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STUDY OF FERRO BORON CONTENT BY PASTE TECHNIQUE ON MICROSTRUCTURE IN HARD FACED MILD STEEL

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Abstract

The application of hardfacing materials as wear resistant coating on components exposed to wear condition not only safeguards environment but also enhances the service life of engineering equipment and gives a boost to economy. Surface properties and quality of the hardfaced component depends upon the nature of hardfacing alloys selected and the welding process used for hardfacing. Ferro boron is an important alloy used in manufacturing metallic glass and magnetic materials, and preparing several steel alloys. Ferro boron plays pivotal role in increasing mechanical properties of steel. Due to easier availability and operational versatility shielded metal arc welding is the most commonly used process for hardfacing. In this study, cheaper and easily available low carbon steel was selected as a substrate material. Three different content of Ferroboron has been used and sodium silicate has been applied as a binder deposited on mild steel and making use of paste coating process. Mild steel plate 100× 75 × 12 mm^3 were used for deposition of hardfacing layers with Ferroboron by paste technique and under shielded metal arc welding for analysis of microstructure and optimizing process parameters namely, Ferroboron content (mg/mm^2) Welding current (A) and Average welding speed (mm/min).

Keywords:

Hardfacing;

paste coating;

microstructure;

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1. Introduction

Hardfacing is primarily carried out to enhance surface properties like resistance to wear, corrosion, and oxidation of the base metal (substrate). Percentage dilution plays a pivotal role in ascertaining properties of a hardfaced surface [Gourd, 1998]. Hardfacing is applied to serve the purpose of enhancing resistance to wear, abrasion, impact, erosion, galling and cavitation. This process is widely used to repair the railway rolling stock, earth moving and agricultural machineries, large gear wheels, conveyor shafts, chutes, turbine parts and innumerable other components [Horsfield,1980]. Usually, selection of an alloy is considered as a compromise between wear and cost, it is also invariably required to take into account other prominent parameters like base metal, deposition process, corrosion and oxidation capacity. Choteborsky et al. (2008) found that service conditions, selection of the hardfacing alloy, compatibility of the hardfacing alloy with the base metal, hardfacing process, level of dilution and the overall cost are the sequential steps for proper and meaningful selection of an alloy.

1.1 Literature review

Whang et al., (2005) attempted to investigate microstructure and properties of TiC/Fe-based alloy hardfacing layers.These hardfacing layers were obtained by shielded metal arc welding (SMAW) wherein H08A bare electrode was coated with a powder mixture of graphite,ferrotitanium, calcium carbonate rutile,and calcium fluoride.Wang et al.,(2006) tried to optimize cobalt based hardfacing in carbon steel by making use of fuzzy logic analysis for robust design and displayed application of fuzzy logic analysis to a Taguchi orthogonal experiment for finding a robust model with high efficiency in multiple performance characteristics (MPCs) of plasma transfer arc welding (PTAW) hardfacing process. Buchanan et al., (2007) presented a comparison between abrasive wear behaviour of iron-chromium based hardfaced coatings deposited by the processes of SMAW and that by electric arc spraying. Shamanian et al., (2009) made an attempt to investigateeffect of silicon content on microstructure as well as characteristics of Fe–Cr–C hardfacing alloys and studied surface of St52 steel alloyed with preplaced powders 55Fe39Cr6C, 49Fe39Cr6C6Si, and 45Fe39Cr6C10Si and using a tungsten-inert gas as the heat source. Kazemipour et al., (2010)studied influence of the matrix microstructure on abrasive wear resistance of heat-treated Fe–32Cr–4.5C wt. % hardfacing alloy.

The abrasion wear resistance of Fe–32Cr–4.5C wt. % hardfacing alloy was found to be a function of matrix microstructure.Goodarzi et al., (2018) analyzed microstructure and sliding wear of hardfaced layers produced by FCAW and using cored wire Fe-B-C-Ti alloy.Shoushtari et al., (2019) attempted to investigate composition and microstructural morphology of the Fe-B-C hardfacing layers.

