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THE EFFECTS OF PREHEAT AND FILLER BUFFER LAYER ON THE MATERIALS OF ASTM A36 IN THE HARDFACING OVERLAY WELDING TO THEIR HARDNESS AND METALLOGRAPHY

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Abstract. ASTM A36 steel overlay products have been used by the industry as liners to protect the main material from abrasion attacks that will occur. From the background above, the formulation of the problem can be written "How were the effects of variations in preheat and filler metal buffer layers in the hardfacing overlay welding of ASTM A36 materials to the hardness values and metallography?" The purpose of this study was to find the results of each test. The experimental re-search design was used by giving the preheat variations of 1000 and 2000 and filler buffer layers E308LT and E316LT. The hardfacing overlay welding process was carried out by using special electrodes with high hardness. The results of the hardness test showed the highest value, namely 698.7 HVN on the specimen with the E316LT buffer layer. The macro test results showed the fusion in welding results. On the other hand, the results of micro testing in the hardfacing layer area were dominated by primary carbide and austenite. The conclusion of this study was that the higher the preheat temperature process, the lower the hardness value. The selection of buffer layer electrodes with a small Ni composition increased the hardness value. This study is expected to contribute to the industry working on hardfacing overlay impressions as the reference.

Keywords: Hardfacing Overlay Welding, Preheat Temperature Variations, ASTM A36 Hardness and Metallography.

1. Introduction

ASTM A36 steel is one of the metals that has been widely used in various applications such as bridges, buildings, marine applications, and other structures. However, when the material is applied in the field, problems often arise that reduce the service life of the material and increase maintenance costs. ASTM A36 steel is included in low carbon steel with a carbon content of <3% and its main components consist of iron (Fe) and carbon (C) and other elements such as Mn, Si, Ni, Cr and so on in small percentages. Low carbon steel has good mechanical properties, relatively high tensile strength, which is between 415 - 550 MPa (60,000 - 80,000 psi), good toughness and is relatively ductile (Pangaribowo et al., 2018).

Company PT X is a fabrication and construction company. One of the fabrications carried out during On the Job Training is producing liners. This component undergoes a surface hardening process using the hardfacing overlay welding method. The hardfacing hardening process aims to increase the thickness of the material and provide better wear resistance. In addition, a problem that often occurs is the emergence of fairly large cracks caused by the presence of two phases that are equally hard.

Cracks that often occur in the hardfacing section are hot cracking types. Preheat itself is a method that can be done to prevent cracking and distortion by providing heat treatment before welding. To carry out the hardfacing welding process and prevent the possibility of hardfacing layer cracks spreading to the base metal, the use of a buffer layer is recommended to avoid cracks. (ESAB, 2017). Therefore, this final assignment will discuss the extent of the influence of the buffer layer and the influence of preheat on overlay hardfacing welding. Based on the background above, it could be formulated the research question; How were the effects of variations in preheat and filler metal buffer layers in the hardfacing overlay welding of ASTM A36 materials to the hardness values and metallography? The objectives were to know the effects on the given treatments.

2. Review and Related Literature

This chapter discussed the review and related literature on the theoretical study on hardness and the metallography. Additionally, this part referred to the references which supported to this research. Previous researches were used to know the gaps of research so that the originalities could be gained. Hardnes Test

The Vickers test was developed in England in 1925. Also known as the Diamond Pyramid Hardness test (DPH). The Vickers hardness test uses a diamond pyramid indenter with a large angle between the facing diamond pyramid surfaces of 136 degrees. There are two different strength ranges, namely micro (10g - 1000g) and macro (1kg - 100kg). The standard usually used is ASTM E384 micro range (10g - 1000g), for the macro range (1kg - 100kg) the standard used is ASTM E92 and ISO 6507 (macro and micro ranges). Vickers method test calculation formula:

$$HVN = \frac{2P\sin\left(\frac{\theta}{2}\right)}{d^2} \qquad (1)$$

Information:

HVN = Vickers Hardness Number
P = Given load (kgf)
D = Average diagonal length of the result
Θ = Angle between facing diamond surfaces 136°

2.1. Metallography Test

It is a combination of science and art that studies the microscopic structure of metals and alloys using optical microscopes, electron microscopes or other types of microscopes. The ability and mechanical properties of a material can be determined from the microstructure of the metal, by analyzing the microstructure of the material, the performance of the material when used can be understood in more detail. Metallography is widely used in the fields of material development, inspection, production, manufacturing and for analysis of construction failures. In the metallographic testing process, the metal will be tested again into two types of tests, namely:

1. Macro testing is defined as visual testing of defects with the naked eye or with low magnification, usually less than x 50 with or without etching.
2. micro is defined as testing using a microscope with a magnification of x 50 to x 500 with or without etching.

the following table could differentiate between the characteristics macro and micro test.

