Researches regarding increase of impact resistance for welded structures by weld micro-alloying

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Abstract. In industrial fabrication, structural steel is the most used grade used in structures and automotive. For these grades, in the last decade automation and standardization leaded to increase of mechanical properties and reduction of fabrication cost. In parallel, control of alloying elements and impurities realized especially in vacuum treatment stations ensured higher mechanical properties in a larger temperature domain. The research scope is to increase of mechanical properties for weld line and obtain higher properties than the base metal. Final goal is to obtain steel structures assembled by welding safer in exploitation. Key point of the research is to increase the impact resistance for weld line by micro alloying and determine the optimum percentage for nickel element inside weld metal.

1. Introduction

Structural steel grades are used more and more in industry because of two important elements, fabrication cost which is lower than medium alloyed steel grades and mechanical properties, that are nowadays comparable with steels grades from superior groups [1].

Automation and standardization of steel production using Electrode Bottom Furnace (EBT) technology allowed to produce structural steel grades as for example S355 and replace gradually S235 grade [2].

Control and reduction of steel impurities which leads to steel fragility as nitrogen and hydrogen done in vacuum degassers permitted to decrease steel fragility. This reduction is visible in mechanical property as steel impact strength. In the next table, is presented this effect where for example, S355K2 with no nitrogen can withstand at 27J impact even at -30 ^{0}C (Table 1) [2].

For welding rods we observed the same tendency of developing new grades and improve material mechanical properties.

This goal is realized in this case by increase of percentage of special elements in welding rod, for example Ni, Cr, W, Ti [3].

Table 1. Chemical composition of S355 sub-grades [2]

Grade	C %	Si %	Mn %	P%	S%	N%	Cu %	Resilience (J)	Temperature (^oC)
S355JR	0.24	0.55	1.6	0.035	0.035	0.012	0.55	27	20
S355J0	0.2	0.55	1.6	0.03	0.03	0.012	0.55	27	0
S355J2	0.2	0.55	1.6	0.025	0.025	-	0.55	27	-20
S355K2	0.2	0.55	1.6	0.025	0.025	-	0.55	27	-30

Even with these improvements, critical point in every structure remains welding line which has a non homogenous structure with three main zones (Figure 1) [4-7]:

- weld metal zone
- heat affected zone
- un-affected zone

Weld metal and heat affected zone forms welding line which is studied in the next paragraph.

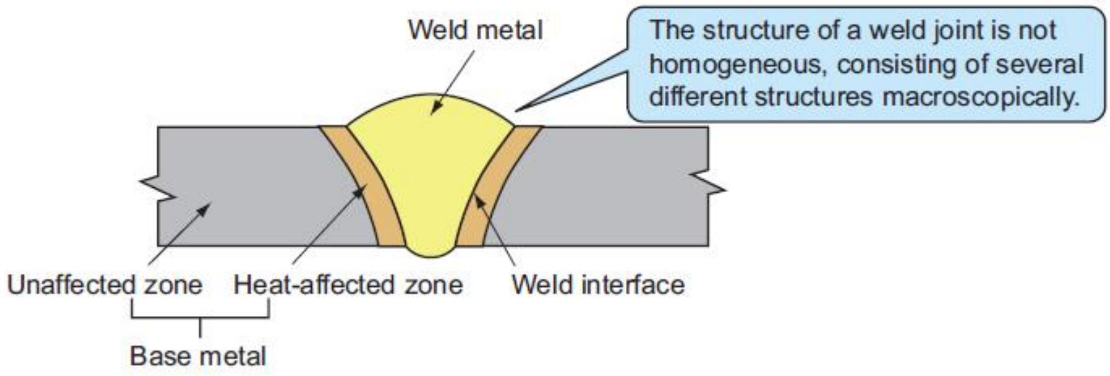

Figure 1. Weld transversal section

2. Scope of research

Scope of this research is the study of weld line, particularly of weld metal from impact resistance point of view. The aim is to obtain better impact resistance, higher than base metal.

In this research the key element is microalloying of weld metal using different wire rods. The element studied for microalloying is nickel.

