Nichrome Dependency in Welding Layer Using \textit{In situ} Fabrication on Hardness and Corrosion Properties

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Abstract
The use of shielded metal arc welding (SMAW) equipment to synthesize alloys is one of the most promising methods as it can be used for in-situ fabrication. The hardness and corrosion properties of the deposited layer during the welding process can be enhanced by dilution of nichrome (NiCr) during the process. Therefore, the alloy was synthesized on the surface of the mild steel using SMAW equipment with various NiCr additions. The properties of the alloy were investigated using an X-ray diffraction (XRD), an Optical microscope, a Potentiostat, and a Vickers hardness apparatus. The appearance of martensite overlaps with the ferrite phase could be affected by the addition of NiCr to the alloy. An increase in NiCr content is followed by an increase in the lattice parameter value of the ferrite phase. The presence of a certain amount of nickel (Ni) contributes to the formation of lower transformation phases, including martensite. At the same time, the incorporation of chromium (Cr) also plays a significant role in promoting the formation of acicular ferrite. An increase in NiCr content in NiCr2 and NiCr3 samples results in a quantitative increase in martensite formation. Adding 0.434 g of NiCr to the weld deposited layer could result in the corrosion rate of the alloy being 0.1118 mm/y. Higher hardness is found in the NiCr3 sample, around 742.06 HV.

Keywords
Alloys, Dilution, Welding Process, Martensite, Corrosion Rate

1. INTRODUCTION
The construction of infrastructure in the coastal area requires heavy equipment such as excavators for material transportation. To operate an excavator in a coastal area, it is important to have a component that has good corrosion resistance and hardness properties (Kuptsov et al., 2021). Improving their hardness and corrosion resistance is necessary to extend the life of excavator blades (Das et al., 2021; Okechukwu et al., 2018).

Various methods were used to solve the problems, such as coating, alloy synthesis, and heat treatment processes (Liu et al., 2020; Wang et al., 2015). Recently, alloy synthesis has been conducted using welding equipment. Compared to other alloy synthesizes methods, this process is both innovative and cost-effective. In addition, welding equipment is a promising method for alloy synthesis as it can be applied in situ. There have been several studies on alloy synthesis in situ with welding equipment (de Almeida et al., 2016; Justus Panicker and Senthilkumar, 2023; Ma et al., 2015). The process of shielded metal arc welding (SMAW) can be easily done. SMAW equipment is frequently used in heavy equipment workshops because of its small size and easy movement. Furthermore, in situ alloy synthesis has been successfully achieved by previous research using the SMAW equipment (Singh et al., 2020; Sopiyan et al., 2024; Syaripuddin et al., 2023).

Nichrome (NiCr) alloy has good mechanical and corrosion properties (Kumar et al., 2020; Li et al., 2021). By diluting NiCr onto the weld layer during the welding process, it could enhance its hardness and corrosion properties. Justus Panicker and Senthilkumar (2023) added NiCr in the welding layer using a rotational arc-based dual wire arc, which could enhance the tensile strength and corrosion resistance properties of the sample. Wang et al. (2023a) conducted alloy fabrication between rare earth Y and NiCr filler alloy using the vacuum brazing process over copper (Cu) pot and found the chromium (Cr) element diffuses in the molten metal and combines with the carbon (C) element to form carbide. Moreover,
with increased Cr content, various carbides such as Cr$_2$C$_2$, and Cr$_7$C$_3$ were formed (Wang et al., 2023a). According to Xu et al. (2022), these carbides could enhance the strength properties of the material. Galchenko et al. (2019) successfully added NiCr powder when joining Cu and steel plates using electron-beam welding, resulting in a weld joint hardness of 350 to 700 HV. Huang et al. (2015), made a composite coating of mixed powder NiCrBSi, NiCr$-$Cr$_3$C$_2$, and WC using plasma spray welding resulting in carbide content in the coating increased with increasing the NiCr NiCr$-$Cr$_3$C$_2$ and WC mass fraction in the mixed powders. Saeedi et al. (2021) conducted laser cladding of NiCr and NiCr$-$TiC composited over AISI 420, and resulting NiCr and NiCr$-$TiC deposited has lower weight loss than AISI 420.

