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Analysis of Shield Metal Arc Welding Effect on Conductor Casing Pipe in Onshore Drilling Rig

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Abstract:
Background:*One of the activities carried out in onshore drilling Rigs is the welding of Shield Metal Arc Welding (SMAW) Conductor Casing Pipe to Temporary Wellhead. Two issues affect the Conductor Casing Pipe. First, is the Temporary Wellhead, which is weld joined to Conductor Casing Pipe, is repeatedly welded before. It is used in one well for initial traject and repeatedly is used in other wells. Second is the Carbon Equivalent (Ceq) of the Conductor Casing Pipe is high, 0.74. There are no studies about the repeated welding effects of Temporary Wellhead to the Conductor Casing Pipe. For this reason, a study was conducted to analyze the effect of dissimilar welding about Conductor Casing Pipe to Temporary Wellhead particularly on Heat Affected Zone (HAZ) of Conductor Casing Pipe based on a review of changes in HAZ width, microstructure, Carbon Equivalent (Ceq) and hardness.*
Materials and Methods: *The Conductor Casing Pipe material is API 5CT Gr.K55, and the Temporary Wellhead material is AISI 4130. Five specimens were prepared as the result of dissimilar welding between the Temporary Wellhead that underwent one to five repeated welding to the Conductor Casing Pipe that was always a new one at every welding join for each specimen. It was preheated 250 °C before each welding. The review was done to HAZ of Conductor Casing Pipe by the test of metallography macro-micro, chemical composition, and hardness.*
Results: *An increasing number of welding of Temporary Wellhead could cause any change on HAZ of Conductor Casing Pipe. The width of HAZ has become wider. The microstructure has changed from small elongated Ferrite to equiaxed Ferrite in few amounts, dark coarse Pearlite to fine Pearlite then the rise of grain boundary Ferrite and Martensite. Increasing Ceq and hardness.*
Conclusion:*Temporary Wellhead material that has undergone repeated welding affects the HAZ area of the Conductor Casing Pipe in terms of width, microstructure phases, andhardness.*
Key Word:*Welding; SMAW; Conductor Casing Pipe; Temporary Wellhead; drilling.*

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I. Introduction

The installation of the Temporary Wellhead to the Conductor Casing Pipe is carried out using SMAW welding. Welding provides heat input to the material being welded, causing changes in the mechanical properties and microstructure of the material. Temporary Wellheads in the field experience repeated welding for the umpteenth time, while the Conductor Casing Pipe is used always new for every different Well.

Regarding repeated welding on a Temporary Wellhead, DNV-OS-F101 Appendix C, sub-section G 300 said that repeated welding should be applied at the same area no more than twice[1]. But there are no limits to repeated welding in API API-1104 standard[2]. Hussin et al studied repeated welding on ASTM A36 low carbon steel, which stated that the weld more than one repair was no quality improvement and the most affected area is HAZ [3]. On the other hand, the Conductor Casing Pipe material has a high Ceq value. Odebiyi et al, state that Ceq more than 0.70 can not be welded[4]. Carbon has a strong effect on the weldability of steel, reducing ductility and toughness[5]. Uzun et al studied that hardness around weld beam increases which is related to carbon content, but ductility decreases with an increasing hardness which can form a brittle zone around the weld beam[6].Palanisamy studied API 5CT Gr.L80 stated that small fraction Martensitecame out when that specimen heated to 1300 °C and cooling down rate at 3 °C/s [7].

The gap with previous research is that there has been no research on dissimilar welding on materials that have undergone repeated welding, in this case, Temporary Wellheads, with materials that have not undergone welding, in this case, the Conductor Casing Pipe. For this reason, this study was conducted to analyze changes in mechanical properties and microstructure from the side of the HAZ of the Conductor Casing Pipe.

II. Material And Methods

This research used five specimens of SMAW welded joints between the Temporary Wellhead replica material, namely AISI 4130, and the actual Conductor Casing Pipe material in the field, API 5CT Gr.K55, 20 inch diameter. The welding rod used is 3.2 mm x 400mm, AWS: A5.1 E7016.

