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Research Paper :

Effects of heat input on grain details of multipass submerged arc weld joint

KISHOR P. KOLHE, PAWAN KUMAR, R.M. DHARASKAR AND C.K.DATTA

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See end of the article for authors' affiliations

Correspondence to:
KISHOR P. KOLHE
Department of Mechanical Engineering, College of Agricultural Engineering and Technology, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, RATNAGIRI (M.S.) INDIA

ABSTRACT

A detailed study on the microstructure, phase analysis and mechanical properties, HAZ width of submerged arc weld metal multi pass joint and heat affected zone of 16 mm thick mild steel plate was carried out using trinacular metallurgical microscopy. The bulk hardness, impact energy and micro hardness of a multipass welded joint were tested by Rockwell hardness testing machine, Charpy V Notch test and Vickers micro hardness test. The various sub-zones in the microstructure were observed in the HAZ of submerged arc weld are Spheroidized, partially transformed, grain refined and grain coarsened. The variation in hardness of weld metal, fractured surface and base metal were compared with the microstructure, to get a defect free weld, and also it was correlated with the microstructure of weld metal and heat-affected zone. The main purpose of present work is to investigate and correlate the relationship between the various parameters; Mechanical properties and microstructure of single "V" butt joint of mild steel plate, and also to perform the phase analysis of the multipass welded joint to get defect free welded structures

Key words : Submerged arc welding, CVN test, Heat affected zone, Micro hardness, Phase analysis

Improvement in the weld quality has been a continuing challenge, as new processes were introduced and existing processes were stretched to their limit. Competition in the field of welding is increasing day-by-day. Fabricators look for welding processes, which are cost effective and are able to give higher deposition rates, better penetration and robust structures. Submerged arc welding is one of the processes having high deposition rate welding speed, deeper penetration - fewer operators fatigue because arc is not visible and welder's manipulative skill not needed. The normal welding variables of submerged arc welding like current, voltage, travel speed and bead geometry are characterized by bead width, height, penetration, hardness and quality. To understand and predict the mechanical properties, a weldement such as strength and toughness, it is important to know the microstructures and micro hardness values of the weld metal and heat affected zone regions. Besides the inclusions ferritic weld plays very important role not only in controlling the microstructures as nucleation sites of acicular ferrite but also in fracture process by acting as sites or cleavage or void formation. The essential requirements of weldable steels are enhanced strength, toughness, better microstructure and durability of the welded structures and economy in fabrication. Toughness is the ability of a metal to resists fracture while being loaded under conditions that are unfavorable for energy absorption and plastic deformation, high toughness of weld and heat affected zone are important characteristics of a weldable steel, high toughness in a certain way ensures good behavior of the welded structures even in case of severe service conditions. Mild steel exhibits good ductility when an ordinary tensile specimen is tested. When the steel contains sharp notch and temperature is low, however, a crack may initiate from the notch, causing brittle fracture of the plate. Alloying elements in the weld metal may come from the base metal, welding electrodes and welding flux. Among these, since the chemistries of the weld metal and welding electrode are generally known, the chemical behavior of welding flux should also be understood for estimating the composition of weld deposit. In multipass SAW there is an inadequate transfer of heat in the fusion as well as in the HAZ and the base metal, therefore, it is necessary to control the microstructure and the various phases of the steel by controlling the welding parameters. Typical microstructure formed in multipass welded regions of base metal and HAZ of mild steel consist of grain boundary ferrite, widmanstatten ferrite, fine pearlite, banite, acicular ferrite and marten site depending on the cooling rate below the AC3 temperature.

