Change of mechanical properties in substrate during rewelding deposit

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Abstract

Chotěborský R., Hrabě P., Kabutey A., 2011. **Change of mechanical properties in substrate during rewelding deposit**. Res. Agr. Eng., *57*: 105–109.

A study was carried out to examine the influence of rewelding deposit of structural low carbon steel and also the changes which occur in heat-affected zone and subcritical zone during rewelding. Optical metallography, microhardness Vickers method and Charpy impact test were employed to analyze these differences. The results show that rewelding deposit increased the heat-affected zone and fine coarse grain heat-affected zone and also has influence on impact toughness of substrate and their microhardness. Again, it was found that rewelding increased the fine coarse grain heat-affected zone. This effect resulted in increasing impact toughness in the heat-affected zone. However, submicroscopic change in substrate ferrite showed decreasing impact toughness.

Keywords: gas metal arc welding (GMAW); heat-affected zone; microhardness; impact toughness

Welding procedures are used in a modern engineering technology to produce specific results as these procedures take on added significance based on the quality requirements that can be involved. In weld deposit process, weld deposit material (electrode) specified in standard CSN EN 14 700 (2006) is used. There were considerable works on the properties of weld deposit (Atamert, Bhadeshia 1990; Buchanan et al. 2008; Chotěborský et al. 2008; Kolhe, Datta 2008) and heat-affected zones (Gubeljak 1999; Eroglu, Aksoy 2000; Poorhaydari et al. 2006). A weld-joint comprises base metal, heat-affected zone (HAZ) and weld metal. The HAZ of mild steel weldments, which has width of approximately several millimeters, is commonly categorized into four sub-zones each exhibiting different microstructures (Easterling 1993; Lancaster 1993). These sub-zones include sub critical (SCHAZ), inter critical (ICHAZ), fine grain (FGHAZ) and coarse grain (CGHAZ) heat-affected zones in the order of their location from the base metal to the weld metal (Lancaster 1993). The role of microstructure on the mechanical properties of the sub-zones is well known (Kim 2001; Liu, Bhole 2002)

However, there is some knowledge on the effect of repeated surfacing of the HAZ and base material. It is known that heat exposure which occurs in low carbon steel result to changes in ferrite, which are defined to as ageing. This process leads to decreased toughness of low carbon steel and an increase in transit temperature (Süleyman 2008; Massardier, Meriln 2009).

The aim of this research work was to highlight the changes which occur in the HAZ during weld deposit repeated low carbon steel.

Supported by the Czech Science Foundation, Project No. GP101/07/P124.

Table 1. Chemical composition of base material (wt. %)

C	Mn	S	P	Fe
0.114	0.31	0.0042	0.015	rest.

Table 2. Chemical composition of electrode

C	Si	Mn	Cr	Ni	Mo	Al	Fe
0.15	0.30	1.10	1.0	2.30	0.50	1.50	rest.

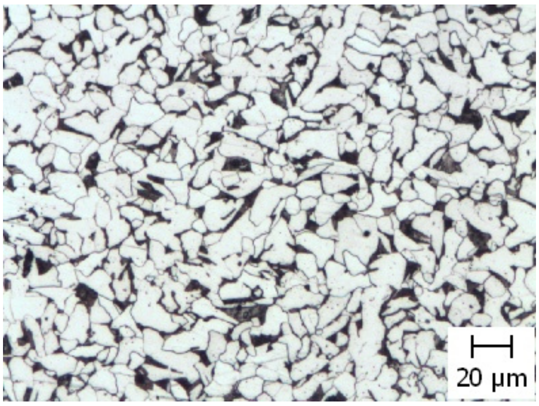

Fig. 1. Structure of base material

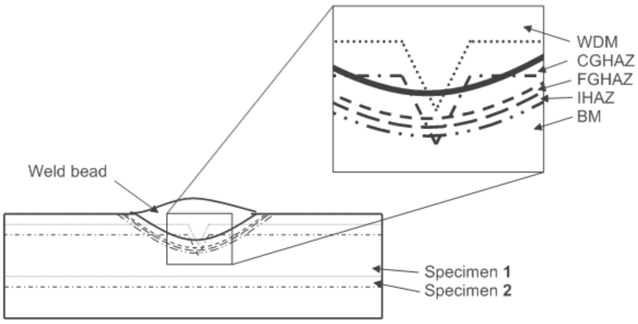

Fig. 2. Schematic of weld deposit and specimen cuts
WDM – weld deposit metal; CGHAZ – coarse grain heat-affected zone; FGHAZ – fine grain heat-affected zone; ICHAZ – intercritical heat-affected zone; IHAZ – intercritical heat-affected zone; BM – base material (without structural change)

MATERIAL AND METHODS

The weld deposit test materials with a thickness of 20 mm were prepared from S235JR (hot rolled) steel of dimension 55 mm × 500 mm. The chemical composition of the steel is given in Table 1 and the structure is also shown in Fig. 1.