Table no 1: Percentage of chemical composition

	%Fe	%C	%Mn	%Si	%P	%S	%Ni	%Mo	%Cr	%V
Conductor Casing Pipe	96.8	0.388	1.28	0.344	<0.003	<0.002	0.175	0.291	0.337	0.0028
Replica Temporary Wellhead (AISI 4130)	97.7	0.281	1.38	0.255	<0.003	<0.002	0.059	0.0232	0.11	<0.0010
Welding rod	-	0.07	1.05	0.55	0.011	0.006	-	-	-	-

Study Design: Comparison of changes in mechanical properties and microstructure between specimens
Study Location: One of drilling Rig in Prabumulih, South Sumatera, Indonesia
Study Duration: January 2021 to July 2021
Specimen size: 5 pcs
Specimen size calculation: Every specimen data is obtained from the average of five data
Subjects & selection method: The selected specimens are those that passed the non-destructive test (NDT)of magnetic particle inspection (MPI). The description of each specimen is as follows:

Table no 2: Specimen treatment description

Specimen	Temporary Wellhead replica		Last Conductor Casing Pipe
	Treatment order before weld joining to the last Conductor Casing Pipe	Total treatment order after weld joining to the last Conductor Casing Pipe	
A	New piece	New piece-weld (1x weld)	New piece
B	New piece-weld-cut	New piece-weld-cut-weld (2x weld and 1x cut)	New piece
C	New piece-weld-cut-weld-cut	New piece-weld-cut-weld-cut-weld (3x weld and 2x cut)	New piece
D	New piece-weld-cut-weld-cut-weld-cut	New piece-weld-cut-weld-cut-weld-cut-weld (4x weld and 3x cut)	New piece
E	New piece-weld-cut-weld-cut-weld-cut-weld-cut	New piece-weld-cut-weld-cut-weld-cut-weld-cut-weld (5x weld and 4x cut)	New piece

Inclusion criteria:
1. Temporary Wellhead replica specimens meet AISI 4130 chemical composition specifications.
2. The Conductor Casing Pipe specimen is taken directly from the actual Conductor Casing Pipe cut in the field.
3. SMAW welding technique.
4. Preheat 250 °C on the Temporary Wellhead specimen and the Conductor Casing Pipe before being welded for each staging in table no.2.

Exclusion criteria:
1. Welded specimen objects that do not pass the MPI NDT test.
2. Testing outside the HAZ area of the Conductor Casing Pipe.

Procedure methodology

Welding is carried out according to the treatment sequence in Table no. 2. Then several tests are carried out on the HAZ area of the casing conductor pipe on each specimen. Specimens that have passed the NDT MPI test are then subjected to macro and micro metallographic testing with an optical lens magnification of 200 and 500 times. This test is to analyze the changes in the HAZ region andthe microstructure phase formed. Then the chemical composition test was carried out using X-ray Fluorescence (XRF) to determine changes in chemical composition. Then the hardness test was carried out using a Rockwell B Dyna Pocket GE 3 mm indenter.

Statistical analysis

The data collected is graphed so that the trend of increasing or decreasing chemical composition, and hardness of the HAZ area of the Conductor Casing Pipe will be known for each additional number of welding experienced by Temporary Wellhead.

III. Result

Based on the results of macro metallography, it is known that the width of the HAZ on the upper surface of specimens A, B, and C (Fig. 1: a, b, and c) did not change at 2 mm. And the HAZ width changes in samples D and E to 3 mm (Fig 1: d and e).

