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THE INFLUENCE OF HEAT INPUT ON THE CONTENT OF ACICULAR FERRITE IN WELD METAL OF MICROALLOYED STEEL

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ABSTRACT
Heat input is an important parameter that affects the microstructure, i.e. the content of different ferrite morphologies in weld metal of microalloyed steel. One hot rolled steel, low alloyed by Ti, Nb and V, was welded in the shielding atmosphere of Ar+5%CO_2+0.91%O_2, with three different heat inputs (4 kJ/cm; 7 kJ/cm; 10 kJ/cm). Detail microstructural investigation was conducted and the contents of acicular ferrite were determined. It is established that the highest content of acicular ferrite (83.3%) is obtained with heat input of 7 kJ/cm. Having in mind that acicular ferrite is the most desirable morphology of ferrite, which provides the best toughness, heat input of 7 kJ/cm is an optimum value for this steel and welding process.
Keywords: microalloyed steel, heat input, acicular ferrite**,** weld metal

1. INTRODUCTION
The welding heat input has a great influence on the weldments properties. Mechanical properties and toughness of weldment depend of microstructure of weld metal [1]. The most important characteristic of heat input is that it governs the cooling rates in welds and thereby affects the microstructure of the weld metal. On the Figure 1 is showned influence of the welding heat input (cooling rate, too) on the displacement of diagram by both axis, what directly brings out appearance of appropriate morphological forms, such as proeutectoid ferrite (PF), Widmanstatten ferrite (WF) and acicular ferrite (AF). Parallel plates of WF, separated by regions of reatined phases, for instance retained austenit, in metallurgy is called ferrite with secondary phase (FS)[2] [3]. Acicular ferrite is the most desirable morphology of ferrite, so this paper analyses influence of the heat input on the ferrite modification in the weld metal, specially on the morphology of acicular ferrite. This morphological form of ferrite is very significant, because it has great influence on the mechanical properties, toughness specially. Morphology of acicular ferrite is characterized by interwoven needles/plates, extending in several directions, that are generally nucleated intragranularly (inside grains) on inclusions [4].

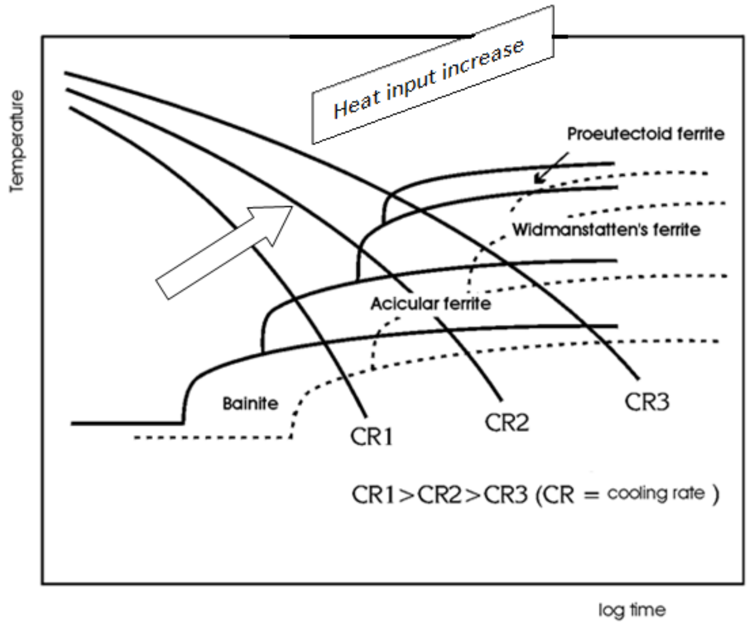


Figure 1. Effect of the heat input on CCT diagrams shape

2. EXPERIMENTAL PROCEDURE

Hot rolled plates of microalloyed steel of chemical composition given in Table 1, were welded by MIG/MAG process. As filler material, electrode wire denoted as VAC60Ni (made by Jesenice, Slovenia) ∅1,2mm and shielding atmosphere Ar+5% CO_2+0,91% O_2 were used. The wire is alloyed with Ni, intended for welding of unalloyed and alloyed steels, with guaranteed mechanical properties at low temperatures, with chemical composition also given in Table 1.

