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# Analysis of Weldox 700 Hsla Steel Using Gmaw Process With E110t5-K4 In Structural Applications

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**Abstract :** The hypothesis of this project is to analyze the effectiveness of welding weldox 700 HSLA steel with E110T5-K4 by caring out different mechanical tests on it. E110T5-K4 flux core wire is used for welding. After this various tests are performed on the weldment to test it and compared to the original HSLA steel. First hardness test was done to check if the hardness has changed drastically. Then its tensile strength is to be found so as to see if the weldment is ductile or not. Then the structure is to be checked to find the presence of hard microstructure. Impact toughness is tested by impact test to see if it is satisfactory. If all the tests given above give satisfactory values then it can be concluded that E110T5-K4 can be used to weld weldox 700 HSLA steel.
**Key words:** Weldox 700 HSLA steel, E110T5-K4,Weldment.

## 1. Introduction:

In today's world metals specially steelplays an important role in a nations economy.it is so important that one of the criteria used to check if the nation is developed or not is its annual steel consumption.in earlier days iron was used as it is but as man's knowledge increased about metals he started making better technologies to improve quality of metals. In modern metallurgy metals are mixed together to form alloys which have better mechanical and physical properties than the original metals. Every day new alloys are discovered and extensive studies are undertaken to test its effectiveness for further use [1].

### 1.1 The Need for the Project

One of the main difficulties faced in using metals is failure of structures. The cause of most structural failures generally falls into two categories:

1) Negligence during design,
2) Construction or operation of the structure.

The existing procedures are sufficient to avoid this type failure, but are not followed by one or more parties involved, due to human error, ignorance, or misconduct.

Application of a new design or material, which produce an unexpected result. This type of failure is much more difficult to prevent. When a new design is introduced, there are invariably factors that the designer does not anticipate.

### 1.2 Fracture:

Fracture is the separation or fragmentation of a solid into two or more parts under the action of stress. The process of fracture is considered to be made up of two components, crack initiation and crack propagation. Fracture on a broad scale can be classified into ductile and brittle fracture. A ductile fracture is characterized by appreciable plastic deformation prior to and during the propagation of the crack. An appreciable amount of gross deformation is usually present at the fracture surfaces. Brittle fracture is characterized by a rapid rate of crack propagation, with no gross deformation and very little micro deformation. The tendency for brittle fracture is increased with decreasing temperature, increasing strain rate and triaxial state of stress. Fractures are classified according to characters such as strain to fracture, crystallographic mode of fracture, and the appearance of fracture [2].

### 1.3 Corrosion:

Corrosion is the gradual destruction of material, usually metals, by chemical reaction with its environment. In the most common use of the word, this means electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Rusting, the formation of iron oxides, is a well-known example of electrochemical corrosion. Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases. One of the reasons alloys are made is to prevent corrosion as alloying affects the properties of the metalsand help to prevent corrosion [3].

### 1.4 High Strenght Low Alloy Steels (Hsla)

They are a group of low alloys steels that are designed to provide better mechanical properties and greater resistance to atmospheric corrosion than conventional carbon steels. They are not considered to be alloy steels generally has they are designed to meet specific mechanical properties rather than a chemical composition. Carbon content of HSLA steels rarely exceeds 0.28% and is usually between 0.15 and 0.22%. Manganese content ranges from 0.85 to 1.60% depending on grade and other alloying elements. Chromium, Columbium, Copper, Molybdenum, Nickel, Nitrogen, Phosphorous, Titanium, Vanadium, Zirconium and silicon are used in various combinations but with combined amount less than 1%. Strength of HSLA steels is between those of carbon steels and the high strength Quenched and tempered steels [9].

HSLA steels are classified into

1) Weathering steels: These contain small amounts of alloying elements like Cu, Ph for improved atmospheric corrosion resistance and solid olution strengthening.
2) Microalloyed ferrite-pearlite steels: These steels contain very small additions of strong carbides or carbonitrides forming elements like Nb, V, Ti for grain refinement, precipitation hardening.
3) As rolled pearlite steels: These steels include C-Mn and also have other alloying elements to increase the weldability, strength.
4) Acicular ferrite (low carbon bainite) steels: These steels are low carbon steels with good weldability and forming.
5) Dual-phase steels: These steels have a microstructure of martensite dispersed in matrix of ferrite and give good ductility and strength.