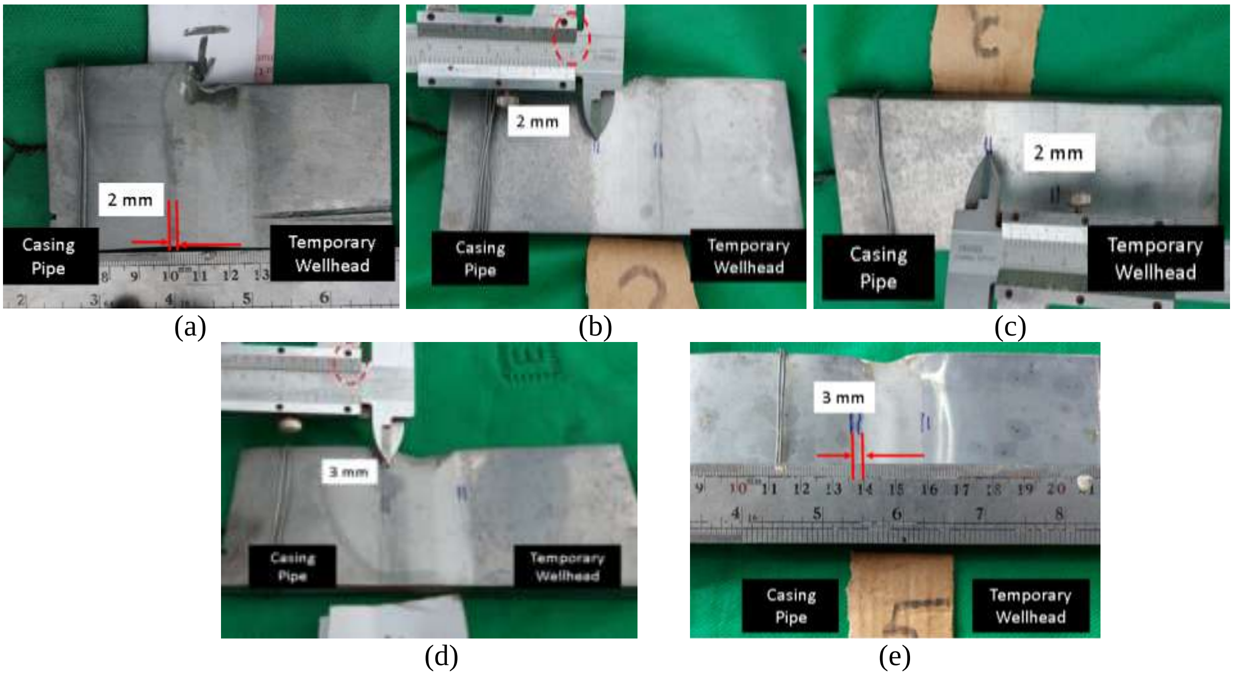


Figure 1.HAZ of the outer surface of (a) Specimen A, (b) Specimen B, (c) Specimen C, have the same width, 2 mm. And (d) Specimen D, (e) Specimen E have the same width are 3 mm

Figured 2: a, b, and c, shows that the width of the HAZ cross-section of specimens A, B, and C has the same width, 5 mm.While specimens D and E have a HAZ width of 6 mm. It can also be seen that the HAZ area of the outer surface of the Fig.1 specimen has a narrower width than in the cross-section area.