The main advantage of Nickel is the fact that can increase considerably impact resistance and maintain this property also in negative temperatures domain.

Another advantage is that does not form nickel carbide and practically can be dissolved in any proportion in austenite and ferrite.

Obtaining a higher impact resistance of the weld line compared with base material is justified due to non-uniformity of welding process. Practically there are variables as welding speed, joint shape assemble shape which can induce residual stress and consequently, reduced impact strength along the weld line even for welding conditions apparent identically.

Wire rods used for weld have been sectioned to cover a wide range regarding nickel concentrations, from base ER70 without nickel till austenitic ER308 grade with 9.5% nickel (Table 2) [8].

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Table 2. Chemical composition of weld rods used for trials [8]

Grade	C %	Mn %	Si %	Ni%	Cr%	P%	S%	Mo%	V%
ER70	0.1	1.62	0.92	0	0	0.02	0.03	0	0
ER100	0.09	1.7	0.7	0.5	0.6	0.1	0.1	0.3	0.1
ER120	0.1	1.8	0.8	2.25	0.35	0.05	0.05	0.5	0.1
ER308	0.08	1.8	0.03	9.5	20	0.03	0.03	0.7	0

To study only the effect of nickel concentration, the other variables which can influence the impact strength were minimized or cancelled by the next actions [9]:

- selection of the same base metal from the same batch
- manufacture identic samples for weld test. In this case, 10mm plate thickness in 50x100mm rectangles were welded together
- weld bevel was machined identically in" double V" shape
- same welding process was applied for all samples with next parameters:
    - MAG (metal active gas) with 92:8 Ar - CO_2 ratio
    - gas flow 18l/minute
    - weld speed 15 cm/minute
    - weld current 220A DC
    - weld voltage 27V
- ensure the same cooling speed post-welding

Metallurgical, the final composition of weld metal depends by three factors, composition of base metal, composition of wire rod and dilution factor.

Dilution factor was evaluated macroscopically in weld section, as ratio between weld metal and bevel section and is equal with 1.42 so 70% will come from wire rod and 30% will come from base metal (Figure 2).

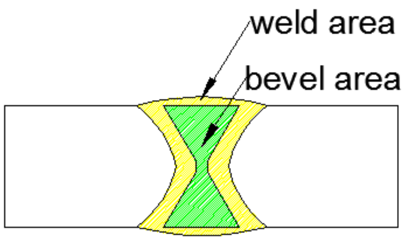


Figure 2. Transversal section before and after welding

This ratio will modify the final concentration of alloy elements in weld metal and can be calculate with lever rule (Table 3).

Table 3. Chemical composition of weld metal

Weld metal	C %	Mn %	Si %	Ni%	Cr%	P%	S%	Mo%	V%
70%S235+30%ER70	0.13	1.61	0.81	0.00	0.00	0.02	0.03	0.00	0.00
70%S235+30%ER100	0.12	1.67	0.66	0.35	0.42	0.08	0.08	0.21	0.07
70%S235+30%ER120	0.13	1.74	0.73	1.58	0.25	0.04	0.04	0.35	0.07
70%S235+30%ER308	0.12	1.74	0.19	6.65	14.00	0.03	0.03	0.49	0.00

The "V" notch was done exactly in the middle of weld line (Figure 4). After impact test results are summarized in the Figure 5.