Automated submerged arc welding is a versatile process, as it gives best quality, saves time, reduces cost, resurfaces wear surfaces on steel castings, improves repair procedure, process control, increases efficiency and productivity (Kolhe and Datta, 2003; Demis *et al.*, 1999; Richard and Richard, 194). Welding parameters, heat input, alloying elements, filler material and dilution are the sole variables to controls the bead geometry, mechanical properties and microstructure (Mallya and Srinivas, 1989; Kotecki, 1996; Hunt *et al.*, 1995; Sindo, 2002; Evans, 1982; Kotecki and Ranjan, 1997 and Kim *et al.*, 1998). The various zones are confined to a very narrow region extending up to 0.2 in, on either side of the weld edge, whatever the thickness of the material. This is so even when the weld is built up from runs, which tends to refine the structure of earlier runs (Eroglu and Aksoy, 2002). The metallurgical feature that directly affected by heat input rate is the grain size in the heat affected zone and the weld metal. Grains in the solidifying weld metal grow coherently with grains in the solid metal at fusion boundary. Therefore, longer time spent above the grain coarsening temperature of the alloy, coarser the structure in the heat-affected zone and in the weld metal .In multi layers welds partial or complete re-crystallization of weld metal occurs, depending upon the heat input, bead dimensions and the time interval between successive deposition, with the exception of final layer, the structure is refined with a corresponding improvement in ductility and toughness (Gunaraj and Murugan, 2002). In the literature there are published studies relating to the effects of alloying elements, flux compositions on the microstructure and mechanical properties of weld metal (Lancaster, 1987). This paper presents the experimental results of hardness, fracture toughness, HAZ width from top and bottom of the weld joint and the theoretical analysis of phases of the steel at different heat input of multipass submerged arc welding from the top of welded joint by using image analysis software and correlates the same to the microstructures of fusion zone as well as the heat affected zone of mild steel.

METHODOLOGY

The material is cut into approximate size of and 80x16 x256 mm by using automatic hydraulic power hexa. Then the standard joint preparation as per British standard was made on turret Ram Milling Machine M1TR of 60° joint, six similar specifications joint were prepared. Then root pass was given to the joint by MMAW of 1.47 mm root gap with 120-amp current 80V voltage. For getting good penetration and avoiding voids the joint was finished on central grinding wheel. To avoid distortion during welding, the samples were fixed by using suitable clamping arrangement on fixture. 3 mm copper coated mild steel electrode was used to carry out the experiments. Flux used during welding was as per ASTM specification manufactured by Advani Orilenkon Mumbai, Multi pass SA weld having 800 amp current fully automatic constant potential submerged arc welding was performed by changing its operating parameters. As suggestions given by Indian Institute of Welding in National conference held at Baroda high initial voltage was set. The charpy specimens were prepared as per British specification, for checking the toughness on the Charpy V Notch testing machine for both welded region as well as heat-affected zone. The bulk hardness of welded region, HAZ and fractured charpy specimens were carried out on Rockwell testing machine. The multipass welded specimens were polished by using different grades of emery papers followed by wet polishing, dipping 2 per cent Nital agent and finally dried by using air blower to study the metallurgical structures and the depth of different passes and HAZ region. The Vickers micro-hardness measurements were carried out in four zones of weldment consisting of weld metal, fusion boundary, HAZ and base metal. The phase analysis was done by calculating the percentage of various phases, such as Ferrite, pearlite, carbide etc.

RESULTS AND DISCUSSION

During welding the surfaces of the prepared joints are raised to fusion temperature, and deposited metal from the electrode with a proportion of fused parent metal progressively solidified in the joint as weld metal with single pass weld, the crystallographic structure of the weld is columnar, but in multipass weld the structure modified by the heating effect of the subsequent passes. While investigation it was observed that in multipass welding the number of passes deposited in the welded groove were less for high heat input and more number of welding passes at low heat input. For low heat input the temperatures attained in the various zones liable to transformation are accompanied by much more rapid cooling rates, leading thorough quenching. The successive runs also affects the structures in the heat-affected zone to a certain extent, so that particularly in thick plates one can find alternating layers of heat affected and partially normalized material. Thus the various structures are confined to a very small volume within which they are intertwined in a very complex manner, because of the superimposition of repeated heat treatment. Simultaneously it affected the width of heat–affected zone region dissymmetry from the top and bottom, and change in penetration pattern was observed due to the repetitive heat treatment, thermal cycles and increased heat input. The rate of increase of heat input affects the dimensions of HAZ width from the top and bottom face of the weld centerline Fig 1 (a). The rate of increase in heat input increases the hardness of fractured surface of weld metal while decreases the hardness of weld metal, this happens due to the increase of thermal