The weld deposit process involving the use of electrode OK Tubrodur 15.43, flux cored tube with a diameter of 1.6 mm was done on a welding machine. Weld deposit measurement (welding voltage was 27 V, welding arc current 250 A and welding speed 20 cm/min) were experimentally tested with penetration depth of 2.2 mm at 30 kJ/cm heat. Weight of the base material allowed an increase of temperature after weld deposit of the maximum value 80°C. The depth of penetration was the size of the ground in order to produce the sample for impact test according to Charpy impact test with notch root as shown in Fig. 2. Chemical composition of the electrode is presented in Table 2. The sample was mounted before surfacing as shown in Fig. 3, to avoid large distortions. Weld bead which exceeded samples subjected to repeated weld depositing (2×, 3×, 5× and 7×) were removed.

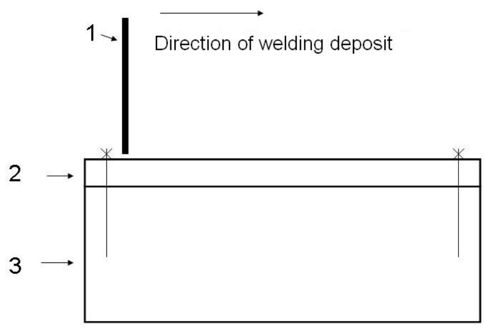

Fig. 3. Schematic of weld deposit process onto base material
1 – electrode, 2 – base material, 3 – attached

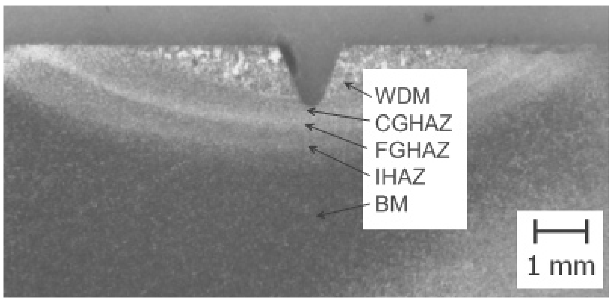

Fig. 4. Optical macrograph of specimen for Charpy impact test (for abbreviations see Fig. 2)

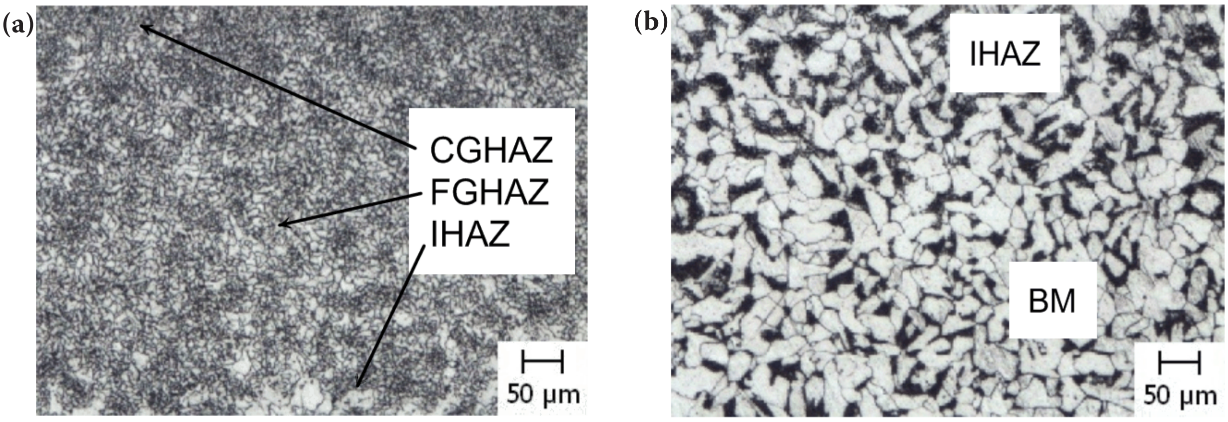

Fig. 5. Optical micrograph of heat-affected zone (for abbreviations see Fig. 2)

Experiment on microhardness using Vickers indenter of 0.1 kg load was carried out. The microhardness was evaluated on metallographic specimens that were prepared from samples used for the Charpy impact test. The microhardness from surfacing to the base material, microhardness of ferrite ICHAZ and SCHAZ were evaluated. Also, the size of the HAZ and FGHAZ were investigated.

