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OPTIMIZATION OF OPERATIONAL PROPERTIES OF STEEL WELDED STRUCTURES

Safety and exploitation conditions of steel welded structure depend on many factors. The main role of that conditions is connected with materials, welding technology, state of stress and temperature. Because of that very important is good selection of steel and welding method for proper steel structure. For responsible steel structure are used low carbon and low alloy steel, very often with small amount of carbon and the amount of alloy elements such as Ni, Mn, Mo, Cr and V in low alloy steel and their welds. In the terms of the kind of steel it is used a proper welding method and adequate filler materials. In the present paper it was tested and optimized the chemical composition of metal weld deposit on the operational properties of steel welded structures.

Keywords*: alloy elements, welds, optimization, impact toughness.*

1. Introduction

Properties of Steel Welded Structures depend on many factors such as welding technology, filler materials, state of stress. The main role of that conditions is also connected with materials, chemical composition of steel and metal weld deposit. Chemical composition of metal weld deposit could be regarded as a very important factor influencing properties of metal weld deposit (MWD). Especially nickel, molybdenum, chromium, vanadium are regarded as the main factors effecting on mechanical properties and metalographical structure of low alloy welds. However there is different influence of those elements on mechanical properties of welds. The influence of the variable amounts of nickel, molybdenum, chromium, vanadium on impact properties of low alloy metal weld deposit was tested. The influence of manganese, nickel, molybdenum, chromium, vanadium contents in weld metal deposit on impact properties was well analysed in the last 15 years [1-8]. Chromium, vanadium, and especially nitrogen are regarded rather as the negative element on impact toughness properties of low alloy basic electrode steel welds in sub zero temperature, meanwhile nickel and molybdenum have the positive influence on impact properties. Authors of the main publications [3-6] present that the content of nitrogen in low alloy weld metal deposit should not be grater than 100 ppm, and that nickel content should not exceed 3%. It is observed that nickel (from 1% to 2%) in metal weld deposit gives good impact toughness properties of welds. The lowest amount of nitrogen in all weld metal gives the best impact results of metal weld deposit. It was suggested that nitrogen has similar role as carbon in the ferrite. The amount of nitrogen in low-carbon and low-alloy steel is limited, but in high alloy steel welds the amount of nitrogen could be sometimes even augmented to obtain optimal mechanical properties of welds. The highest amount of nitrogen (up to 0.04%) is in “Duplex” and “Super Duplex Steel”. Toughness properties of low-carbon and low-alloy steel welds decrease in terms of the amount of nitrogen. However some authors [2, 3, 7] assume that some nitride inclusions such as TiN, BN, AlN could have a positive influence on the formation of acicular ferrite in welds. Because of that nitrogen might not be treated only as a negative element in steel and welds. Welding parameters, metalographical structure and chemical composition of metal weld deposit are regarded as the important factors influencing the impact toughness properties of deposits [7-8]. In the present paper it was tested and optimized the chemical composition of metal weld deposit on the operational properties of steel welded structures.

2. Experimental procedure

To assess the effect of nickel, molybdenum, chromium, vanadium on mechanical properties of deposited metals there were used basic electrodes prepared in experimental way. The electrode contained constant or variable proportions of the following components in powder form:

technical grade chalk	30%,
fluorite	20%,
rutile	4%,
quartzite	3%,
ferrosilicon (45%Si)	6%,
ferromanganese (80%Mn)	4%,
ferrotitanium (20%Ti)	2%,
iron powder	31%.

The principal diameter of the electrodes was 4 mm. The standard current was 180A, and the voltage was 22V. A typical weld metal deposited had following chemical composition:

0.08% C,
0.8% Mn,
0.37% Si,
0.018%P,
0.019% S.

The oxygen content was in range from 340 to 470 ppm, and the nitrogen content was in range from 70 up to 85 ppm The acicular ferrite content in weld metal deposit was above 50%. The oxygen content was in range from 340 to 470 ppm, and the nitrogen content was in range from 70 up to 85 ppm. The acicular ferrite content in weld metal deposit was always above 50%.

This principal composition was modified by separate additions:

ferromanganese (80%Mn)	up to 5 % (at the expense of iron powder),
ferrochromium powder	up to 2% (at the expense of iron powder),
ferrovanadium powder	up to 1.5% (at the expense of iron powder),
ferromolybdenum powder	up to 1.5% (at the expense of iron powder),

ferronickel powder up to 6.5% (at the expense of iron powder).

A variation in the manganese, nickel, molybdenum, chromium, vanadium amount in the deposited metal was analysed from:

0.8 up to 2.4 Mn%,
1 up to 3 Ni%,
0.2 up to 0.6 Mo%,
0.2 up to 0.6 Cr%,
0.05 up to 0.15 V%.