WELDOX700 is a brand name of HSLA steel supplied by SSAB Oxelösund steels, Sweden. WELDOX 700 is a general structural steel with minimum yield strength of 700 MPa indented for applications where its high strengthpermits weight savings to be made. The steel has good bending properties and very good weldability. WELDOX 700 has good impact toughness at temperature down to – 60 $^{o}$C.

### 1.5 Chemical Composition

The chemical composition of WELDOX 700 steel are given in Table 1

**Table 1: Chemical composition of WELDOX 700**

| **Alloying Element** | **C** | **Si** | **Mn** | **P** | **S** | **B** | **Nb** | **Cr** | **V** | **Cu** | **Ti** | **Mo** | **Ni** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Percentage | 0.2 | 0.6 | 1.6 | 0.02 | 0.01 | 0.005 | 0.04 | 0.7 | 0.09 | 0.3 | 0.04 | 0.7 | 2 |

### 1.6 Mechanical Properties

The mechanical properties of WELDOX 700 steel are given in Table 2

**Table 2: Mechanical properties of WELDOX 700**

| Yield trength MPa | Tensile strength MPa | % Elongation | Charpy impact energy at -20°C |
|---|---|---|---|
| 700 | 780-930 | 14 | 27 |

### 1.7 Applications

Dump trucks, mobile cranes, industrial trucks, loaders, lorries, excavators, bull dozers, buckets, cranes, railway wagons, penstocks, fans, pumps, lifting equipments, dolphins, pipes, bridges, steel structures, offshore structures etc.

### 1.8 Welding Process Employed

Though WELDOX 700 can be welded using all conventional arc-welding processes, GMAW process is employed in this thesis work.

#### 1.8.1 Gas Metal Arc Welding

Gas metal arc welding (GMAW) is an arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an external supplied gas and without the application of pressure. The process is also called metal inert gas (MIG) welding process if argon or helium is used as shielding gas. If reactive gas like carbon dioxide is used has shielding gas the process used is called metal active gas (MAG) process.

The GMAW process incorporates the automatic feeding of a continuous electrode that is shielded by an external supplied gas. After initial settings by the operator, the equipment provides for automatic self-regulation of the electrical characteristics of the arc. Thus, the only manual controls required by the welder for semiautomatic operation are the travel speed and direction, and gun positioning [8].

#### 1.8.2 Uses and Advantages

- Only consumable electrode process that can be used to weld all commercial metals and electrodes.
- Welding can be done in all positions.
- Deposition rates are higher.
- Welding speeds high.
- Minimal postweld cleaning is required.

#### 1.8.3 Limitations

- The welding equipment is more complex, more costly and less portable.
- GMAW is more difficult to use in hard-to-reach places.
- The welding must be protected against drafts, so that the shielding gas flow I is lamellar.

## 2. Experimental

### Selection of system

Base material: WELDOX 700 a high strength low alloy steel.

### 2.1 Filler material:

For welding WELDOX 700 E110T5-K4 flux cored wire was used.

### 2.2 Welding process:

GMAW process using Argo shield heavy (80%Ar-18%$CO_2$-2%$O_2$) shielding gas was used.

### 2.3 Methodology

#### 2.3.1 Radiographic Inspection

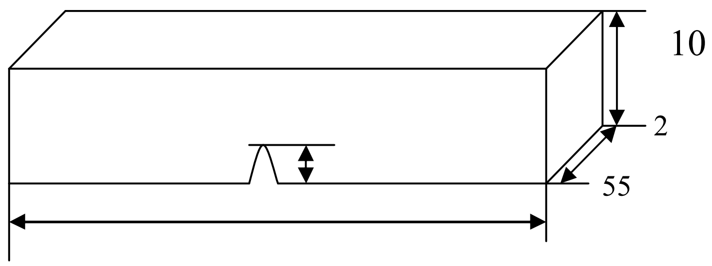
After completion of welding the plates were examined for defects employing radiographic inspection. The welded plates were inspected using gamma rays.