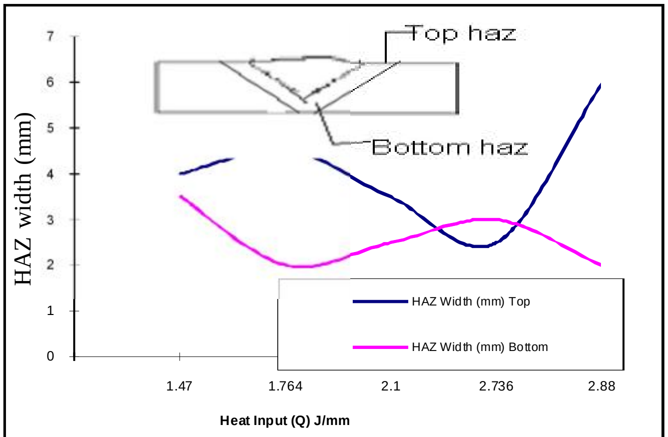

Fig. 1 (a): Influence of heat input on HAZ width (Tom and bottom) from the weld centre line

cycles from the weld metal to base metal tending to sufficient cooling, which results in such type of change in hardness and the increase in ferrite phase in the microstructure. The successions of superimposed runs modify the overheated zone structure and consequently the mechanical properties. The tempering effect can be detected by the variations in hardness from point to point in the fusionzone, heat affected zone as well as parent metal. Due to continuous temperature transformation in multi-pass SAW the mechanical properties of a welded joint change as a result of recurrent of thermal cycles. From Fig 1 (b) it is clear that for low heat input rate of transformation of weld metal remains same because of which same micro hardness was observed and the microstructure showed widmanstatten ferrite plates in coarse size pearlite colonies and acicular ferrite grains, where as for higher heat input more number of thermal cycles take place, which shows slight variations in micro

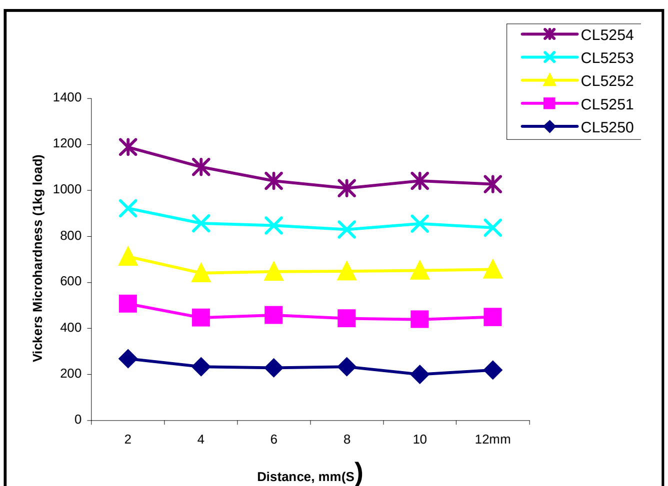

Fig. 1 (b): Influence of microhardness of the multipass SAW weld metal

hardness values and the ferrite, colonies of pearlite and the widmanstatten structure of fusion and heat affected zone. The results of micro hardness transverse from the base metal, through the HAZ into the weld metal for reprehensive mild steel multipass SAW. The HAZ and weld *i.e.* no excessive HAZ hardening or softening was observed. This is an agreement with the base metal fracture locations in the transverse weld tension tests. The lowest toughness values were obtained for specimen (CL5252, CL5255) are 38 J, 60 J at the heat input of 2.1 KJ/mm, and 3.0 J/mm (Fig. 1(c)). Detail investigation of microstructure and phase analysis it proved that the