RESULTS

The heat-affected zone shown in Fig. 4 describes the CGHAZ, FGHAZ and IHAZ. The microstructure is shown in Fig. 5. In these zones martensite or bainite structures using optical metallography were not found.

Fig. 6 shows the relationship between hardness and distance from weld bead. It was obvious that repeated weld deposit influenced the change of hardness of the base material, heat-affected zone and intercritical heat-affected zone shown in Fig. 7. Also it was observed that repeated weld deposit increased in the HAZ and FGHAZ, but FGHAZ increase was higher than the HAZ as shown in Fig. 8; in the same figure, FGHAZ increase was higher than CGHAZ and partially higher than IHAZ.

Results of the experiment show that each repeated weld depositing on the base material increased by transit temperature as shown in Fig. 9. It was evident that from third cycle of weld deposit, Samples 1 had similar increasing transit temperature. The impact energy at –40°C had increasing trend as shown in Fig. 10. This fact was attributed to the size of FGHAZ which at temperature of –40°C showed a toughness crack, although CGHAZ, base material and IHAZ was brittle cracked as shown in Fig. 11. Also, the size of ferrite grains in FGHAZ increased from 6.5 µm after the first welding and then to 7.5 µm after seventh welding as a result of the increase in transit temperature.

To a different effect, Samples 2 at –40°C showed brittle failure with the value of impact energy of 4 ± 0.5 J.

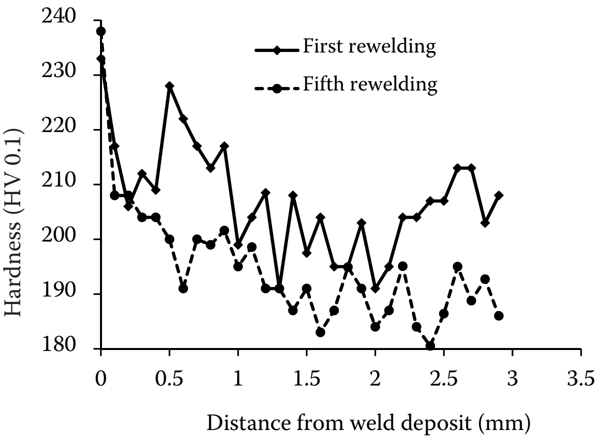

Fig. 6. Effect of hardness on distance from weld deposit bead

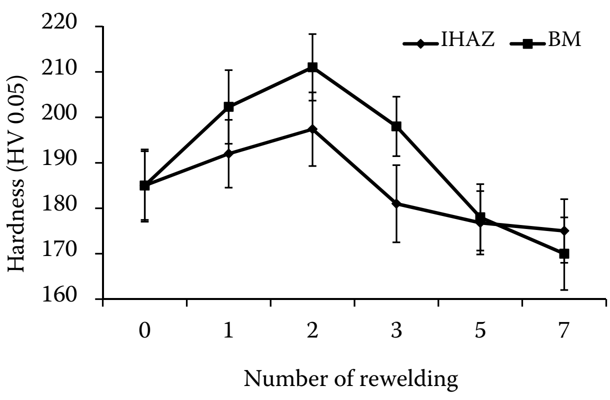

Fig. 7. Effect of rewelding on hardness of ferrite in IHAZ and BM (for abbreviations see Fig. 2)