#### 2.3.2 Hardness Suevey

After the completion of radiographic inspection, a sample was cut for hardness survey. The hardness test across the weld was carried out using ZWICK Vickers micro hardness tester under a load of 0.5 kg and a loading time of 30s.

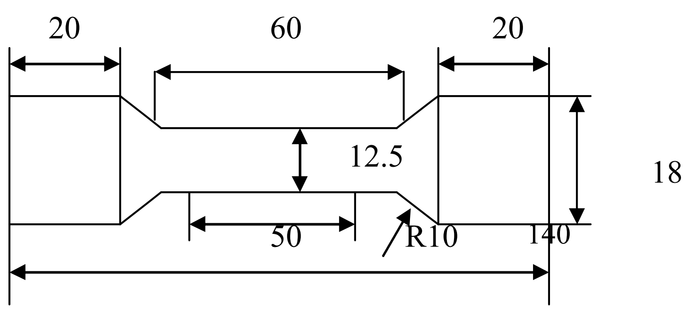
#### 2.3.3 Impact Test

To determine the impact toughness of the weld metal, heat affected zone (HAZ) and the base material, Charpy impact test was carried out. The V notch was placed on the weld metal, HAZ and the base metal. The specimen dimension was 10x10x55 mm. The impact tests were carried out at – 12$^{o}$C. Three samples each were used for the three different regions. The samples were soaked in dry ice for half an hour and then taken out and tested within a time period of 5 seconds.




#### 2.3.4 Tensile Test

To analyze the fracture surface and determine the notch strength ratio both notched and unnotched tensile tests were carried out. Cylindrical specimens were used in both the conditions. The unnotched tensile test was carried out according to ASTM A370. The notched tensile test was carried out in accordance with ASTM E602. The specimens had a gauge length of 50 mm. The tests were carried out using a 1000 KN capacity universal testing machine [7].



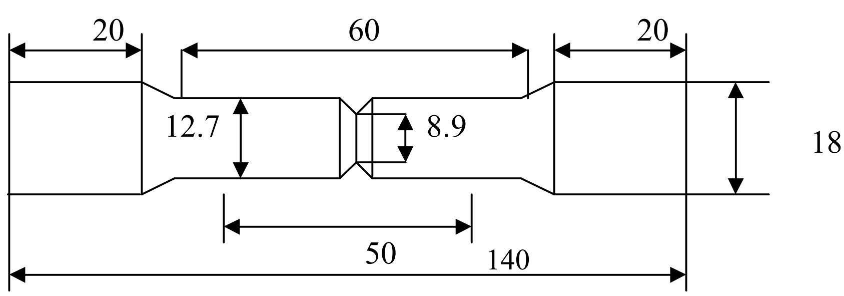




**Figure 3.3 Notched tensile specimen**

### 2.3.5 Microstructural Examination

In order to study the microstructural variation resulting across the weld due to the heat of welding, a sample was polished using conventional metallographic techniques. The sample was etched using 2% Nital and observed under a Carl Zeiss microscope and analysed with a metal power image analyzer [6].

## 3. Results and Discussions

### 3.1 Radiograpgic Inspection

To inspect the welds for defects the welds were subjected to radiographic inspection using gamma rays. Both the welds passed the radiographic inspection ensuring that they were free from all kinds of flaws.

### 3.2 Microstructural Analysis

The base metal microstructure is shown in Figure 4.1. The upper banitic structure growing from prior austenite grain boundaries is revealed. The banitic structure is observed due to quenching and tempering treatment [5]. Also traces of ferrite and carbides are seen. The interface between the weld metal and base metal revealing the columnar grains of the weld metal is shown in Figure 4.1(b). Faster cooling has resulted in higher pearlite content both in the weld metal and in the coarse grain region of the HAZ. Higher magnification image of the fine pearlite present in the weld metal is shown in Figure 4.1(c). The HAZ region between two weld beads is shown in Figure 4.1(d). The HAZ region has pearlitic and ferritic structure. The amount of ferrite is higher in HAZ than in the weld metal due to reheating and slow cooling. The normalized region of the HAZ revealing globular pearlite and ferrite is shown in Figure 4.1(e).

