with EN-10025-2:04. Figure 1 ilustrates the extract from the certificate of base material, while Table 1 presents the chemical composition of the steel plate.



A02 INSPECTION CERTIFICATE 3.1 AS PER EN 10204:2004
INSPECTION CERTIFICATE 3.1 AS PER ISO 10474:2013
MATERIAL TEST REPORT (MTR)

A10 Advice of dispatch No./ Date of dispatch
370819-04.10.19

A05 Established Inspecting body
DF

A06 Purchaser
Final receiver

B02/ Steel design. S355J2+N AD2000-W1:18
B03 Any suppl. requirements EN-10025-2:04/AWS-1.21:REV.2

B01-B99 Description of the product

B14 Item No.	B08 Number of pieces	B09 Thickness		B10 Width MM		B11 Length	B12 Theoretical mass KG	B04 Product delivery condition	B07.2 Heat No.	B07.1 Rol.plate No./ Test No.	A09 Purchaser article
02	1	10,00	x	2500	x	6000	1200	N	474744	280035-03	
02	1	10,00	x	2500	x	6000	1200	N	474744	280035-04	
02	1	10,00	x	2500	x	6000	1200	N	474744	280035-05	
02	1	10,00	x	2500	x	6000	1200	N	474745	276127-03	

Figure – 1 : Certificate of base material

Table – 1: Chemical composition (in %)

C	Si	Mn	P	S	N	Cu	Mo	Ni	Cr	V
0.158	0.525	1.479	0.015	0.008	0.0047	0.024	0.007	0.024	0.035	0.001

Prior to start the test it was prepared a welding procedure specification (WPS) and weld details were established. In figure 1 the welding sketch can be visualizsed where it is clearly marked the gap of 2-3 mm between base materials. Number of welding beads is estimated at 10.

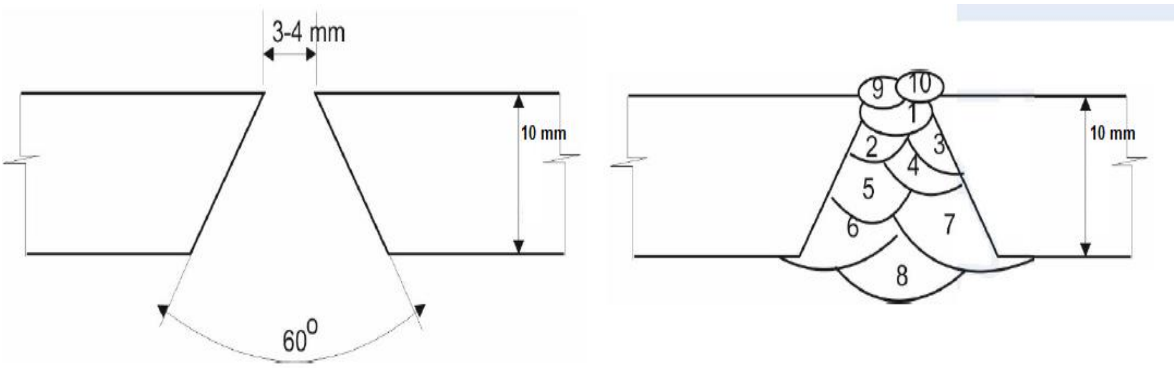


Figure 2 – weld preparation details

The steel surface was prepared accordingly by mechanical grinding and cleaning as necessary and the testing was carried out in a controlled environment, where any chance of contamination by dust and impurities was eliminated.
As filler material was used basic coated electrodes for MMA welding process, standardized as FM1 as per ISO 9606-1 of 2.5 mm and 3.5 mm diameter.

A high voltage DC generator with rectifiers capable of supplying current up to 600 A, along with air and water cooled electrode holders were utilized for the welding operation.

The welding process involved abutting pairs of prepared metal plates with a 3 mm gap between them. The gap was filled completely, taking into account the root, hot pass, fill, cap and bead. After welding, the samples were allowed to cool for 24 hours and were tapped with a chipping hammer to remove slag, ensuring the gap was completely filled. Four independent process variables were selected for this study: welding current, welding voltage, welding speed and electrode diameter. Impact test were conducted using Charpy V-notch testing machine, with each experiment repetead at least three times and average values recorded. The hardness was determined using a Vickers hardness tester. Aditionally, transverse tensile test specimens were cut from the welded butt joints to determine their transverse tensile strenght.