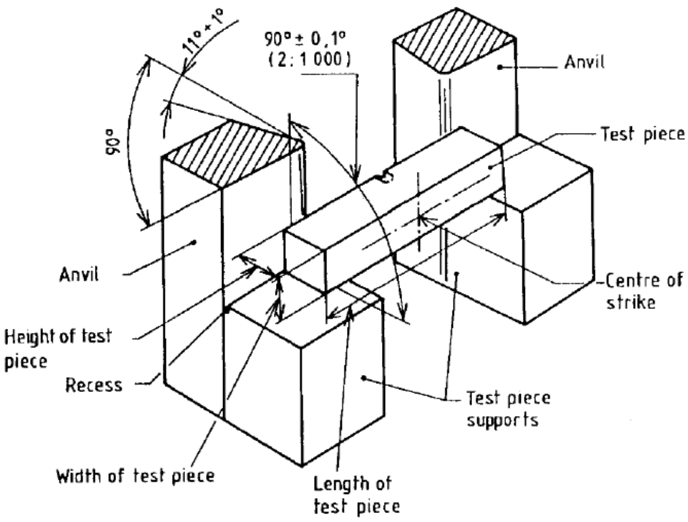


Figure 3. Samples trial preparation

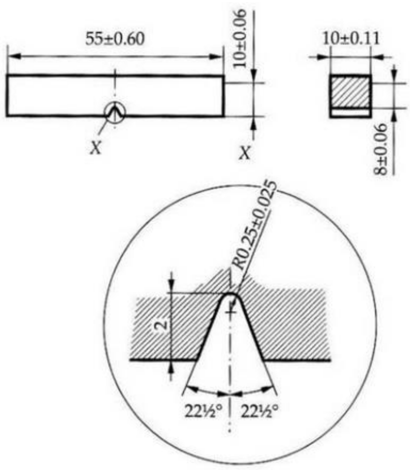


Figure 4. Samples notch preparation

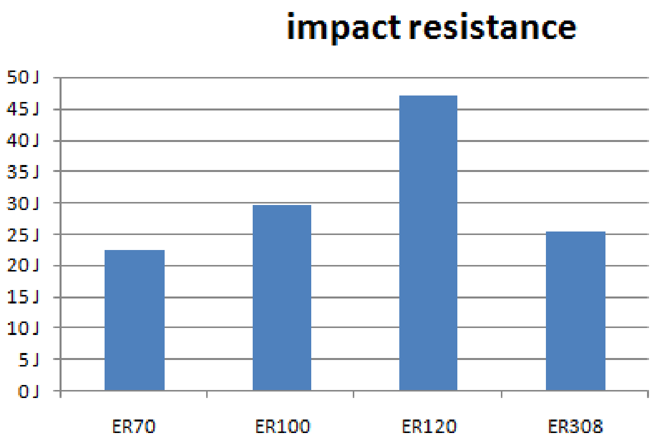
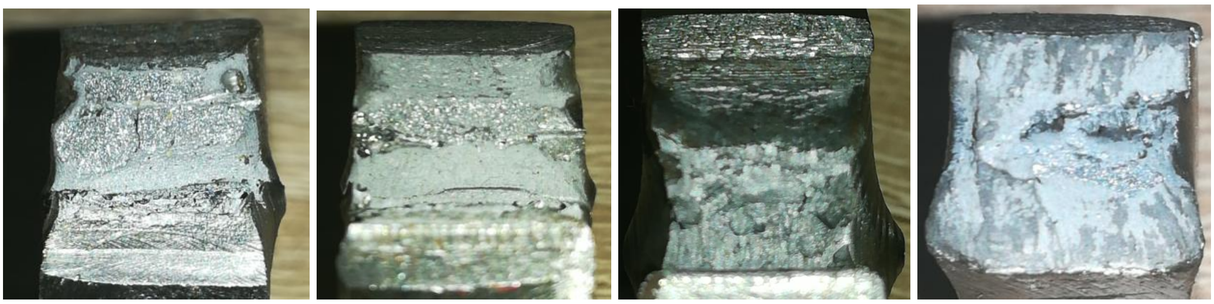


Figure 5. Impact test results

The aspect of fracture after impact test is presented in Figure 6.



ER70 sample ER100 sample ER120 sample ER308 sample

Figure 6. Aspect of fracture after impact test

3. Conclusions

From mechanical test the best results is achieved when nickel content is in the range of 2-3% in wire rod means a content of 1.6% in weld metal.

For studied samples, ER120 rod material was the best and weld metal fracture shows a fine structure with columnar aspect.

The further increase of the nickel shows a decrease of impact resistance but can be favorable in negative temperature domain. This is visible in ER308 sample, which had a better resistance than the rod without nickel (ER70).

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