Many researchers investigated different processes such as an automatic flux cored wire, TIG, SMAW or plasma transferred arc welding,a laser, electron beam for surface alloying and using low/high alloy ferrous materials, carbides nickel base alloy or cobalt base alloys and high chromium white irons. It has been found that very less work appears reported in the literature related to pure boron powder or powder containing boron for surfacing in SMAW process. Hence, this paper aims at studying the effect of various parameters namely ferro-boron content (mg $/mm^2$), welding current (A) & average welding speed (mm/min) on microstructure of the weld metal in SMAW welding process.

2. Research Method

A plan of experiments generated through Taguchi technique was followed to analyze phenomenon of hardfacing with Ferro-boron by paste technique based on L9 orthogonal array. Analysis of Variance (ANOVA) and Signal to Noise ratio (S/N) have been used to investigate the influence of ferroboron content, welding current and average welding speed on microstructure of weld metal.

For experimentation, L9 orthogonal array was used.

The standard L9 orthogonal array is shown in Table -1, where A, B, & C represent control factors and each has three levels.

Table 1

Standard layout of L9 orthogonal array

Runs	Factors		
	A	B	C
1	1	1	1
2	1	2	2

3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Here, factors A, B, and C have three levels each. Interaction between column 1 and 2 is orthogonal to all columns and hence, estimation can be carried out without sacrificing any column [Phadke, 1989].

3. Results and Analysis

Ferroboron powder is used in the form of paste constituted of sodium silicate and ferro-boron powder. Then it was applied with the help of paint brush on the base plate using custom made dies. The paste coated plates are shown in Fig.-1. In trial runs, three different amount of ferroboron i.e. 10 g, 20 g, and 30 g were used on 2500 mm^2 area. The amount of ferro-boron was measured with the help of digital weighing-machine. The quantitative values of 3 levels of process control parameters are shown in Table-2.

Table 2

Process parameters and their working range

Parameter	Ferroboron content(mg/mm^2)	Welding current(A)	Average welding speed(mm/min)
Level 1	4	90	45
Level 2	8	120	90
Level 3	12	150	135

Fig.1. Paste coated plate

A well prepared paste coating of ferro-boron and sodium silicate was deposited on mild steel plate. The paste was applied with the help of paint brush on the base plate. Three important process parameters ferro-boron content, welding current and average welding speed were selected on the experimental work. Paste was applied on 9 different plates with three different ferro-boron content such as 4, 8 and 12 mg/mm^2 and these plates were subjected to three different welding current 90,120 and 150 A and three different average welding speed 45, 90 and 135 mm/min as per the combination selected from and based on the orthogonal array. The hard-faced mild steel plates are shown in Fig.-2

Fig.2. Hard-faced mild steel plate

4.1. Microstructural analysis

Microstructural analysis of hard faced plates was carried out under optical electron microscopes. Optical electron microscope was used for the examination of microstructure of the specimens. For microstructural analysis,the specimen plates are polished with emery paper up to 3000 grit size and etched with 3% nital for 10 seconds and then specimen plates were examined under high magnification microscopes to record images of microstructures. Test method was followed in accordance with ASM VOL-9, ASTM E112:1996(RA-2004). In present study, ametallurgical microscope, Make: Nikon Model: Epiphot200, mag. 50-1000 was used. Sample size of 20×12 mm was prepared to study the micro-structure. The samples for microstructure testing are shown in Fig.-3 and the microstructures for all the samples are shown in Figs. 4-13.