3. Hardness testing and results

Vickers hardness test, easier to use than Brinnel test method, due to the fact that required calculations are independent of the size of the indenter and can be used on all materials, irrespective of its hardness. The principle of this method is to observe material ability to resist plastic deformation from a standard source. The unit of the hardness is Vickers pyrdamid number (HV). The test is done by punching into the piece to be testd, using a determined force, a pyramid indenter with a square base, and later measuring the diagonal of the indent left in the piece, after having removed the load.

After analyzing the probes, following results were obtained, results wich were ploted against welding parameters such as Voltage, Current, Welding speed and Electrode diameter. In normal conditions, when it comes to welder certification or welding procedure approval, the hardness is done on: welding seam, heat affected zone and base material, however we will use only weld area hardness results for our study.

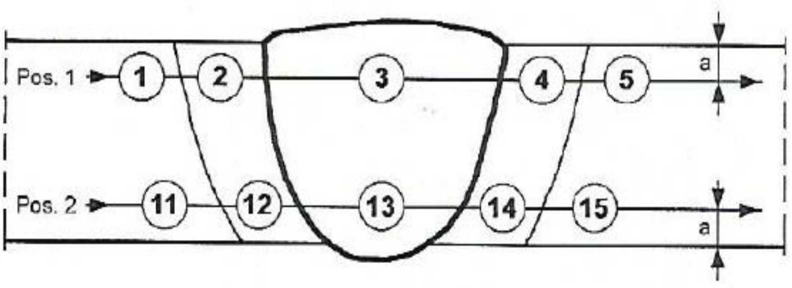


Figure 3 – Positions of the hardness testing indentations.