Table 1. Metallography Test

Macro Test	*Micro Test*

Visual Test for Defects	Visual Test for defects and grain structure
Visual Test under magnification five times multiplied.	Visual Test under magnification 100 to 1000 times multiplied.
Polishing with abrasive paper up to grit 400	Polishing with abrasive paper up to grit 1200 + 1µm alumina powder
Etching by using 5-10% nitric acid solution	Etching by using 1-5% nitric acid solution

On the other hand, the difference between both items above could be seen in the following pictures. Left Picture is the macro test results and the right one is the micro test results.

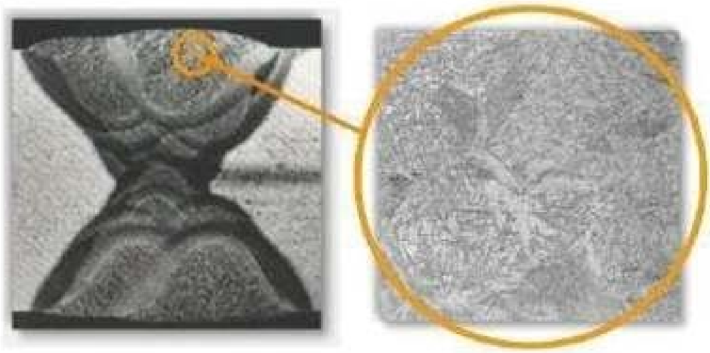


Fig. 1. Metallography

Both evaluations are really needed in the welding process to know the next procedure in order to get the better results of welding.

3. Research Methodology

This study was experimental research. the tests were carried out include hardness testing, and metallography. The test was intended to determine the effect of the buffer layer as a binder between the base metal and the hard surface. Hardness testing was carried out by applying a load to the surface of the specimen using an indenter so that a trace was produced. Based on the hardness test, the hardness value of the material that had been welded was obtained. The hardness test used the Vickers method, using a diamond pyramid with a load of 30 kg.

The materials used to support this test are hardness test specimens, tissue, and rubbing paper. The steps in hardness testing using the Vickers method were:

1. The surface of the test material is smoothed to be observed using a Polishing Machine with a 320 grid.
2. If the test material is not smooth, it can be smoothed again using a 320 or 400 grid with a direction 900 different from the original direction.
3. When finished, the material is dried using tissue.
4. Set the load to be used, in this test a load of 30 kg was used.
5. Set the dwell time to 15 seconds.

6. Place the specimen in a vise and adjust the focus for the area to be tested.
7. Press the start button.
8. Measure diagonal 1 and diagonal 2 on the indentation results.
9. Repeat procedures 4 to 8 for each predetermined point.

On the other hand, Metallographic testing was carried out to determine the macrostructure and microstructure that occurs after the overlay hardfacing process with variations in preheat and buffer layers. For macro and micro testing, 1 test specimen was used from each existing variable.

Microstructure testing aimed to determine the microstructure of the base metal, weld metal, and HAZ. Micro testing was carried out based on standards (ISO 17639, 2003). Before testing using a tool, the surface of the weld metal had to be etched first. Based on the standard (ISO-TR 16060, 2003) carbon steel and low alloy carbon steel would be etched using a nital solution with a composition of 95ml ethyl alcohol (C2H5OH) with 5 ml nitric acid (HNO3). The steps for micro testing are as follows:

1. The cutting process is carried out on the specimen to be tested.
2. The mounting process is carried out if the material to be tested has a small size
3. Grinding Process
   a. Take the coarsest grit sandpaper (grit 320) then shape it according to the shape of the hand grinding disc and install it on the hand polishing and install it on the hand polishing machine.
   b. Turn on the polishing machine, then open the valve so that water flows on the sandpaper and until the surface is smooth.
   c. Lift the specimen and observe the surface of the specimen. If the scratches are not in the same direction, rub again until the scratches are in the same direction.
   d. If the scratches are in the same direction, turn off the polishing machine and water flow, then change the sandpaper to a finer grit (320, 400, 600, 1200, and
   e. 5000)
   f. When the grinding process is complete, turn off the polishing machine and water flow, then wash the specimen with water.
4. Polishing by the following steps;
   a. Wool cloth paper is installed on the polishing machine.
   b. Polishing machine The polishing machine is turned on, then open the water valve slightly so that the water flow is not too hard
   c. The specimen is taken, placed face down on the polisher with a little pressure and held until the object is smooth.
   d. Specimen The specimen is then lifted and seen if there are still scratches from the previous grinding process.
   e. If the specimen is smooth, the surface will be like glass
   f. The specimen is washed until clean and then dried with a hair dryer or rubbed using soft tissue
5. Etching
   a. Preparing the tools to be used such as pipettes, beakers, and hair dryers
   b. Taking 5ml of HN03 solution then pour it into the beaker.
   c. Mixing the HN03 solution with 95ml of Ethyl alcohol then stir.
   d. Putting the specimen in the HN03 + alcohol liquid for a few seconds then rinse with water.
   e. Dry the specimen with a hair dryer.

In this test, each specimen was taken at 3 points for micro testing, as in the following Figure:

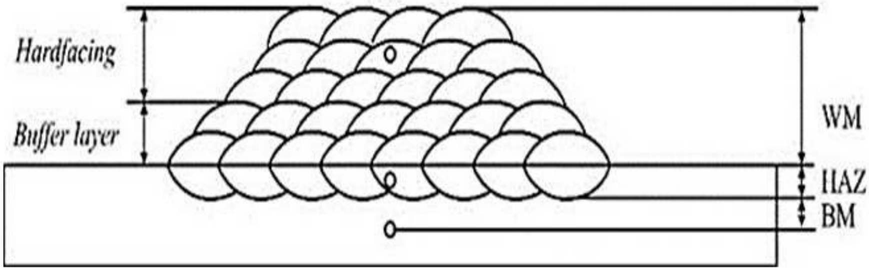


Fig. 2. micro testing

3.1. Result of Research

This part discussed on the results of hardness test and metallography based on the data collection technique explained in the research methodology.

Hardnes Test Results

Hardness testing was carried out to determine the hardness value of each part in each process variation, using the Vickers hardness testing method. Testing was carried out on cross-sections of the specimen carried out on the base metal, buffer layer, and hardfacing layer with an indentation distance of 1mm. The load used was 10kgf with a dwell time of 10 seconds. Hardness testing was carried out at 3 points in each area. The following were the results of hardness testing on each specimen shown in the following Table and Figure:

Table 2. Hardness testing

Speciment	**Indentasi**	***Base Metal***	***Buffer Layer 1***	***Buffer Layer 2***	***Hardfacing Layer 1***	***Hardfacing Layer 2***
V1 (*Preheat* 200 +*Buffer-Layer* 316LT)	1	148,5	251,4	258,9	458,6	558,0
	2	151,6	256,4	265,3	476,9	572,5
	3	154,7	248,7	267,8	496,7	581,0
Rata-rata		151,6	252,2	264,0	477,4	570,5
V2 V2 (*Preheat* 200 +*Buffer-Layer* 308LT)	1	147,8	244,6	258,6	466,7	552,2
	2	149,6	252,3	255,3	462,3	563,4
	3	152,9	257,6	267,5	484,5	543,0
Rata-rata		150,1	251,5	260,5	464,5	552,9
V3 (*Preheat* 100 +*Buffer-Layer* 308LT)	1	141,9	232,4	223,6	424,6	523,0
	2	144,5	244,6	234,5	433,1	531,2
	3	148,7	267,8	241,0	458,0	533,0
Rata-rata		145,0	248,3	233,0	438,6	535,7