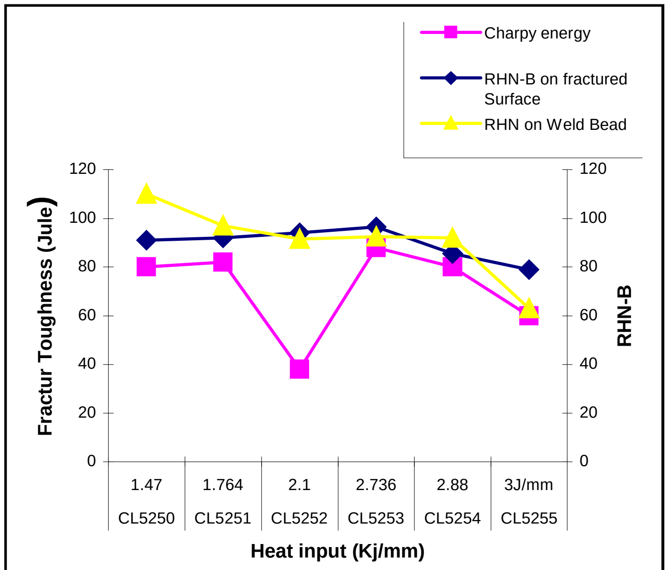

Fig. 1 (c): Effect of heat input on fracture toughness and hardness

percentage of phases, such as graphite pearlite, ferrite and carbide in this conditions was less and other phases percentage like martensite austenite etc was increased for this condition due to rapid cooling rate, this loss of toughness is mainly associated with the presence of widmanstatten ferrite and martensite in the microstructure as shown in Fig. 2 (a-f). Contrast specimen (CL5251) demonstrated the highest toughness 82 J for a heat input of 1.764 kJ /mm, because of ductile phase such as ferrite and pearlite in the microstructure. From figure the bulk hardness of the welded sample was low at low heat input where as slight increase and decrease for high heat input. But the bulk hardness of fractured sample was high at low heat input and it decreased for high heat input. The micrographic section of a multipass welded joint shows distinct zones, namely the fusion zone with its immediate surroundings and the parent metal. But in multipass what ever be the passes, the fusion zone entire metal that has

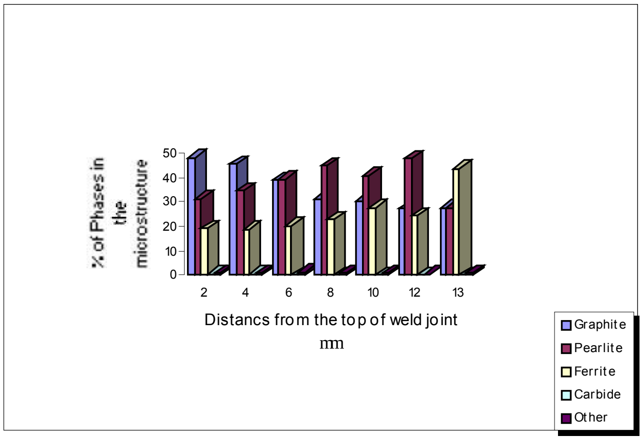

Fig. 2 (a): Influence of distance on phases in the microscructure at 1.47J/mm heat input (CL 5250 sample)