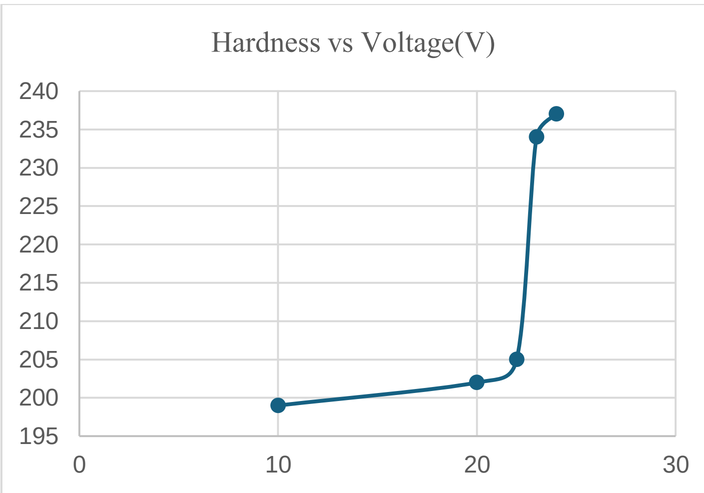


Figure 4a

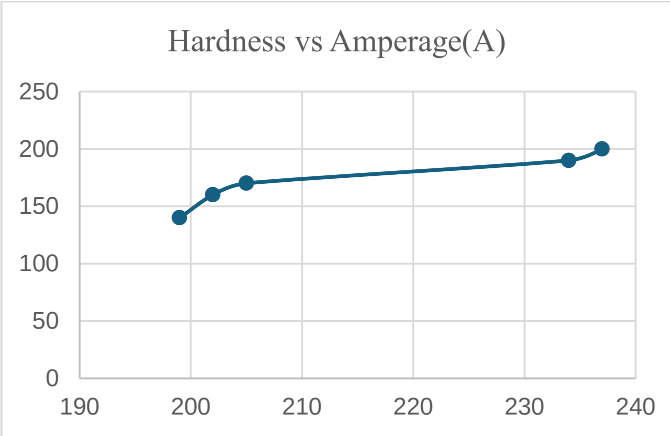


Figure 4b

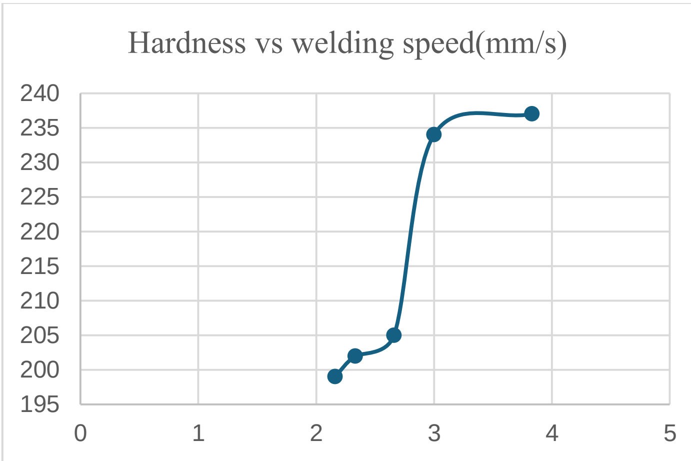


Figure 4c

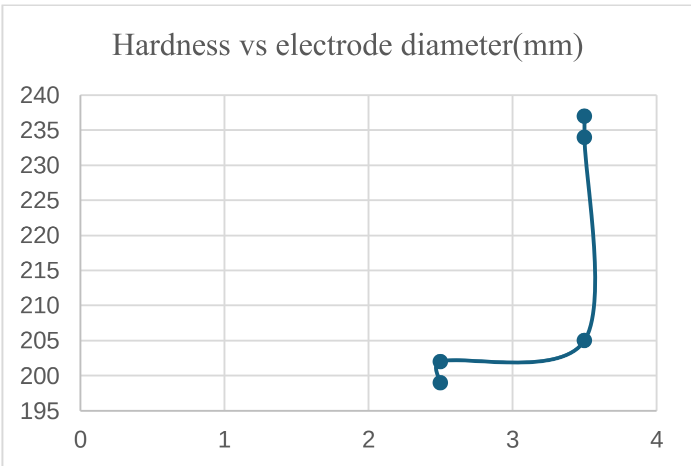


Figure 4d

Figures above are showing the consequences of the welding variables on the hardness of the welded joints steel samples. Figure 4a demonstrates tat hardness of the welded probe changed with change of voltage between 23-25V. The sample welded at 24V shows a big spike in hardness compared with previous welded sample. Analyzing fig4b, increase in welding current from 140 to 230 resulted in a slight increase of hardness, an effect similar to the welding voltage. In images 4c and 4d the hardness increased with increased speed of welding, the highest value of hardness being obtained with 3.5 mm welding electrode. Regarding the welding speed from 2.2 to 3.8 mm/s will influence the hardness of the welded probes. This effect might be related to the chemical and physical characteristics change of the welding parameters and may show that the welding will be prone due fracture and to avoid this, post welding heat treatment shall be utilized to optimize its physicial and chemical properties.