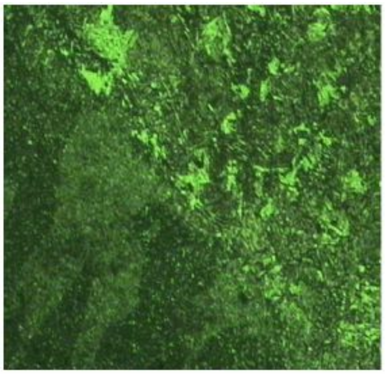


**Figure 4.1(a) Base metal structure at 250 X**

**Figure 4.1(b) Interface between the weld metal and base metal at 250X**

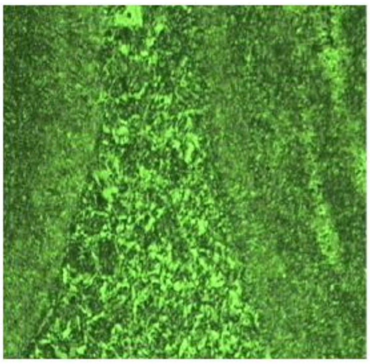


**Figure 4.1 (c) Higher magnified image of the weld metal 600X**

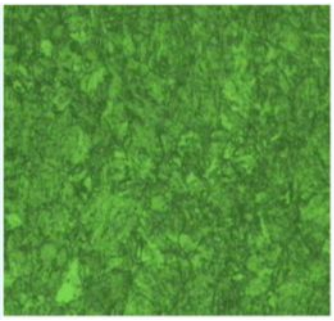


**Figure 4.1 (d) Heat affected zone (HAZ) between two beads**

**Figure 4.1(e) Normalized region of HAZ at 600X**

### 3.3 Hardess Survey

The hardness survey shows the highest hardness in the coarse HAZ near the weld metal, a value of 276 HV. The base metal and the weld metal have matching hardness of 258 HV .The annealed region of the HAZ recorded the lowest hardness value of about 204 HV. The normalized region of the HAZ had a hardness value in the range of 241-249 HV. The general comment is that the hardness across the weldment is not very high and is less than the recommended maximum value of 350 HV for avoiding hydrogen cracking.

**Table 3: Tensile Test for Un notched samples**

| Yield strength MPa | Tensile strength MPa | Percentage elongation | Type of fracture | Fracture surface appearance |
|---|---|---|---|---|
| 700.8 | 782 | 13 | Cup and cone | Predominantly fibrous |

**Table 4: Impact Test**

| SL no | Notch location | Impact energy Joules | Average Joules |
|---|---|---|---|
| 1 | Base metal | 63 | 68 |
| 2 | | 69 | |
| 3 | | 73 | |
| 4 | Weld metal | 167 | 173 |
| 5 | | 181 | |
| 6 | | 171 | |
| 7 | HAZ | 233 | 221 |
| 8 | | 196 | |
| 9 | | 233 | |

## 4. Conclusions

Based on the experiments carried out the following conclusions can be made:

The welding of WELDOX 700 with E110T5-K4 results in a matching weld metal. The hardness across the weldment does not vary drastically to cause high hardness in the HAZ. The use of preheat temperature of 200$^{o}$C is sufficient. The weld metal shows fibrous fracture surface and undergoes cup and cone type of fracture, indicating the higher ductility.

The tension test show enough ductility in the weld metal and base metal. The notch strengthening ratio calculated was around 1.5, indicating reduced notch sensitivity of the weld metal. The microstructures observed across the weldment do not reveal the presence of any hard microstructure. The impact toughness of the various regions of the weldment is well above the required value of 27 J.

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