V4 (*Preheat* 100 ... +*Buffer-Layer* 316LT)	1	138,2	247,6	251,3	426,7	541,0
	2	152,6	234,5	229,1	446,0	552,7
	3	148,5	243,6	228,3	458,2	532,3
Rata-rata		145,0	241,9	236,2	443,6	542,0
V5 (*None Preheat+BufferLayer* 316LT)	1	135,2	284,5	270,0	458,3	572,0
	2	143,0	296,7	257,3	489,2	584,4
	3	138,7	289,0	283,4	492,4	580,2
Rata- rata		139,0	291,1	270,2	480,0	578,9
V6 (*None Preheat+BufferLayer* 308LT)	1	137,7	276,5	266,4	464,2	578,0
	2	135,0	287,6	265,9	479,0	567,3
	3	142,3	262,5	275,2	493,5	553,3
Average		138,3	275,5	269,2	478,9	566,2

The results above was supported by the following chart showing the hardness values in the area base metal, buffer layer 1 and 2, even hardfacing 1 and 2. The chart was as follows;

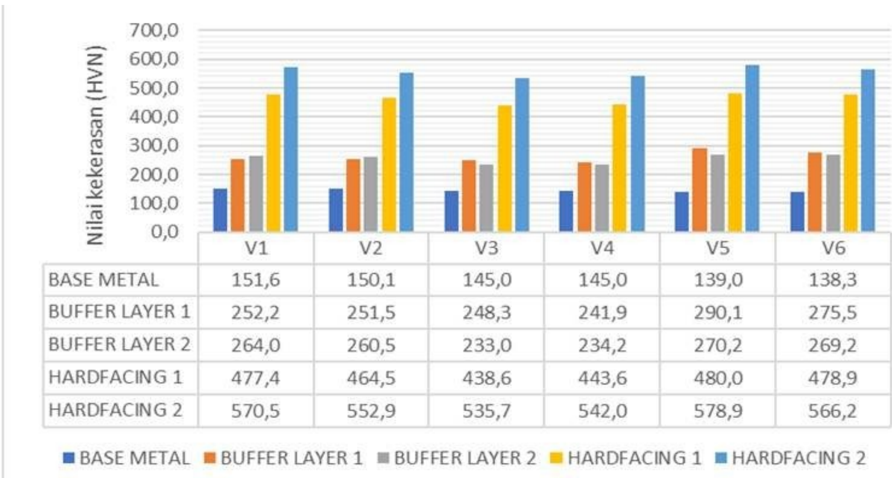
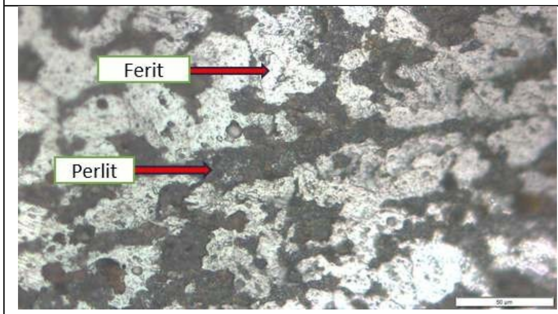
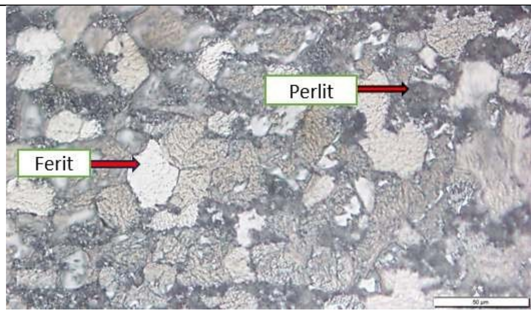
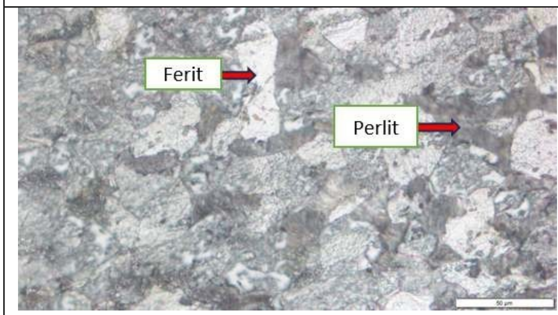
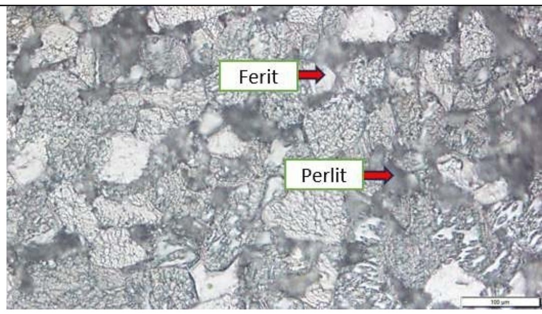
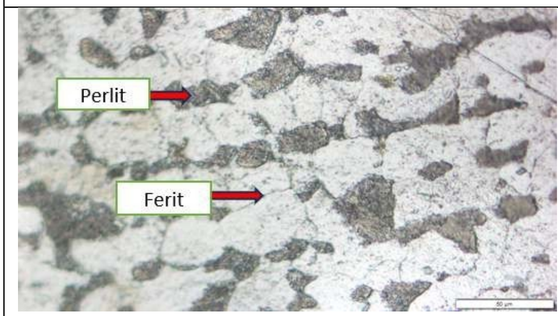
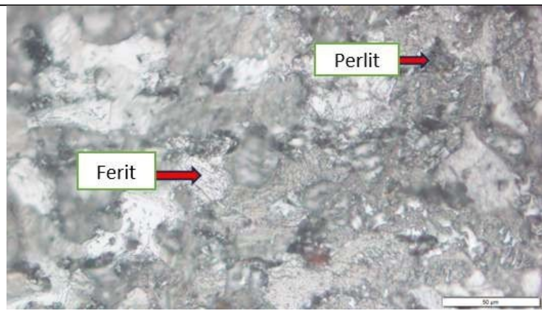