4.Tensile properties

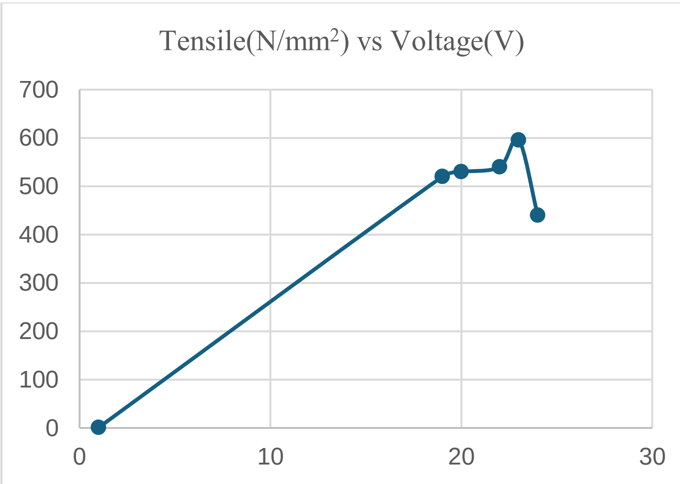


Figure 5a

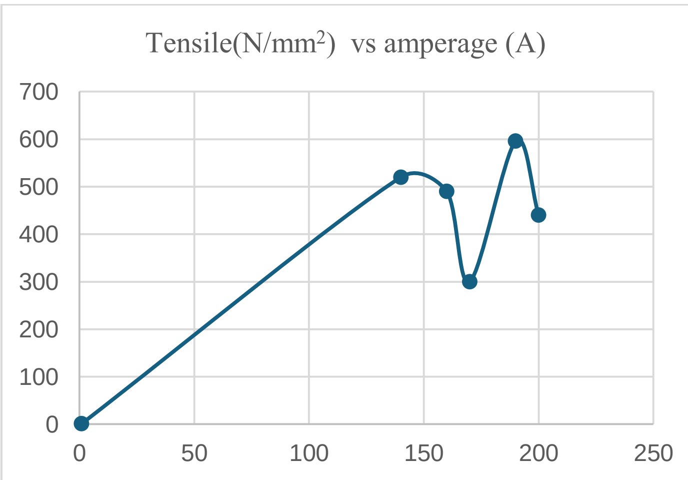


Figure 5b

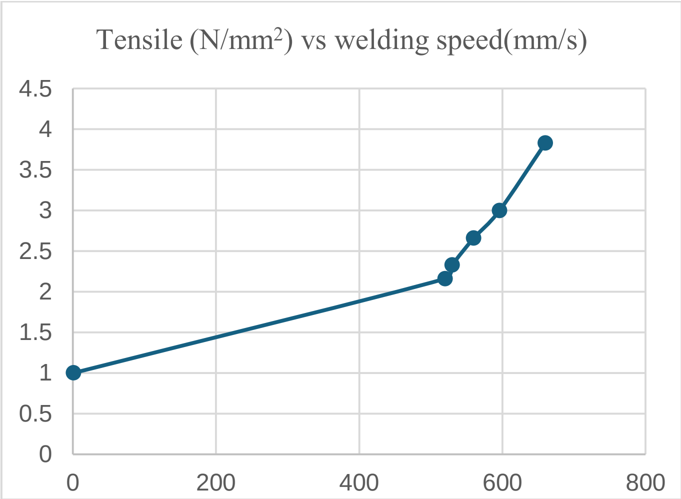


Figure 5c

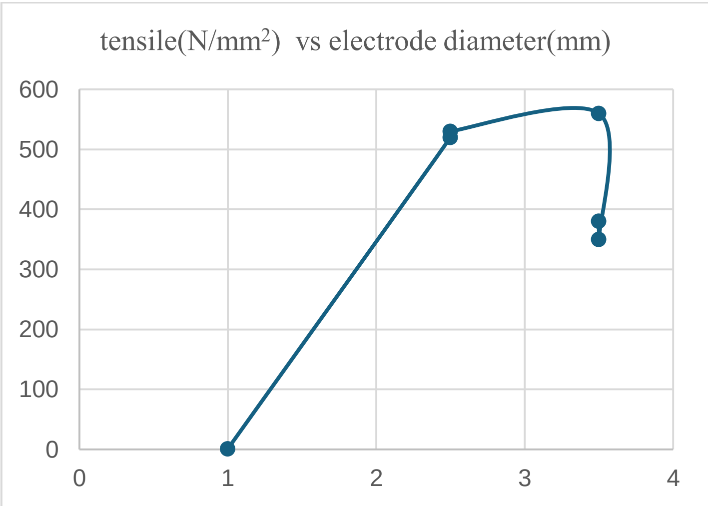


Figure 5d

The influence of variations in welding voltage, current, speed and electrode size on the yield strenght of the welded parameters is depicted in figure 5. All figures ilustrates a decrease in yield strenght with increased voltage. Conversely, an increase in weldign speed correlates with higher yield strenght of welded joints. For a current value of 160A, the tensole strenght was outside of the range of tensile strenght of the base material (490-70) and a notable decrease in tensile strenght is observed with further increase in current. This decline in strenght may be attributed to the presence of welding defects arrising from increased current, as well as excessive grain growth which could impair welding proeprties. The data clearly indicates that weldign current and electrode diameter play significant roles in determining tensile proeprties of the steel. It is imperative to carefully monitor these parameters to achieve desirable outcomes. Excessive welding current should be avoided, while an electrode diameter of 2.5 mm demonstrates superior tensile properties. Additionally, based on the figures, a travel speed of 2.33-3.00 mm/s exhibits the most favourable combination of tensile properties, closely resembling those of the base material.