3. Results and Discussion

After the welding process using basic coated electrodes there were gettable metal weld deposits with the variable amounts of tested elements (Mn, Cr, Mo, V, Ni) in it. After that the chemical analysis, micrograph tests, and Charpy notch impact toughness tests of the deposited metal were carried out. The Charpy tests were done mainly at +20°C and -40°C with 5 specimens having been tested from each weld metal. The impact toughness results are given in figures 1-5.

Analysing figure 1 it is possible to deduce that impact toughness of metal weld deposit is not strongly affected by the amount of manganese. Absorbed energy in terms of the amount of vanadium in metal weld deposit is shown in figure 2.

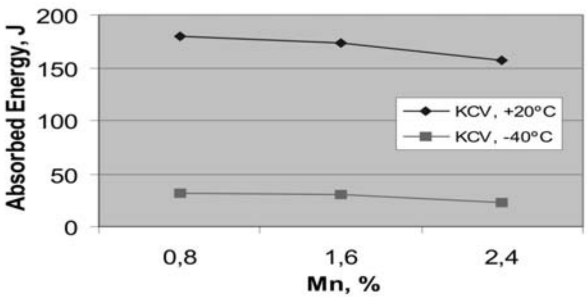

Fig. 1. Relations between the amount of Mn in MWD and the impact toughness of MWD

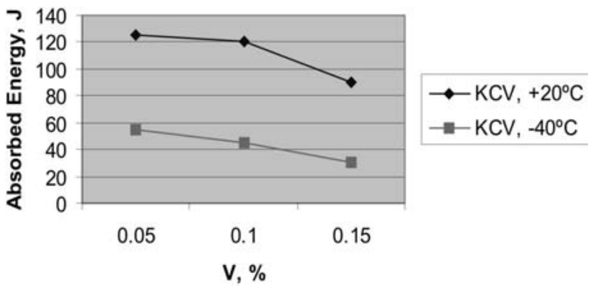

Fig. 2. Relations between the amount of V in MWD and the impact toughness of MWD

Analysing figure 2 it is possible to deduce that impact toughness of metal weld deposit is much more affected by the amount of vanadium than manganese. Absorbed energy in terms of the amount of chromium in metal weld deposit is shown in figure 3.

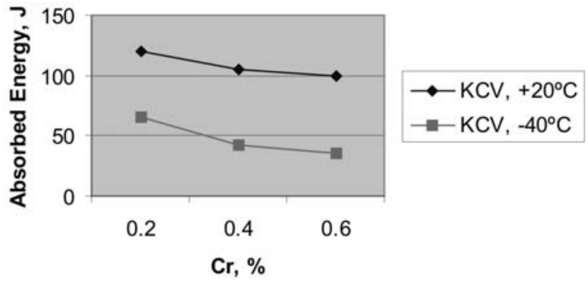

Fig. 3. Relations between the amount of Cr in MWD and the impact toughness of MWD

Analysing figure 3 it is possible to observe that impact toughness of metal weld deposit is also much more affected by the amount of chromium than manganese. Absorbed energy in terms of the amount of nickel in metal weld deposit is shown in figure 4.

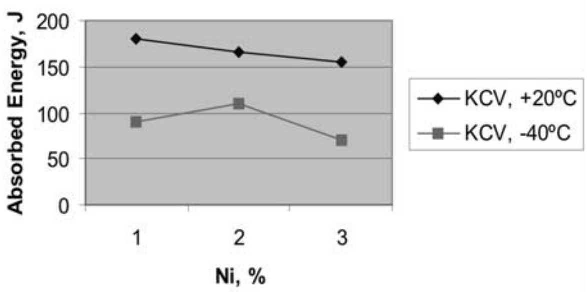

Fig. 4. Relations between the amount of Ni in MWD and the impact toughness of MWD

Analysing figure 4 it is possible to deduce that impact toughness of metal weld deposit is very positively affected by the amount of nickel. Absorbed energy in terms of the amount of molybdenum in metal weld deposit is shown in figure 5.