HV 600 is a commercial electrode that can be applied single, double, and triple layers over steel using SMAW equipment which resulted in the hardness between 440$-$540, 520$-$600, and 540$-$675 HV, respectively (Nikko Steel, 2014). Besides the amount of layers, the current and polarity that were set in the SMAW equipment during synthesis also influenced the hardness of the formed deposited layer. Many efforts have been conducted to enhance the deposited layer properties when welding using an HV 600 electrode such as heat treatment, and the additional amount of titanium (Ti) or NiCr in the deposited layer during welding. A previous study conducted direct quenching in various media (engine oil and palm oil) of the deposited layer where welded by HV 600 over mild steel, resulting in higher hardness of the deposited layer when quenched in palm oil (Syariipuddin et al., 2023). Moreover, previous research also welded over carbon steel using an HV 600 electrode and adding three pieces of Ti wire ($150 \times \varnothing 0.65$ mm) into the deposited layer during welding resulting in enhanced hardness from 503.48 to 686.1 HV (Syariipuddin et al., 2023). Furthermore, previous research welded carbon steel using an HV 600 electrode and adding NiCr wire around $2.52$ g into the deposited layer during welding resulting in a corrosion rate and hardness is 0.337 mm/y and 581 HV (Sopiyan et al., 2024).

Dilution of NiCr onto the deposited layer during the welding process has been proven to enhance its hardness and corrosion properties. Unfortunately according to previous research corrosion resistance and hardness of the deposited layer do not reach optimal conditions (Sopiyan et al., 2024). Therefore, the present research focuses on the varying composition of NiCr that is added to the deposited layer during welding using the SMAW process with an HV 600 electrode. This research aims to deeply explore the hardness and corrosion behavior of the formed alloy in the deposited layer. The X-ray diffraction (XRD), Optical microscope, Potentiostat, and Vickers hardness apparatus were used to determine the structure, microstructure, electrochemical behavior, and hardness value of the deposited layer.

2. EXPERIMENTAL SECTION

2.1 Materials

In the present work, were used carbon steel, NiCr, and HV 600 as the base material ($75 \times 10 \times 10$ mm), NiCr addition, and filler metal, respectively, which were similar to the previous study (Sopiyan et al., 2024; Syariipuddin et al., 2023). The NiCr wire was cut and weighed for approximately 0.434, 0.844, and 1.292 grams to be added to the deposited layer.

2.2 Methods

The HV 600 filler metal was dried in an oven at 150°C for 1 hour prior to welding (Nikko Steel, 2014). Each weighed NiCr wire (0.434, 0.844, and 1.292 g) was placed on the top surface of the base material and the samples were namely NiCr1, NiCr2, and NiCr3. Afterward, the single-layer welding process was performed using SMAW (Fro BF 443), DCEP, and 90 A. The natural cooling process for samples was carried out after the welding was completed.

2.3 Characterizations

The formed alloys were checked using XRD, Optical microscope, Potentiostat, and Vickers hardness apparatus. XRD was performed from 20$-$110° using PANalytical Aeras (CoK$\lambda = 1.7890$ Aand step size 0.0217°). The Rietveld method was utilized to determine the lattice parameters, which included phase composition, using XRD data. Furthermore, to investigate the microstructure of the alloy, it was mounted in epoxy resin, polished, and etched with 2% Nital. It was later obtained using an Optical microscope (Olympus BX53M).

A Potentiostat (Gamry References 600) was used to investigate the electrochemical behavior of the alloy in 3.5% NaCl solution at 25°C which is near to simulated seawater (Pauzi et al., 2023). The electrochemical behavior of the sample was investigated through open circuit potential (OCP), potentiodynamic polarization, and electro-impedance spectroscopy (EIS) measurements. Firstly, OCP measurements were performed until 1200s to evaluate the stability voltage of various samples. Then, the potentiodynamic polarization was scanned at a rate of 1 mV/s. Where the sample is the working electrode, Platinum (Pt) is the counter electrode, and saturated calomel is the reference electrode. Following the potentiodynamic polarization measurement, Tafel extrapolation was used to determine the corrosion current density ($I_{corr}$) and potential ($E_{corr}$). The corrosion rate ($Corr Rate$) was found from the Equation (1) (Syamsuir et al., 2023).