Fig.3. Sample for microstructure testing

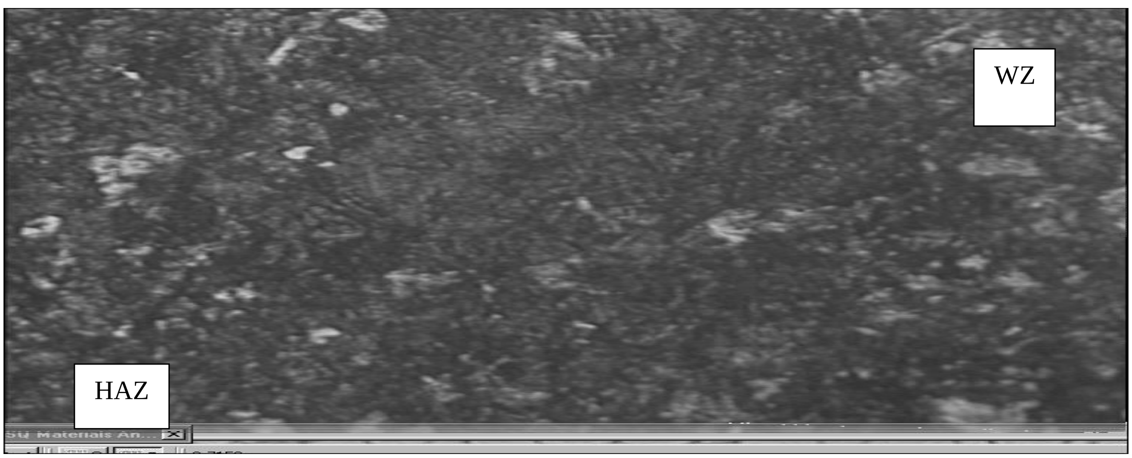

Fig.4.Microstructure of Weld zone & HAZ (4 mg/mm^2 ferro boron content, 90 A welding current & 45 mm/min welding speed)

Fig.4. shows fine pearlite, ferrite at weld bead zone and martensitic and sorbitic are found at HAZ zone.Dark region is pearlite. Light coloured region is ferrite.

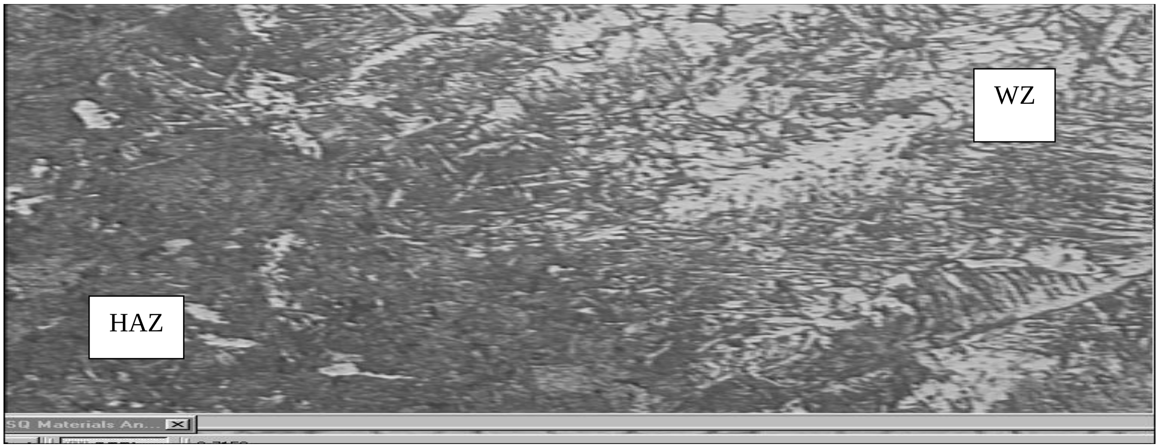

Fig.5. Microstructure of Weld zone & HAZ zone (4 mg/mm^2 ferro boron content, 120 A welding current and 90 mm/min average welding speed)

In Fig.5.weld bead zone shows columnar grains and HAZ shows martensitic, fine pearlite and ferrite.