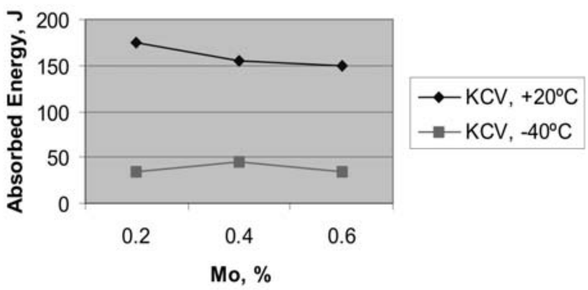

Fig. 5. Relations between the amount of Mo in MWD in MWD and the impact toughness of MWD

Analysing figure 5 it is possible to observe that impact toughness of metal weld deposit is also very positively affected by the amount of molybdenum. The microstructure and fracture surface of metal weld deposit having various amount of nickel and vanadium was also analysed. Acicular ferrite and MAC phases (self-tempered martensite, upper and lower bainite, rest austenite, carbides) were analysed and counted for each weld metal deposit. Amount of AC and MAC were on the similar level in deposits with Ni and Mo, also for deposits with V and Cr there were observed rather similar structure. Results of deposits with various structure are shown in figures 6, 7.

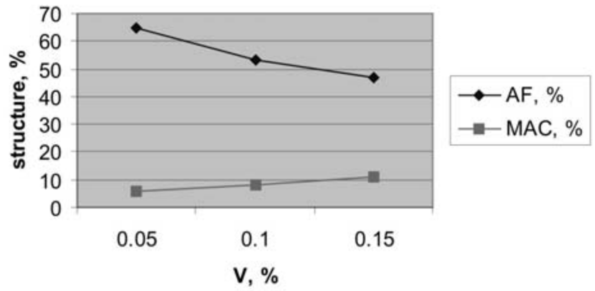

Fig. 6. Metalographical structure with V in MWD

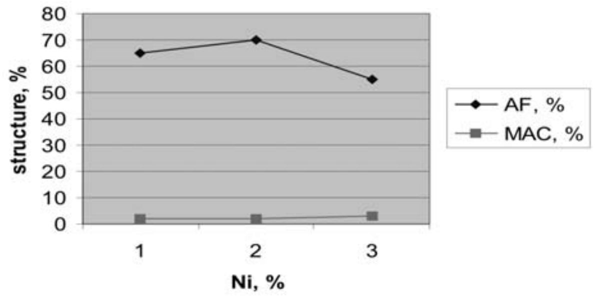

Fig. 7. Metalographical structure with Ni in MWD

It was easy to deduce that nickel and molybdenum have positive influence on the structure. That relation was firstly observed in impact toughness tests. Nickel and molybdenum could be treated as the positive elements influencing impact toughness and structure of MWD because of higher amount of acicular ferrite and lower amount of MAC. Chromium and vanadium could be treated as the negative elements influencing impact toughness and structure of MWD. Manganese could be treated as a neutral element influencing impact toughness of MWD. Additional fracture surface observation was done using a scanning electron microscope. The fracture of metal weld deposit having 1.1% Ni is presented in figure 7, and the fracture of metal weld deposit having 0.6% Cr is presented in figure 8.

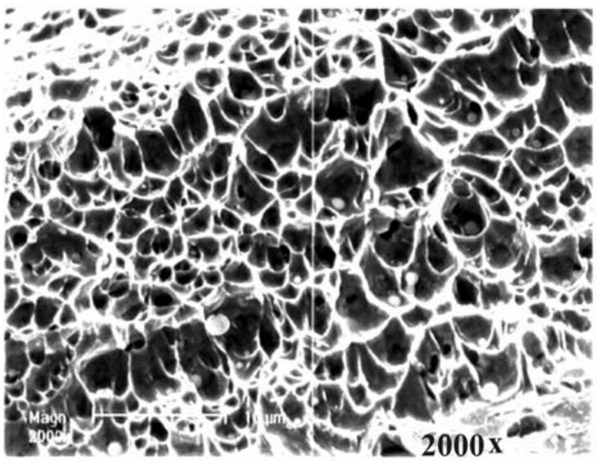

Fig. 8. Fracture surface of metal weld deposit

The surface is ductile, because of the beneficial influence of nickel on the deposit structure. After microscope observations it was determined that the amount of nickel (or molybdenum) has a great influence on the character of fracture surface. The surface was ductile also for MWD having Mo in it. The character of fracture surface changed from ductile to much breatle in terms of the increscent of the amount of vanadium (or chromium). The typical fracture of metal weld deposit having 0.6% Cr is presented in figure 9.