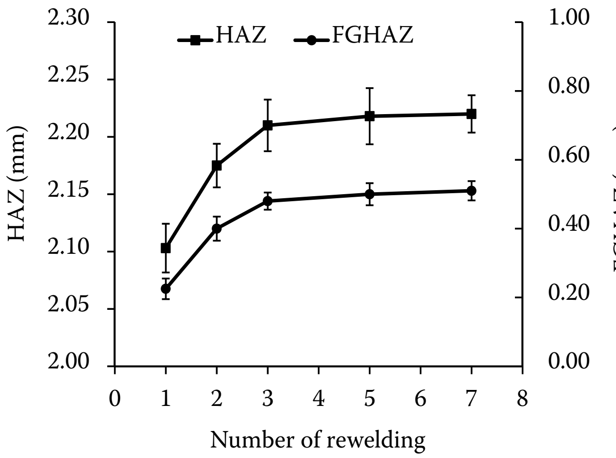

Fig. 8. Effect of rewelding on size of HAZ and FGHAZ (for abbreviations see Fig. 2)

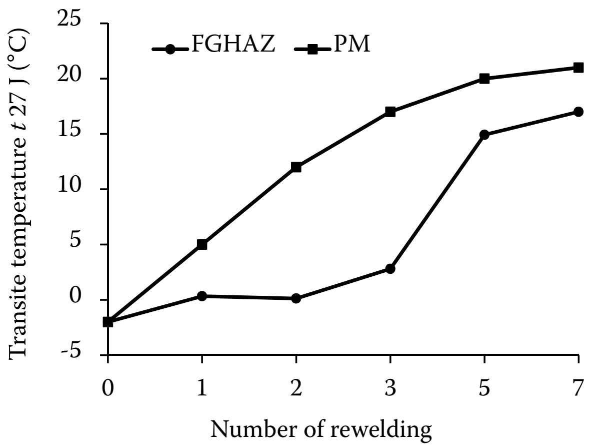

Fig. 9. Effect of rewelding on transit temperature base material and specimen (for abbreviations see Fig. 2)

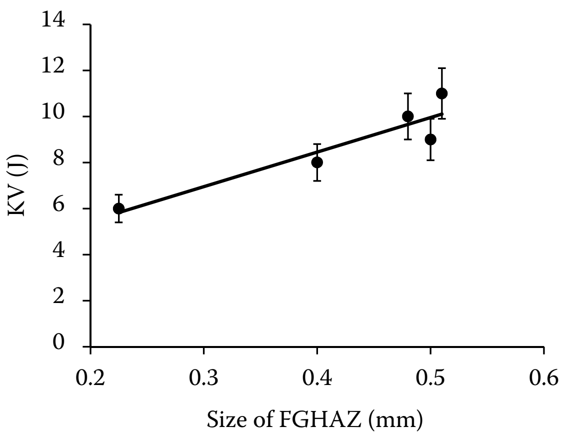

Fig. 10. Effect of size of FGHAZ on impact energy specimens at –40°C (for abbreviations see Fig. 2)

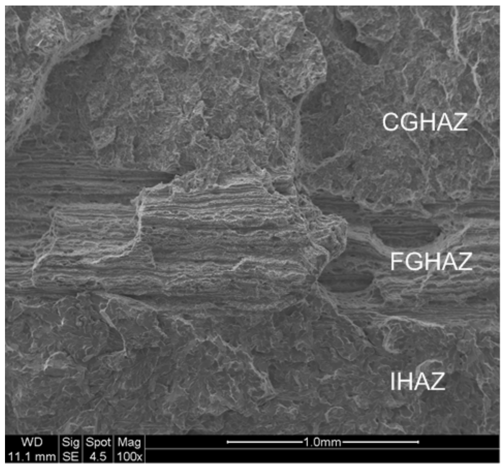

Fig. 11. SEM fractography showing fracture features of specimen after seventh rewelding at –40°C temperature test (for abbreviations see Fig. 2)

CONCLUSION

Results of the experiment showed a similar effect on repeated weld depositing of the changes occurred in the heat-affected zone and subcritical zone of the base material. It was found that

- repeated weld depositing in the heat-affected zone increased to 3 cycles,
- repeated weld depositing influenced the FCHAZ to 3 cycles, especially at the expense of CGHAZ,
- effect of repeated deposition softened the structure of CGHAZ,
- repeated weld depositing increased the transit temperature of base material,
- impact energy of FGHAZ increased with increasing size of FGHAZ, the value of impact energy was affected by grain size.

Weld depositing results in embrittlement of the base material. FGHAZ will not grow as in creating layers in weld bead which overlaps while in the HAZ there is a shift. This would be important for re-surfacing in the worn surfaces, when FGHAZ can be bumpered to cracking line from hardfacing to base material.

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Received for publication October 5, 2010
Accepted after corrections March 1, 2011

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