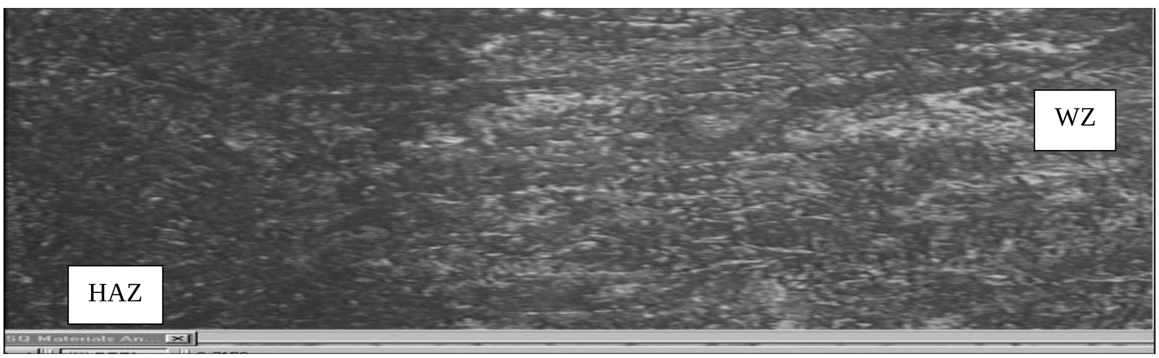

Fig. 6 Microstructure of weld zone & HAZ zone (4 mg/mm^2 ferro-boron content,150 A Welding current & 135 mm/min average welding speed)

In Fig. 6 weld bead zone shows columnar grains and HAZ zone shows martensitic.

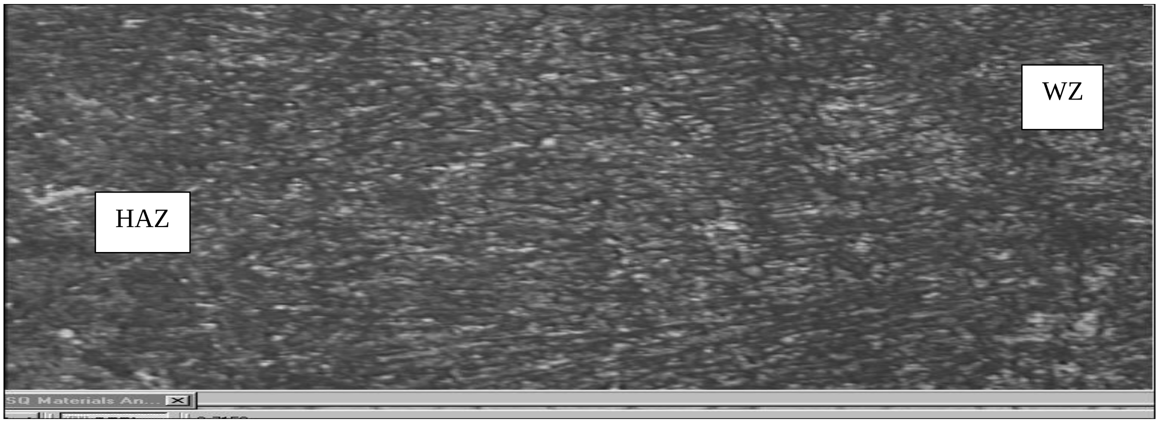

Fig.7 Microstructure of Weld zone& HAZ zone (8 mg/mm^2 boron content, 90 A welding current & 90 mm/min average welding speed)

Weld bead zone shows columnar grains and HAZ shows fine pearlite and ferrite structure as depicted in Fig.-7.