5. Impact properties

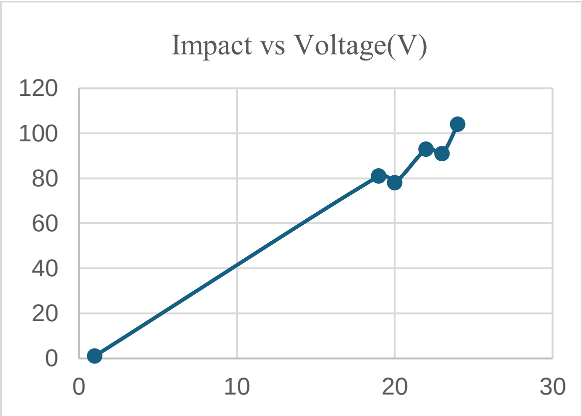


Fig. 6a

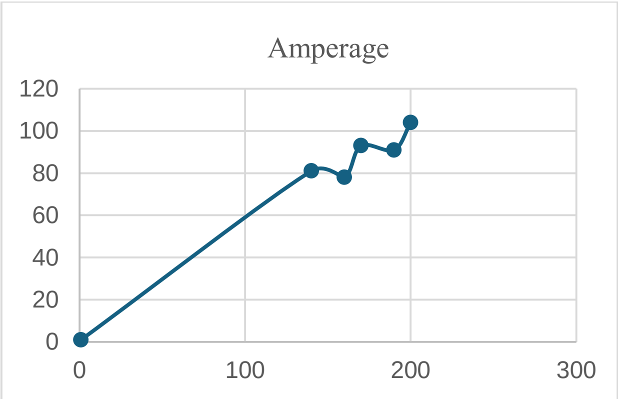


Fig. 6b

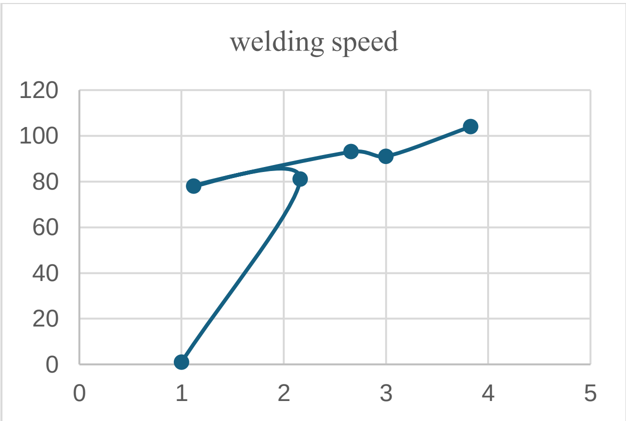


Fig. 6c

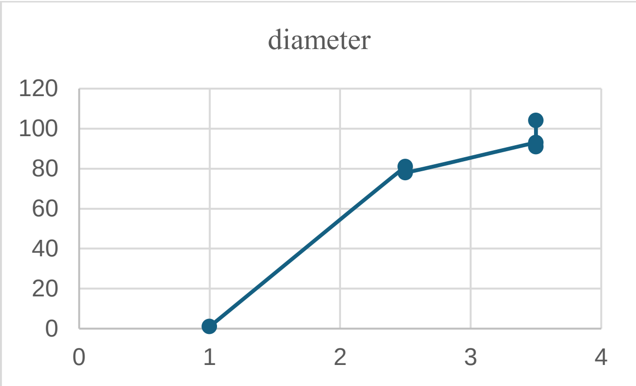


Fig. 6d

6.Conclusions

The impact of varying welding parameters was investigated to better understand and predict the performance of welded carbon steel samples. The findings revealed significant effects of the selected welding parameters on the mechanical properties of the welded samples. Specifically, an increase in arc voltage and welding current led to higher hardness values but decreased yield strength, tensile strength, and impact toughness. This trend is attributed to the increased heat input resulting from higher current and voltage, potentially leading to defect formation and subsequently reduced mechanical properties. The observed increase in hardness could be attributed to electrode coating, which introduces alloy additions to the weld deposit. In future studies, the authors intend to explore the influence of these welding variables on the microstructure of the steel samples. Additionally, they plan to characterize the relationship between structure and properties.

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