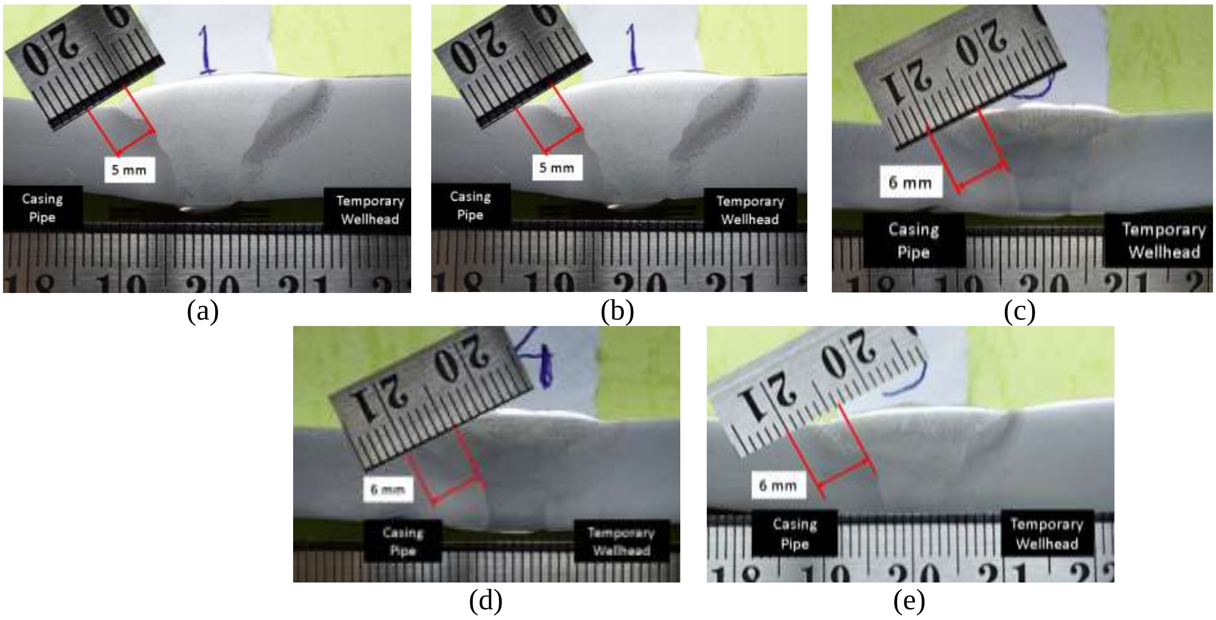
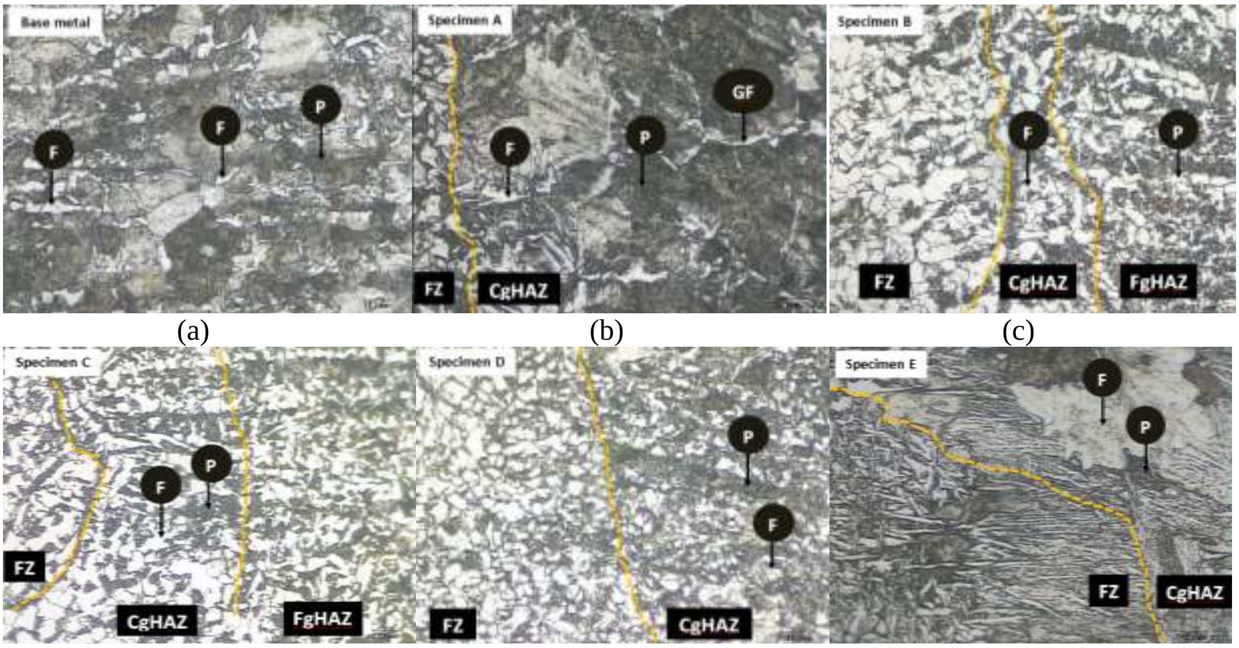


Figure 2.HAZ of the cross section of (a) Specimen A, (b) Specimen B, (c) Specimen C, have the same width, 5 mm. And (d) Specimen D, (e) Specimen E have the same width are 6 mm