Fig. 3. Nilai kekerasan (HVN)

Micro observations were conducted to determine what phases and structures are contained in the hardfacing material. Microstructure observations were conducted on the base metal, buffer layer, and hardfacing layers, for each variation with a magnification of 500X. The observed microstructure provides information on the mechanical properties and transformation processes that occur during welding until the weld metal liquid solidifies. The image can be seen as follows:

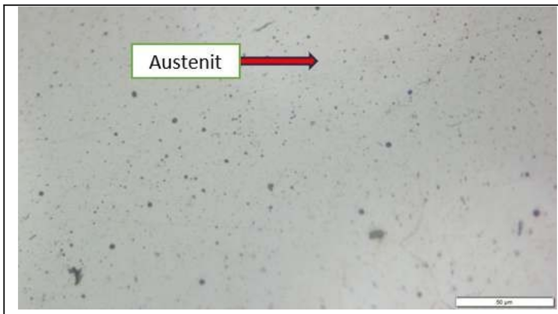
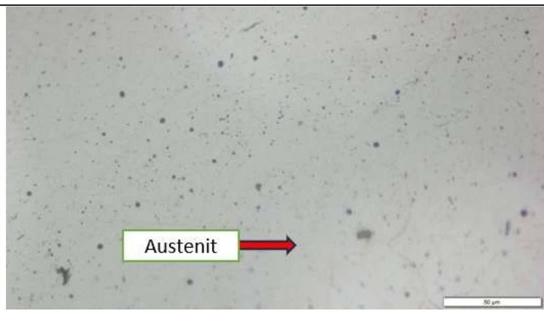
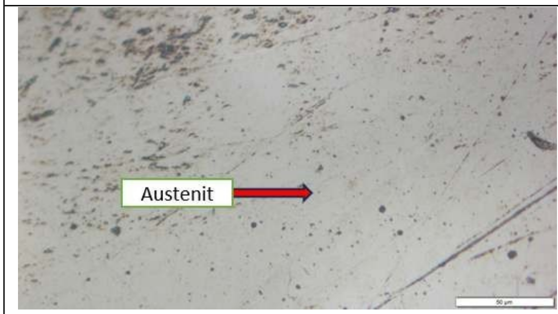
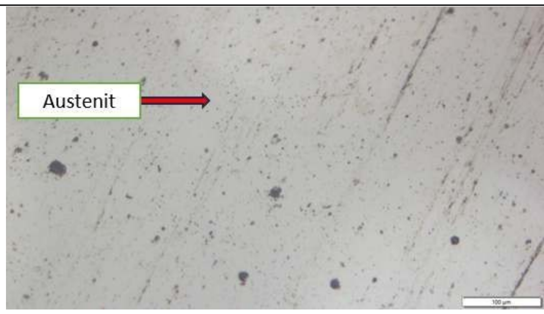
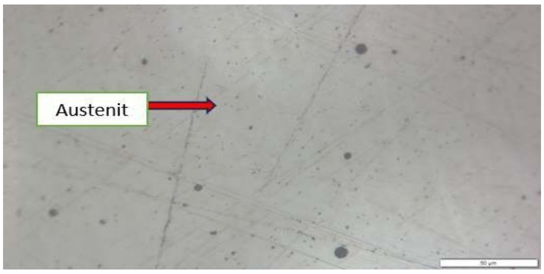
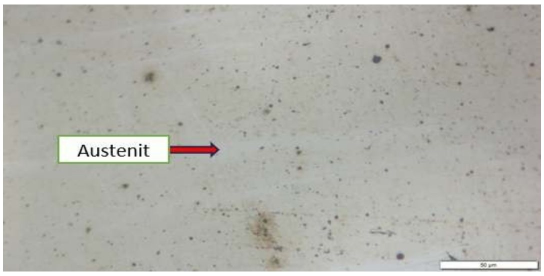
1. Base Metal