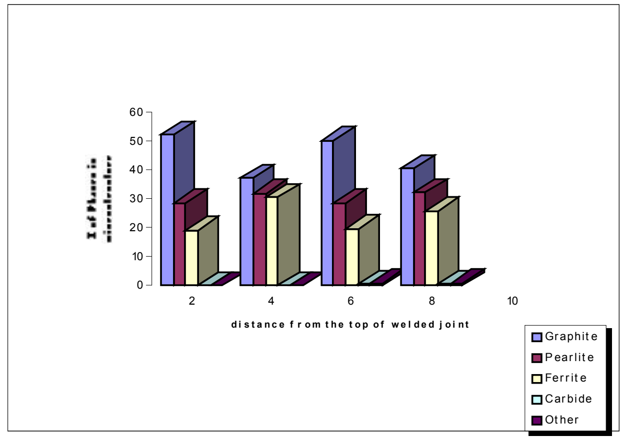

Fig. 2 (d): Influence of distance on the phases in the microscructure at 2.74J/mm heat input (CL 5253 sample)

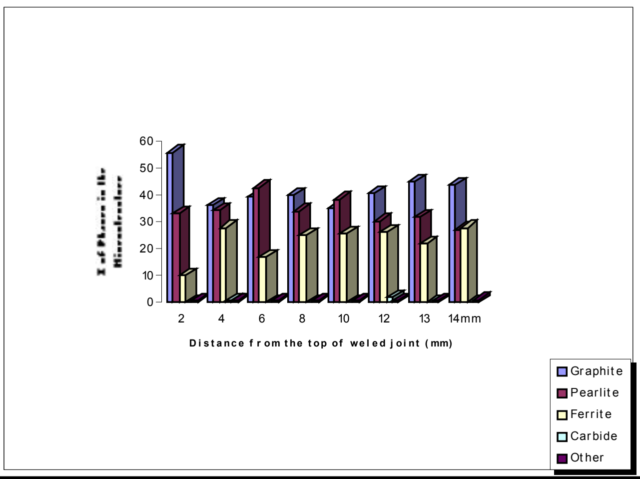

Fig. 2 (b): Influence of distance on the phases in the microscructure at 1.77J/mm heat input (CL 5251 sample)

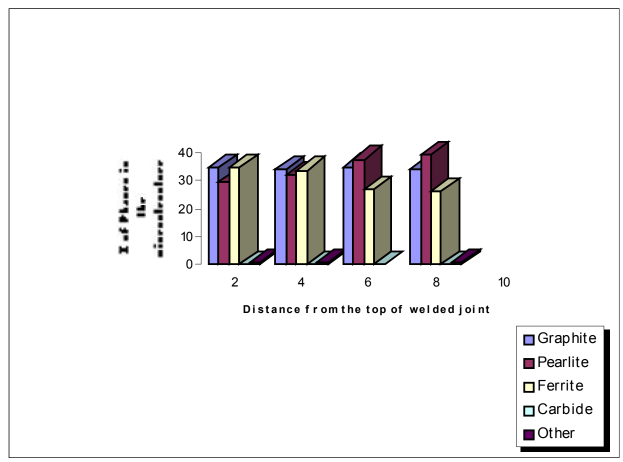

Fig. 2 (e): Influence of distance on the phases in the microscructure at 2.88J/mm heat input (CL 5254 sample)

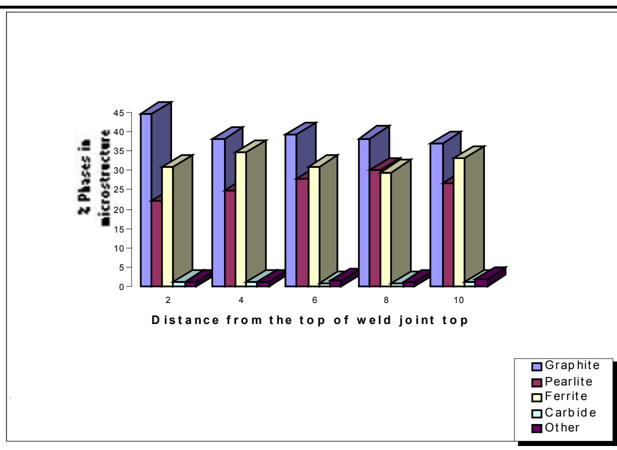

Fig. 2 (c): Influence of distance on the phases in the microscructure at 2.1J/mm heat input (CL 5252 sample)