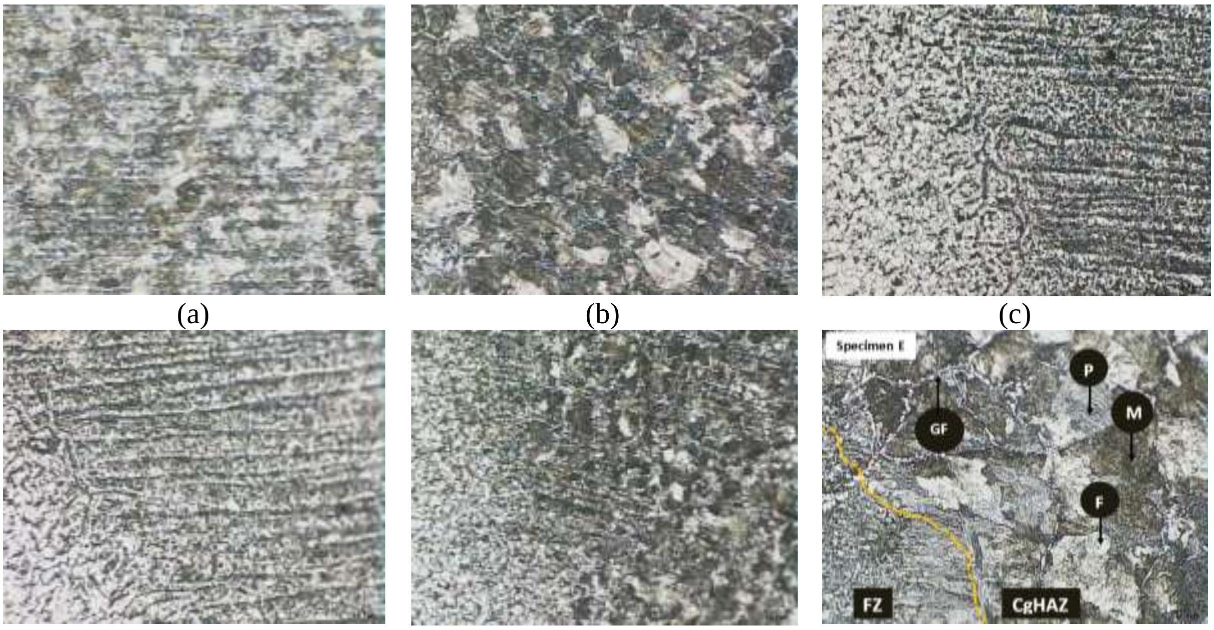
According to Fig.3, the Base metal of the Conductor Casing Pipe consists of elongated Ferrite and Perlite in higher amounts. Ferrite is a proeutectoid. In specimen A, the elongated Ferrite begins to change to a grain boundary Ferrite (GF) and Pearlite become coarser with increasing cementite content. In specimens, B, C, and D, the grain boundary Ferrite is disappeared because it changes to equiaxed Ferrite while Pearlite changes from coarse to smaller. In Fig. 4 (f), it is known that the Martensite phase begins to form in specimen E. Martensite morphology is the same as the results of research by Palanisamy et al [7].



(a) (b) (c)

(d) (e) (f)

Figure 3.HAZ microstructure at 500 times magnification for (a) Base metal, (b) Specimen A, (c) Specimen B, (d) Specimen C, (e) Specimen D, (f) Specimen E. F for Ferrite, P for Pearlite, GF for grain boundary Ferrite, FZ for Fusion Zone, FgHAZ for Fine grain HAZ and CgHAZ for Coarse grain HAZ

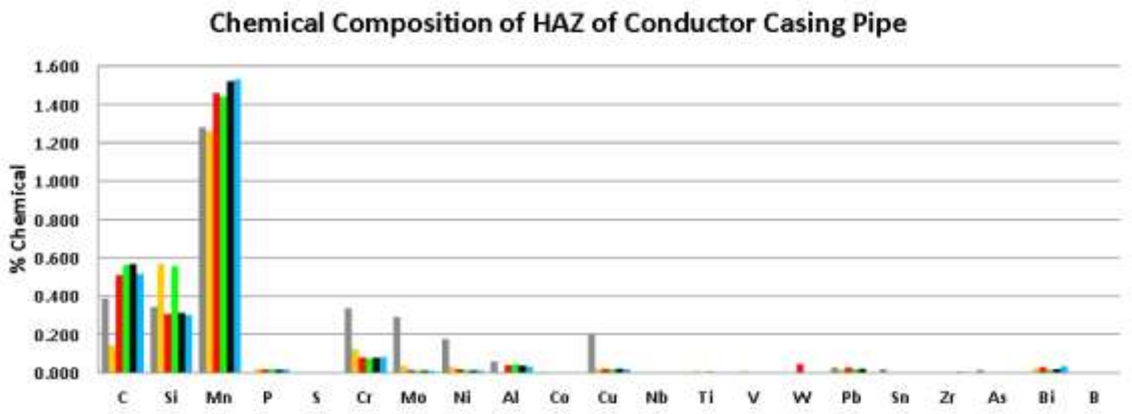


(a) (b) (c)

(d) (e) (f)

Figure 4.HAZ microstructure at 200 times magnification for (a) Base metal, (b) Specimen A, (c) Specimen B, (d) Specimen C, (e) Specimen D, (f) Specimen E. M for Martensite

Figure 5 shows that the replica of the Temporary Wellhead, which has undergone several welding processes, affects the chemical composition of the HAZ of the Conductor Casing Pipe because of the C and Mn elements. It tends to increase with the increase in the number of welds on the Temporary Wellhead, but randomizes on the Si element and does not significantly affect the other elements.