$$Corr Rate (mm/y) = \frac{C(M \times I_{corr})}{n \rho}$$ (1)

Where $Corr Rate$ is corrosion rate (mm/y), $C$ is corrosion rate constant (mm/y), $M$ is atomic weight (g/mol), $I_{corr}$ is corrosion current density ($A/cm^2$), $n$ is the number of electrons involved, and $\rho$ is density (g/cm$^3$). Furthermore, the electro-impedance spectroscopy (EIS) was performed at 0.05 sd 4500 HZ to obtain the Nyquist and Bode plot.
Finally, various samples were tested using an FV-300e Vickers hardness tester with a load of 5 kg. A total of ten repeatable tests were carried out. The average hardness value is presented in Figure 8.

3. RESULTS AND DISCUSSION

3.1 Phase and Structure Analysis

Figure 1 shows the diffraction pattern of carbon steel samples after the addition of NiCr filler during the welding process. Based on the diffraction reflection of the three samples, it appears that the substance belongs to the ferrite phase (α—Fe) with a body center cubic (bcc) crystal system. Ferrite and Fe oxide (Fe$_3$O$_4$) phases were present in the NiCr1 sample. The results are similar to the ferrite phase peaks reported by Elena Astafurova and Soliz (Astafurova et al., 2023; Soliz et al., 2022) at angles of 2θ = 52.03, 77.12, and 99.37°. The appearance of a martensite phase (α’—Fe) at an angle of 2θ, which overlaps with the ferrite phase, can be influenced by the addition of NiCr filler during the welding process. This area exhibits an asymmetric pattern with overlapping peaks, as seen in Figure 1. An asymmetric pattern and peak broadening indicate that there are two distinct phases: ferrite and martensite phases (Tanaka et al., 2020; Zhang et al., 2017). The asymmetric pattern increases at a peak angle of 2θ=52° in the NiCr3 sample. Additionally, it can be observed in the NiCr3 diffraction pattern that the ferrite phase peak has been shifted and its intensity has decreased. A higher content of the martensite phase could be qualitatively. According to the evidence, the NiCr3 sample has the greatest change in shift and intensity drop. The shift indicates that NiCr filler may have replaced the ferrite phase, which could result in lattice distortion. The NiCr3 sample also had other phases like the FeO$_2$ phase detected.

Table 1 displays the composition of each phase of the three samples. The calculation results indicate that the NiCr1 sample has a ferrite phase with a lattice parameter value of 2.8709 Å. The lattice parameter values of the ferrite phase are identical to those published by Soliz et al. (2022). Increase in NiCr content followed by an increase in the lattice parameter value of the ferrite phase. For the NiCr2 and NiCr3 samples, the lattice parameters of the ferrite phase are 2.8713 Å and 2.8724 Å, respectively. The crystallographic data for the three samples can be found in Table 1.

3.2 Microstructure of Weld Layer

Figure 3 represents the microstructure of various deposited layers. The light optical micrographs in Figures 3 (b) and (c) reveal the presence of martensite in the NiCr2 and NiCr3 samples. Generally, the formation of the martensite phase occurs spontaneously due to rapid cooling. This rapid cooling hinders the decomposition of austenite into ferrite and cementite through diffusion (Li et al., 2022). In the welding process, the rapid cooling phenomenon may occur due to the temperature difference between the weld metal and the electrode or filler. Moreover, the presence of a certain amount of nickel (Ni) contributes to the formation of lower transformation phases, including martensite (Kong et al., 2019; Umale et al., 2019). The martensite phase appears as a dark brown constituent lo-
Figure 3. Microstructure of Weld Layer (a) NiCr1, (b) NiCr2, and (c) NiCr3