Base Metal V1	*Base Metal* V2
	
Base Metal V3	*Base Metal* V4
	
Base Metal V5	*Base Metal* V6
	

The image above shows the microstructure with a microscope magnification of 500x. In the specimen above, the microstructure of the A36 base metal consists of pearlite and ferrite. The pearlite phase is dark and light in color and the ferrite phase is light in color. Ferrite was a solid solution phase that has a BCC (body centered cubic) structure. Ferrite in a balanced state can be found at room temperature, namely alpha-ferrite or at high temperatures, namely delta-ferrite. In general, this phase is soft, ductile, and magnetic up to a certain temperature. The solubility of carbon in this phase is relatively small compared to the solubility of carbon in the austenite phase. At room temperature, the solubility of carbon in alpha-ferrite is only around 0.05%. While pearlite is a lamellar mixture of ferrite and cementite. This is formed from the decomposition of eutectoid. Pearlite has a harder structure than ferrite. The main cause is the presence of cementite or carbide phases in the form of lamellae. (Putri et al., 2023)

2. Buffer Layer

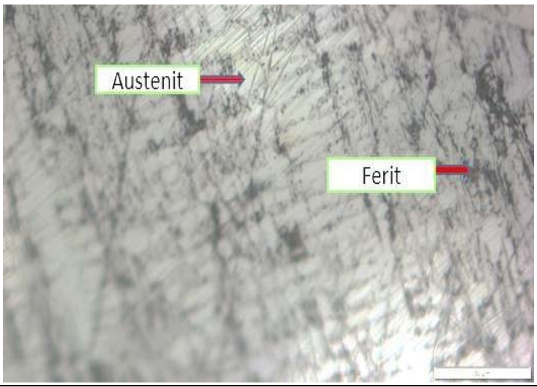
Buffer Layer V1	*Buffer Layer* V2

	
Buffer Layer V3	*Buffer Layer* V4
	
Buffer Layer V5	*Buffer Layer* V6
	

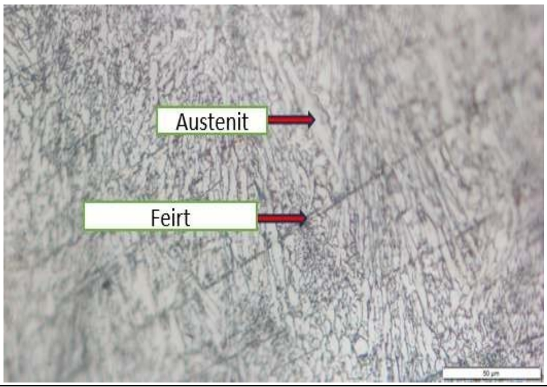
The image above shows the microstructure of the buffer layer which is dominated by austenite. This is due to the use of austenitic stainless steel electrodes, namely E308LT and E316LT electrodes. In this buffer layer, the microstructure is seen to be dominated by the austenite phase, which is a result of the chemical composition of the electrode containing alloying elements such as chromium and nickel. The austenite phase has an FCC (facecentered cubic) crystal structure and provides properties such as good corrosion resistance and high tensile strength to the stainless steel (Sims, 2003; ASTM, 2020).