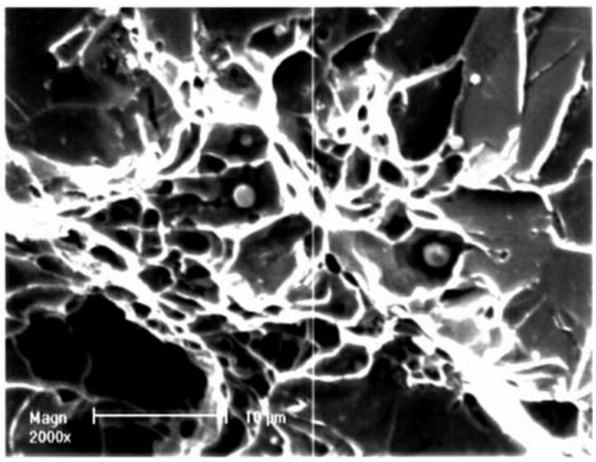

Fig. 9. Fracture surface of metal weld deposit

The surface is less ductile, because of the higher amount of chromium in deposit. The surface was breatle also for MWD having V in it. After microscope observations it was determined that the amount of chromium (or vanadium) has also a great influence on the character of fracture surface. The character of fracture surface changed from ductile to much breatle in terms of the increscent of the amount of chromium. In the present paper it was tested and optimized the chemical composition of metal weld deposit on the operational properties of steel welded structures. The influence of the variable amounts of nickel, molybdenum, chromium, vanadium on impact properties of low alloy metal weld deposit was tested. Chromium, vanadium, and especially nitrogen are regarded rather as the negative element on impact toughness properties of low alloy basic electrode steel welds in sub zero temperature, meanwhile nickel and molybdenum have the positive influence on impact properties. It was observed that nickel and molybdenum could be treated as the positive elements in low alloy metal weld deposits, meanwhile chromium and vanadium are negative elements influencing properties of MWD. The optimal chemical composition of steel low alloy MWD should be treated for deposits having 0.4 % Mo or 2% Ni.

4. Summary

Design engineers should base on actual welding technology. A close cooperation should be done with competent welding personnel during the design stage. Manufacture of welded structures ought to be supervised both by civil and welding engineers. Safety and exploitation conditions of steel welded structure depend on many factors. The cause of collapse, damages and deformation of steel structures is often connected with no proper choice of materials and their joining technology. The main role of that conditions are connected with welding technology. The damages of important constructions such as steel roof structures of workshops in Tychy (in 2006) and Zagreb (in 1993) are the best prove of that [9]. Summing up the paper it has been concluded, that especially important is a good selection of steel and welding method for proper steel structure. For responsible steel structure are used low carbon and low alloy steel, very often with a small amount of carbon and amount of other alloy elements such as Ni, Mn, Mo, Cr and V in low alloy steel and their welds. Only some of that elements could be treated as positive elements influencing MWD properties. In the present paper it was tested and optimized the chemical composition of metal weld deposit on the operational properties of steel welded structures. It was found that only nickel and molybdenum are treated as the positive elements in low alloy metal weld deposits. It has been proved that optimization of operational properties of steel welded structures might be done in terms of the chemical composition of MWD.

5. Conclusions

1. Optimization of operational properties of steel welded structures might be done in terms of the chemical composition of MWD.
2. Nickel, molybdenum, chromium and vanadium could be treated as the elements strongly influencing impact toughness properties of low alloy MWD.
3. Nickel and molybdenum are positive elements in low alloy metal weld deposits.
4. Chromium and vanadium can not be treated as positive elements in low alloy metal weld deposits.
5. Manganese could be rather treated as a neutral element influencing impact toughness properties.

6. References

[1] Judson, P., Mc Keown, D.: *Advances in the control of weld metal toughness*, Offshore welded structures proceedings, London, V2., 1982.
[2] Lancaster, J.F.: *Physics of Welding*, Pergamon Press, 1986.
[3] Wegrzyn, T.: *Oxygen and nitrogen in low carbon basic electrode weld metal deposits*, IIW Doc.II-A-1181-92, 1992.
[4] Allum, C.J.: *Nitrogen absorption from welding arc*, IIW.Doc.II-1115-88, 1988.
[5] Wegrzyn,T.: *A relation between the impact strength and the contense of manganese, nickel, molybdenium and nitrogen in the deposited metal of low-alloy low-hydrogen electrodes*, Przeglad Spawalnictwa, Poland, Nş 11/12: 1-6, 1996.
[6] Paton, B.E,.Lakomsky, V.I.: *Interaction of molten metal with nitrogen from arc plasma*, IIW.Doc.II-A-871-92, 1992.
[7] Wegrzyn T.: *The influence of the main factors on the impact toughness properties of low carbon steel welds*, Proceedings of ISOPE'97, Honolulu, USA, 1997.
[8] Wegrzyn T.: *The classification of metal weld deposits in terms of the amount of nitrogen*, The Proceedings of ISOPE'2000, Seattle, USA, V4: 130-134, 2000.
[9] Turcic, F.: *The couse of collapse and rehabilitation of steel tanks roof structures" nitrogen*, The Proceedings of the XI International conference on metal structures, Seattle, ICMS-2006, Rzeszów 2006.

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