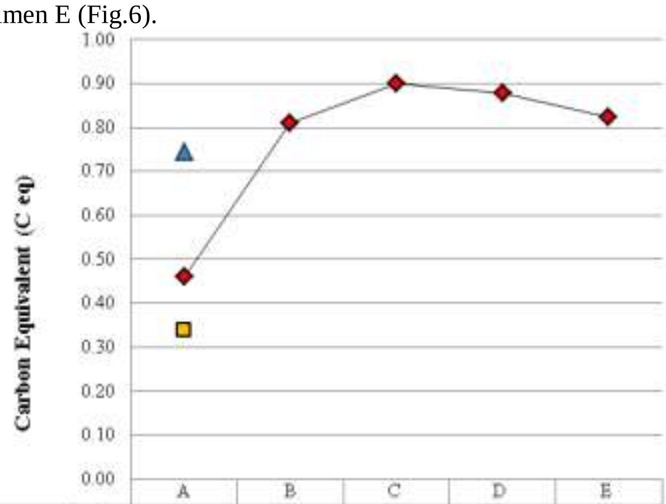
	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Nb	Ti	V	W	Pb	Sn	Zr	As	Bi	B
Conductor casing pipe	0.388	0.344	1.280	0.000	0.000	0.337	0.291	0.175	0.060	0.004	0.205	0.000	0.000	0.003	0.000	0.027	0.010	0.000	0.014	0.000	0.000
A	0.143	0.569	1.260	0.021	0.000	0.123	0.035	0.033	0.000	0.000	0.022	0.000	0.008	0.008	0.000	0.018	0.000	0.000	0.000	0.025	
B	0.510	0.307	1.460	0.018	0.000	0.081	0.015	0.019	0.039	0.000	0.021	0.000	0.001	0.000	0.046	0.037	0.000	0.000	0.000	0.030	0.000
C	0.562	0.556	1.440	0.018	0.000	0.076	0.011	0.014	0.044	0.000	0.018	0.000	0.008	0.003	0.000	0.020	0.000	0.003	0.000	0.016	0.000
D	0.568	0.312	1.520	0.015	0.000	0.079	0.012	0.013	0.037	0.000	0.021	0.000	0.001	0.000	0.000	0.022	0.000	0.004	0.000	0.020	0.000
E	0.514	0.300	1.530	0.018	0.000	0.083	0.010	0.011	0.033	0.000	0.019	0.000	0.002	0.000	0.000	0.000	0.000	0.003	0.000	0.035	0.000

Figure 5. Chemical composition in HAZ of each specimen of Conductor Casing Pipe

Table no 3. Carbon equivalent (Ceq) value in HAZ Conductor Casing Pipe

Material	Ceq
Basemetal	0.74
Welding rod	0.34
Specimen A (1x weld)	0.46
Specimen B (2x weld, 1x cut)	0.81
Specimen C (3x weld, 2x cut)	0.90
Specimen D (4x weld, 3x cut)	0.88
Specimen E (5x weld, 4x cut)	0.82

The carbon equivalent (Ceq) value of the Base metal of the Conductor Casing Pipe is 0.74. The Ceq value of the welding rod is 0.34. The Ceq value of the HAZ area of the specimens is shown in table no 3. The Ceq value of the HAZ of specimen A is smaller than Base metal. Then its value increases to specimen C and then decreases gradually to specimen E (Fig.6).



	A	B	C	D	E
Ceq HAZ Conductor casing pipe specimen	0.46	0.81	0.90	0.88	0.82
Ceq Base metal	0.74				
Ceq Welding rod	0.34				

Figure 6. Trend of Ceq of Conductor Casing Pipe as function of repeated welding of Temporary Wellhead

The base metal of the Conductor Casing Pipe has a hardness value of 84.37 HRB. While the HAZ of the Conductor Casing Pipe for specimen A has a hardness value of 86.88 HRB and then tends to increase to 89.20 HRB in specimen E, although the level of increase is not significant (Fig. 7).