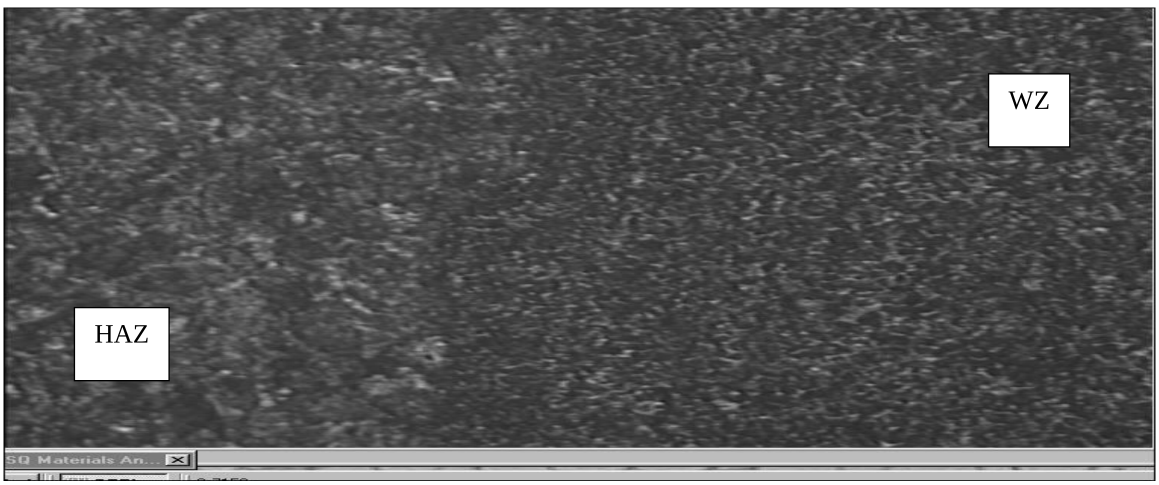

Fig.- 8 Microstructure of weld zone& HAZ zone (8 mg/mm^2 ferro boron content, 120 A welding current& 135mm/min average welding speed)

In Fig.-8 weld bead zone shows dendritic and at the HAZ shows fine pearlite and ferrite and sorbitic structure.

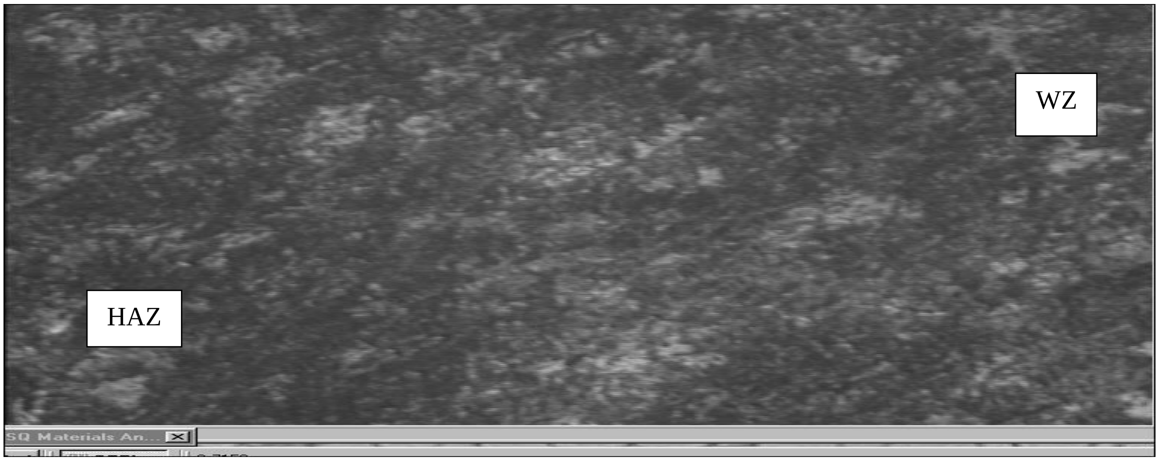

Fig .-9 Microstructure of weld zone& HAZ zone (8 mg/mm^2 ferro boron content, 150 A welding current & 45mm/min average welding speed)

In Fig.-9 weld bead zone shows pearlitic and ferritic structure and HAZ shows martensitic and sorbitic structure.