cated on top of the white-colored acicular ferrite phase. The welding process employed resulted in the formation of acicular ferrite as the primary phase of the weld metal (Durmuşoğlu et al., 2015; Jorge et al., 2018). Additionally, the incorporation of Cr also plays a significant role in promoting the formation of acicular ferrite (Lee and Lee, 2015). On the other hand, the NiCr1 sample exhibits no martensite formation. This is likely attributed to the insufficient critical cooling rate to reach the martensite start temperature (Ms), leading to the retention of the parent phase (ferrite). This observation is further supported by the XRD results discussed earlier. Furthermore, the increased NiCr content leads to a qualitative enhancement in martensite formation within the NiCr2 and NiCr3 samples. This is further corroborated by the observed increase in the intensity of the $\alpha'$-Fe martensite phase in the XRD results. This enhancement is also attributed to the influence of Ni, which plays a role in reducing the critical cooling rate and consequently leads to an improvement in the mechanical properties.
3.3 OCP
OCP was performed until 1200s, as seen in Figure 4. Various samples show similar behavior; increasing the immersion time would shift the OCP value negatively. This behavior means the dissolution of the oxide on the surface of a sample. According to an XRD analysis, Fe$_3$O$_4$ oxide was found in all samples, while FeO$_2$ oxide was only found in NiCr3. Generally, all oxides of iron (Fe) have low stability and, therefore, poor protection, which could dissolve into the solution during OCP measurement (Wang et al., 2020).

According to Figure 4, NiCr1, NiCr2, and NiCr3 samples have OCP values of -0.5616, -0.535, and -0.5099 V when compared to SCE. Moreover, until the 1200s measurement, all samples moved in a negative direction to reach a steady state.

Table 1. Crystallographic Data of Various Samples

<table>
<thead>
<tr>
<th>Source</th>
<th>NiCr1</th>
<th>NiCr2</th>
<th>NiCr3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ferrite (α−Fe) phase</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System crystal: cubic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space group: im-3m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase fraction (wt.%)</td>
<td>66.69</td>
<td>58.16</td>
<td>49.67</td>
</tr>
<tr>
<td>Lattice -a=b=c (Å)</td>
<td>2.8709</td>
<td>2.8713</td>
<td>2.8724</td>
</tr>
<tr>
<td><strong>Martensite (α′−Fe) phase</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System crystal: tetragonal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space group: i4/mmm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase fraction (wt.%)</td>
<td>23.65</td>
<td>31.28</td>
<td>34.91</td>
</tr>
<tr>
<td>Lattice -a=b (Å)</td>
<td>2.8561</td>
<td>2.8606</td>
<td>2.8595</td>
</tr>
<tr>
<td>Lattice -c (Å)</td>
<td>2.9623</td>
<td>2.9558</td>
<td>2.9363</td>
</tr>
<tr>
<td><strong>Fe$_3$O$_4$ phase</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System crystal: cubic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space group: fd-3m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase fraction (wt.%)</td>
<td>9.66</td>
<td>10.56</td>
<td>8.74</td>
</tr>
<tr>
<td>Lattice -a=b=c (Å)</td>
<td>8.4041</td>
<td>8.3847</td>
<td>8.4014</td>
</tr>
<tr>
<td><strong>FeO$_2$ phase</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System crystal: orthorhombic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space group: Am a m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase fraction (wt.%)</td>
<td>n/a</td>
<td>n/a</td>
<td>6.68</td>
</tr>
<tr>
<td>Lattice -a (Å)</td>
<td>n/a</td>
<td>n/a</td>
<td>3.8942</td>
</tr>
<tr>
<td>Lattice -b (Å)</td>
<td>n/a</td>
<td>n/a</td>
<td>12.6481</td>
</tr>
<tr>
<td>Lattice -c (Å)</td>
<td>n/a</td>
<td>n/a</td>
<td>3.0405</td>
</tr>
<tr>
<td>$\lambda^2$</td>
<td>1.219</td>
<td>1.303</td>
<td>1.378</td>
</tr>
<tr>
<td>wRp (%)</td>
<td>4.09</td>
<td>4.19</td>
<td>5.48</td>
</tr>
</tbody>
</table>

Figure 4. OCP Measurement Result

Figure 5. Potentiodynamic Polarization Curve of Various Samples
This indicates that iron oxide is still dissolving in the solution and the cathodic process is still occurring (Dagdag et al., 2020).