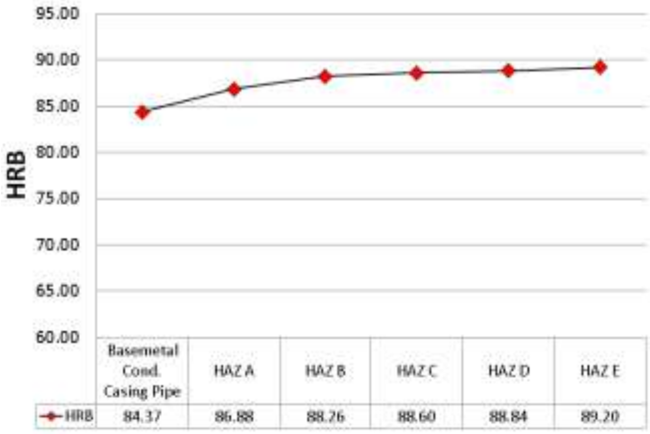


Figure 7. HRB value of specimen

IV. Discussion

The results showed that the Conductor Casing Pipe welding on the Temporary Wellhead that underwent repeated welding showed several things, including the HAZ on the cross-section area having a wider area than the HAZ on the outer surface area of the specimen. That's because the heat transfer on the surface area of the specimen while welding to the outside air is better than the heat transfer in the cross-section area. The HAZ area on the surface of specimens A, B, and C has the same width, which is 2 mm, but changes in specimens D and E, which is 3 mm. Likewise, in the cross-section, specimens A, B, and C have the same width of 5 mm but have changed in specimens D and E which have a HAZ width of 6 mm. That's because the cumulative effect of repeated welding heat received on the Temporary Wellhead also affects the HAZ of the Conductor Casing Pipe that is welded together in the Temporary Wellhead.

Repeated welding on the Temporary Wellhead also affects the HAZ microstructure of the Conductor Casing Pipe. The base metal of the Conductor Casing Pipe had a dominant coarse Pearlite phase followed by a small elongated ferrite phase. In specimen A, as the welding result of the new material of the Conductor Casing Pipe to the new material replica of Temporary Wellhead, is found that microstructure on the HAZ area of the Conductor Casing Pipe, consists of dominant Pearlite, acicular Ferrite, and grain boundary Ferrite (GF) which comes from small elongated Ferrite. In specimen B, as the welding result of the new material of the Conductor Casing Pipe to a replica of Temporary Wellhead which has undergone one welding before, changes in the microstructure are found, namely equiaxed Ferrite and equiaxed coarse Pearlite which are in almost the same amount. These conditions were found to be the same in specimens C and D. In specimen E, which was the result of welding the Conductor Casing Pipe to a replica of the Temporary Wellhead which had undergone four weldings before, and after the fifth welding, the HAZ microstructure of the Conductor Casing Pipe was found the grain boundary Ferrite (GF), equiaxed Ferrite in small amounts, fine Pearlite and Martensite. The formation of Martensite is due to the effect of repeated welding five times experienced by the Temporary Wellhead.

The carbon equivalent (Ceq) on the HAZ of the Conductor Casing Pipe is also affected by repeated welding on the Temporary Wellheads before, which welded to it. Generally, the HAZ's Ceq value of the Conductor Casing Pipe increases if it is welded to a Temporary Wellhead replica that experienced more repeated welding. It is due to the diffusion of C and Mn elements into the HAZ region that causes increasing the Ceq value

The value of HRB hardness on the HAZ of the Conductor Casing Pipe tends to increase if the Conductor Casing Pipe is welded to the Temporary Wellhead which experiences more repeated welding. That's because the change in grain size is getting smaller from specimen B to specimen D. Meanwhile, the Martensite phase is found in specimen E.

V. Conclusion

In welding the Temporary Wellhead to the Conductor Casing Pipe, the presence of the Temporary Wellhead that has undergone repeated welding can affect the mechanical properties and microstructure of the HAZ area of the Conductor Casing Pipe. The HAZ area of the outer surface Conductor Casing Pipe and the cross-section of the specimen experiences an increase in width when welded to the Temporary Wellhead which has experienced more and more repeated welding. The outer surface HAZ area is narrower than the cross-section because the surface experiences better welding heat transfer to the outside air environment. The Ceq value of the HAZ area of the Conductor Casing Pipe increases if it is welded with a Temporary Wellhead that has experienced an increasing number of welding. In addition, the hardness value of the HRB of the HAZ area will also increase if are welded to Temporary Wellheads which experience an increasing number of repeated welding.

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