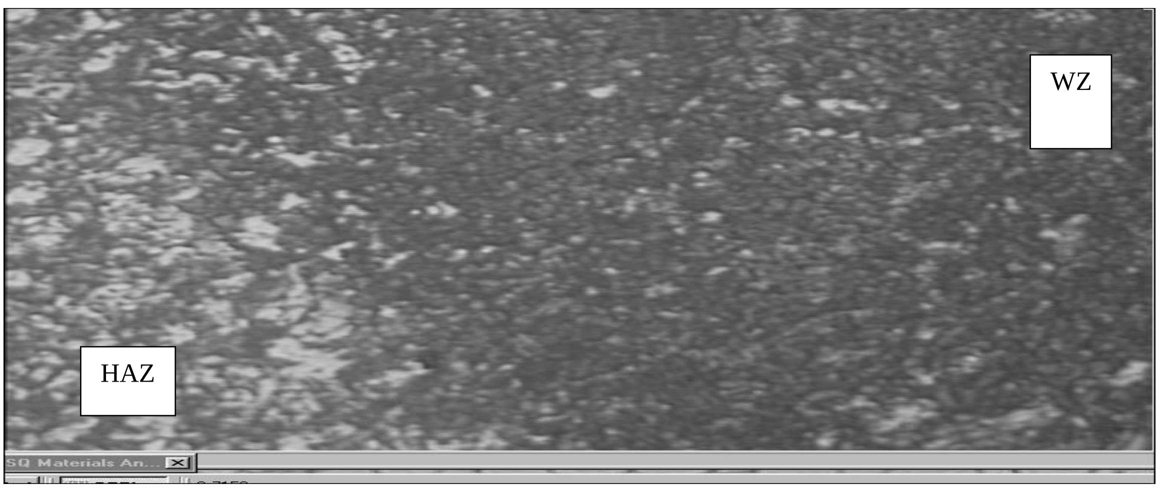

Fig.-10 Microstructure of weld zone& HAZ zone (12 mg/mm^2 ferro boron content, 90 A welding current & 135mm/ min average welding speed)

In Fig.-10 weld bead zone shows fine pearlite and ferrite structure and HAZ shows fine pearlite and ferrite.

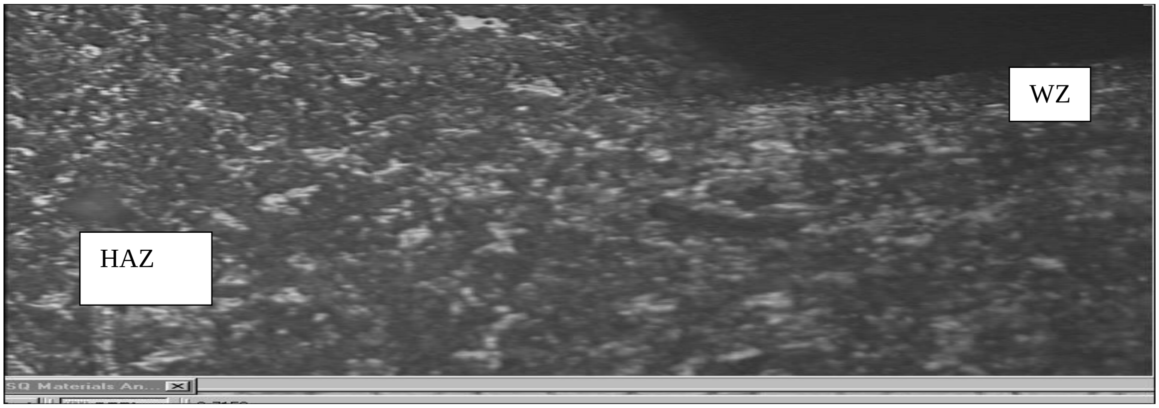

Fig.-11. Microstructure of weld zone& HAZ zone (12 mg/mm^2 ferro boron content, 120 A welding current & 45mm/min average welding speed)

In Fig.11 weld bead zone shows columnar grains and HAZ shows fine pearlite and ferrite.