### 3.4 Potentiodynamic Polarization

Potentiodynamic polarization was conducted after the OCP measurement in 3.5% NaCl. The results of the potentiodynamic polarization scans can be seen in Figure 5. All samples show the passive area, which only extends to a small range of potential. The current suddenly increases steeply without any sign of oxygen evolution. This behavior indicates the breakdown of passive films and the initiation of pitting corrosion propagation.

Consequently, the influence of the Cl⁻ species on the corrosion rate of the specimens can be interpreted as a balance between the two processes competing on the specimen, stabilization of the passive film due to OH⁻ adsorption, and disruption of the film by Cl⁻ ions adsorption. Corrosion will occur when Cl⁻ ions activities overcome OH⁻ ions (Nady et al., 2017). The reversible formation of Fe(OH)₅ads adsorbed on the specimen is the first process during corrosion and is followed by several sequences as seen in the reaction (2-5) (Nady et al., 2017).

\[
\begin{align*}
\text{Fe} + \text{OH}^- & \rightarrow \text{FeOH}^\text{ads} \quad (2) \\
\text{FeOH}^\text{ads} & \rightarrow \text{FeOH}^\text{ads} + e^- \quad (3) \\
\text{FeOH}^\text{ads} + \text{OH}^- & \rightarrow \text{Fe(OH)}_2^\text{ads} + e^- \quad (4) \\
\text{Fe(OH)}_2^\text{ads} + \text{OH}^- & \rightarrow \text{FeOOH} + \text{H}_2\text{O} + e^- \quad (5)
\end{align*}
\]

The presence of the Cl⁻ ions decreases the Fe(OH)₅ads coverage, increasing the specimens’ anodic dissolution. The phenomena will be explained in the reaction (6-7) (Nady et al., 2017).

\[
\begin{align*}
\text{Fe} + \text{Cl}^- & \rightarrow \text{FeCl}^\text{ads} + e^- \quad (6) \\
\text{FeCl}^\text{ads} & \rightarrow \text{FeCl}^+_\text{ads} + e^- \quad (7)
\end{align*}
\]

\(E_{\text{corr}}\) and \(I_{\text{corr}}\) were found by using the Tafel extrapolation method (see Table 2). Based on Table 2, it can be seen that increasing NiCr content in the alloy is leading to a shift in the more positive direction of \(E_{\text{corr}}\) and increasing the \(I_{\text{corr}}\) value. Furthermore, using Equation (1), the corrosion rate will be found and summarized in Table 2.

#### Table 2. Potentiodynamic Polarization Result

<table>
<thead>
<tr>
<th>Samples</th>
<th>(E_{\text{corr}}) (V vs SCE)</th>
<th>(I_{\text{corr}}) (A/cm²)</th>
<th>Corr Rate (mm/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NiCr1</td>
<td>-0.738</td>
<td>3.903×10⁻⁵</td>
<td>0.1118</td>
</tr>
<tr>
<td>NiCr2</td>
<td>-0.706</td>
<td>4.228×10⁻⁵</td>
<td>0.1212</td>
</tr>
<tr>
<td>NiCr3</td>
<td>-0.688</td>
<td>8.821×10⁻⁵</td>
<td>0.2528</td>
</tr>
</tbody>
</table>

The NiCr3 sample shows more positivity than other samples, which suggests that it has nobler behavior. \(I_{\text{corr}}\) is inversely proportional to corrosion resistance. Increasing NiCr content leads to an increase in corrosion rates. NiCr1 has a corrosion rate that is less than that of other samples. The \(E_{\text{corr}}\) of this sample is about 2 times lower than NiCr3. Compared with the previous research, it has found that \(E_{\text{corr}}\) -0.711 V vs Ag/AgCl, \(I_{\text{corr}}\) 1.52×10⁻⁴, and corrosion rate 0.3265 mm/y (Sopiyan et al., 2024). Therefore, presenting NiCr in the alloy of around 0.434 g could decrease the corrosion rate, but increasing the NiCr content in the alloy promoted an increase in corrosion rate.