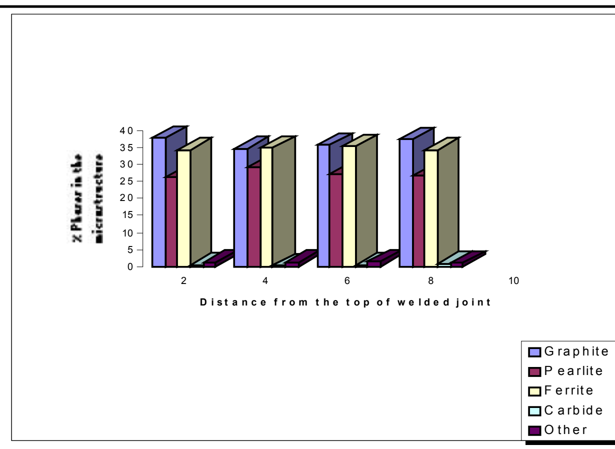

Fig. 2 (f): Influence of distance on the phases in the microscructure at 3.0J/mm heat input (CL 5255 sample)

been melted and solidified in every pass after going certain cooling cycle which undergoes certain changes of chemical, physical or a structural nature. The parent metal is subjected to a post weld heat treatment, due to which the complete microstructure of a fusion as well as heat affected zone becomes more and more intricate that affects the width of HAZ on the top and bottom remains unsymmetrical, for this reason certain physiochemical transformation were also seen. The complexities of the microstructure at every pass will be increased due to the new grain refinement of a complete welded structure. The thermal cycle and actual nature of the alloy decides whether it is hardenable, sensitive to phase changes by precipitation, austenitic or so on. It is visible that for low heat input more percentage of graphite and pearlite phases are seen nearer to the fusion zone where as distance increases from the top of welded bead the percentage of ferrite also progressively increases due to more refined grains in the microstructure. Weld metal Charpy V-notch toughness increases with increasing percentage of ferrite in the weld metal. The interlocking nature of acicular ferrite, together with its fine grain size, provides maximum resistance to crack propagation by cleavage. The formation of grain boundary ferrite, ferrite side plates, or upper banite is determined by weld toughness.

Conclusion:

Based on the experimental results it is concluded that, the variations in microstructures and mechanical properties were observed at every pass of SAW weld Joint due to continuous change in thermal cycle and inadequate heat transfer in the welded metal following results were obtained

– The CVN value of fusion zone with the increase in ferrite content decreased with the increase in marten site–austenite (M-A) contents in the microstructure. Welding heat input can control the percentage of phases in the welded structures.

– More variations in bulk hardness of the fractured samples were observed than welded samples.

– More HAZ width at top region of welded specimen was seen than that of bottom region, where as highest top HAZ width (6mm) for specimen CL5254, and lowest bottom 2.0 for specimen (CL5251, CL5254) was noted.

– For increase in heat input the percentage of graphitic phase was slightly decreased whereas the percentage of ferrite sharply increased and finally the ferritic structures were observed.

– The proportionate value of micro hardness was observed for low heat input where as for increased heat input variations in hardness value was observed.

These results would solve weldability issues, improve weldment properties, analyze weld joint failures and evolve satisfactory welding procedures for fabricating advanced materials. As newer and more advanced techniques of micro structural characterization become available, the utilization of this powerful tool will become even more effective and useful. Welding parameters of submerged arc welding used to control the microstructure, phases in the steel, mechanical properties of a welded joint and help to get the robust welded structure of mild steel.

Authors' affiliations:
PAWAN KUMAR AND R.M. DHARASKAR, Department of Mechanical Engineering, Delhi Engineering College, DELHI, INDIA
C.K. DATTA, Department of Mechanical Engineering, College of Agricultural Engineering and Technology, Marathwada Agricultural University, PARBHANI (M.S.) INDIA

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