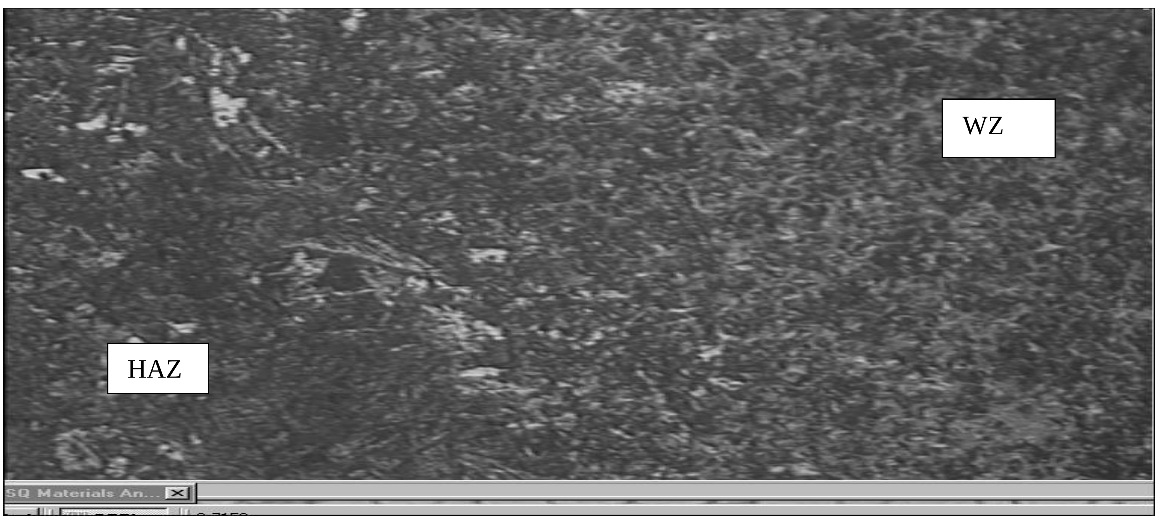

Fig.-12 Microstructure of Weld zone & HAZ (12 mg/mm^2 ferro-boron content, 150 A welding current & 90 mm/min average welding speed

In Fig.-12 weld bead zone shows inter dendritic structure and HAZ shows fine pearlite and ferrite.

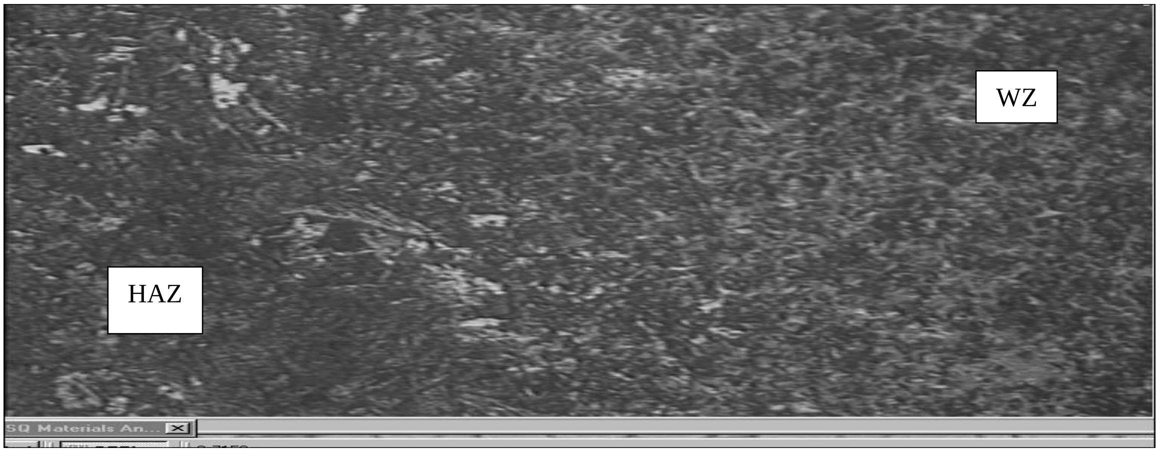

Fig.-13 Microstructure of Weld zone& HAZ (12 mg/mm^2 ferro boron content, 150 A welding current & 90mm/min average welding speed)

In Fig.-13 weld bead zone shows inter dendritic structure whereas HAZ shows fine pearlite and ferrite.

4. Conclusion

The analysis of result obtained from the study of the process parameters of hardfacing with ferro boron by paste technique using shielded metal arc welding the following conclusions may be drawn.

- Microstructure of weld metal and HAZ zone changes with change of amount of boron content. Increase in boron content increase in primary Fe_2B and small quantity of Fe_2B martensite eutectic.
- The formation of sorbitic pearlite may possibly be related to the higher cooling rate of shielded metal arc surfacing process. Relatively higher cooling rate causes the formation of fine pearlite called as sorbitic pearlite. The martensite observed in the coating is related to the both the carbon rich austenite and relatively higher cooling rate

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