Table 1. Chemical compositions of base material and filler material

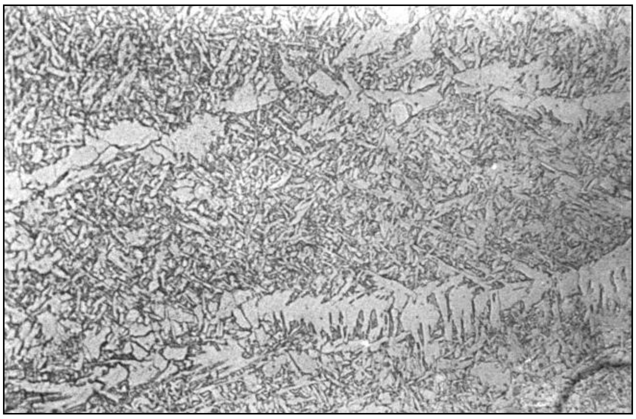
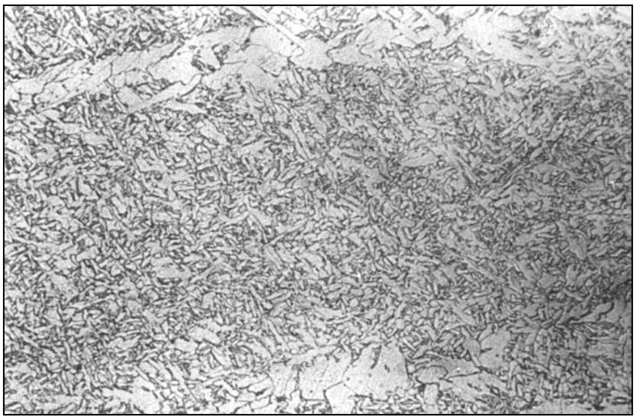
	Chemical composition, %										
element	C	Si	Mn	P	S	Cu	Al	Nb	Ti	V	Ni
steel	0.056	0.32	1.28	0.012	0.005	0.031	0.049	0.045	0.02	0.054	-
Electrode wire	0.08-0.10	0.70-0.85	1.40-1.60	<0.025	<0.025						1.0-1.2

Butt welded joints (V) had been prepared and plates were welded with three different heat input values, 4; 7 and 10 kJ/cm. Volume content of phases in the last pass was determined by linear method of semi-automatic image analysis. Device for semi-automatic image analysis (MOP-Videoplan, company Kontron) in conjunction with a microscope (MeF3, company Reichert-Jung) was used.

3. RESULTS AND DISCUSSION

In table 2 are showned phase volume contents of microstructural components in cover pass for three different heat inputs, with characteristic photographs (x401). On the figure 2 is showned content of the AF in dependence of the heat input in the steel weld metal for the cover pass. The weldments microstructural analysis indicates presence of great volume of AF, whereas the presence of the other morphological forms of ferrite is lower. The highest volume content of AF in the cover pass is for heat input of 7 kJ/cm (83,3%). With lower and higher welding heat input, volume content of AF is lower (80.3% AF at 4kJ/cm, and 75.7% AF at 10 kJ/cm) on account of coarser morphological forms, like PF, FS and WF (specially with higher heat inputs). This is due to higher or lower cooling rate, which directly affects the point of beginning of the decomposition of austenite.

Table 2. Volume content of the microstructural components in last pass at the different heat inputs

Q [kJ/cm]	Phase volume content	
7	**83.3% AF** The rest is PF and FS	 a)
4	**80.3% AF** The rest is coarser PF and WF	 b)
10	**75.7% AF** The rest is very coarse PF and FS	 c)

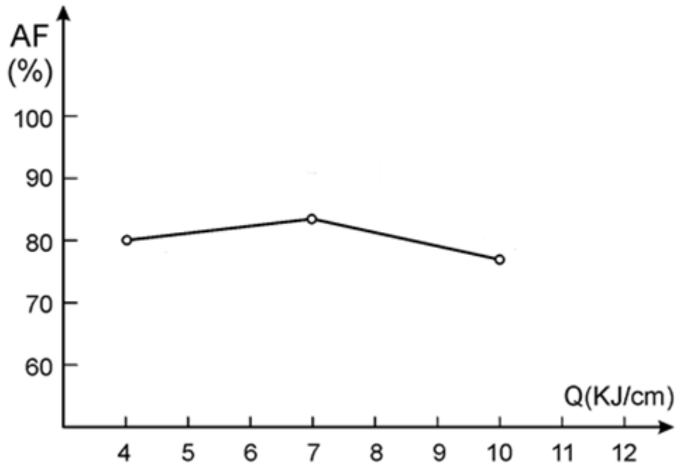


Figure 2 . Content of the AF in dependence of the heat input

4. CONCLUSIONS

Based on the analysis of the experimental results, the following conclusions can be deduced:

1. The welding heat input is an important welding parameter, which affects on the structure and properties of the weld metal. Weld metal tougness is extremely sensitive to the welding heat input.
2. Acicular ferrite is the most desirable morphology of ferrite, because it provides the best properties of weld metal. By selecting corresponding parameters, such as heat input, it is possible to obtain a high volume of this morphology.
3. In the weldments microstructure, the highest presence of AF (83.3%) is in the cover pass with heat input of 7 kJ/cm. The volume content of AF is lower with lower heat input, and, specially, with higher heat input, what directly affects on toughness.
4. Values of heat input were chosen on the base of literature data for similar steels. It was shown that optimum values of heat inputs are within the limits of the assumed, i.e. that value of 7 kJ/cm is optimal for applied welding procedure.

Acknowledgement

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