3. Hardfacing Layer

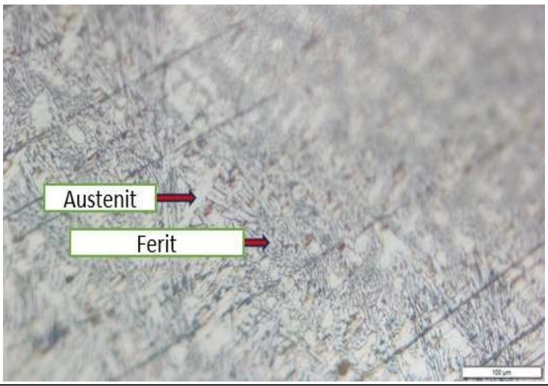
Hardfacing V1	*Hardfacing* V2



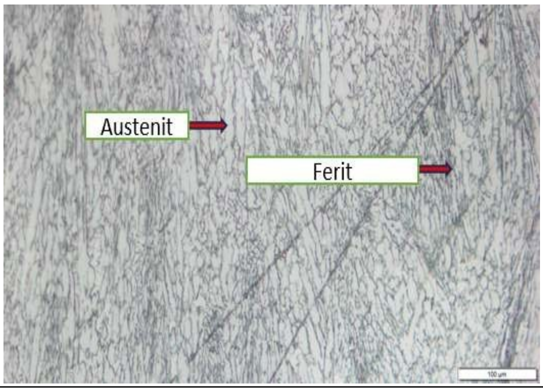
Hardfacing V3



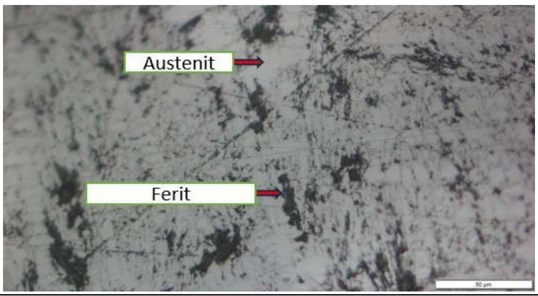
Hardfacing V4

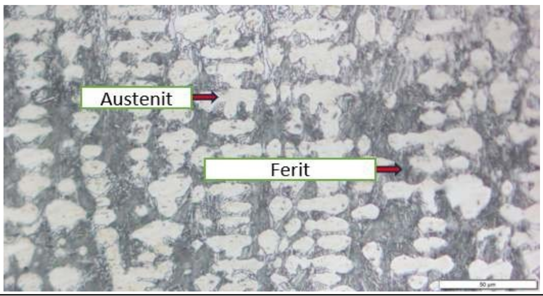


Hardfacing V5



Hardfacing V6





The image above shows the microstructure in the hardfacing layer area. From the microstructure test, it shows that the phases formed are ferrite and austenite phases. The ferrite phase tends to be dark in color and austenite tends to be white or light in color. The ferrite phase is more dominant than the austenite phase, so the higher the hardness value achieved in the weld metal results. shows that the ferrite phase is more dominant than the austenite phase. The dominance of the ferrite phase has important implications for the mechanical properties of the weld metal, especially in terms of hardness. The higher the proportion of the ferrite phase, the higher the hardness value achieved in the weld metal results. This is due to the nature of the ferrite phase which provides resistance to plastic deformation and increases the strength of the material. Thus, the optimal microstructure, with the dominance of the ferrite phase, not only increases the hardness but also affects the wear resistance and durability of the resulting components.

4. Conclusion

From the results of the hardness test, the most optimum hardness value is the V6 variation given none preheat using the E308LT buffer layer. The use of a buffer layer can reduce the hardness quite significantly. The microstructure resulting from the ASTM A36 hardfacing overlay material process is quite complex. In the base metal section, the resulting microstructure is not much different, dominated by ferrite and pearlite structures. In the buffer layer area, the resulting microstructure is an austenite structure. In the hardfacing layer area, the resulting microstructure is a ferrite and austenite phase form.

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