Nady et al. (2017) investigated carbon steel (0.34 C, 0.93 Mn, 0.20 Si, 0.02 S, 0.04 P, 0.01 Cr, 0.02 Ni, and Fe balance) in 3.5% NaCl found \(E_{\text{corr}}\) -0.9996 V vs SCE and \(I_{\text{corr}}\) 5.49×10⁻⁵ A/cm². This results in less negative \(E_{\text{corr}}\) than present research due to less Ni and Cr content in the carbon steel. Wang et al. (2016) found \(E_{\text{corr}}\) Ni -777 V vs Ni/NiF and \(E_{\text{corr}}\) Cr -507 V vs Ni/NiF₂. Moreover, Wang et al. (2016) have found that increasing the Cr content tends to increase a mass loss which is in perfect agreement with the potentiodynamic polarization result. Furthermore, Chen et al. (2021) found that increasing the corrosion rate of dual-phase steel attributed due to present martensite could enhance the micro-galvanic effect. Based on the microstructure and XRD evaluations, an increase in NiCr content led to an increase in the martensitic phase. Hence, increasing the NiCr content in the alloy promoting to decrease corrosion resistance.

### 3.5 EIS

Figure 6 represents the Nyquist plot for various samples. There is just one loop seen in each sample, which indicates that each sample has one time constant. Moreover, the highest loop tends to have higher corrosion resistance as seen in the NiCr1 sample (Nikitasari et al., 2022).
Figure 7 represents the Bode plot of various samples. One phase maxima was present at a lower frequency, which is attributed to the appearance of the protective oxide film. The lowest phase maxima are found in the NiCr3 sample, which indicates a higher corrosion rate (Wang et al., 2023b). The total impedance magnitude value of the samples increases with a decrease in the NiCr content, implying a decrease in the corrosion rate due to the passive film growth till the steady state is achieved (Nady et al., 2017).

Table 3. Charge Transfer Resistance and Solution Resistance

<table>
<thead>
<tr>
<th>Samples</th>
<th>$R_{ct}$ ($\Omega$)</th>
<th>$R_s$ ($\Omega$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NiCr1</td>
<td>$1.16 \times 10^7$</td>
<td>5.730</td>
</tr>
<tr>
<td>NiCr2</td>
<td>$9.75 \times 10^7$</td>
<td>4.846</td>
</tr>
<tr>
<td>NiCr3</td>
<td>$4.24 \times 10^7$</td>
<td>6.373</td>
</tr>
</tbody>
</table>

$R_{ct}$ is the charge transfer resistance, and $R_s$ is the 3.5% NaCl solution resistance. $R_{ct}$ and $R_s$ were found by fitting data from an electrical equivalent circuit (EEC) in Figure 7 and those values are presented in Table 3. Increasing the $R_{ct}$ value signifies improving the corrosion resistance (Nikitasari et al., 2022). NiCr1 has the maximum $R_{ct}$ value and highest corrosion resistance among the other samples, consistent with the potentiodynamic polarization result. Nikitasari et al. (2022) have found that a reduction in the corrosion rate is in line with an increase in the $R_{ct}$ values due to charge transfer from solution to steel and vice versa inhibited due to an increase in inhibitor concentration.

3.6 Hardness

Figure 8 shows the average hardness of various samples. Less hardness is found in sample NiCr1, and higher hardness is found in the NiCr3 sample. The perfect agglomeration of the NiCr addition also indicates an increase in hardness. Compared to the previous research, it can be seen that adding NiCr could enhance the average hardness of samples from 510 to 581 HV (Sopiyan et al., 2024). Martensitic formation in the welding layer leads to an increase in hardness (Faria et al., 2019). Katiyar et al. (2019) found that martensitic steel was held at 950°C for 12 minutes and followed by quenching in oil media, resulting in a hardness of $65.84 \pm 0.52$ HRC ($\approx 970$HV). Based on the microstructure and XRD observations, it can be seen that an increase in NiCr content led to an increase in the martensite phase (See Figure 8 and Table 1). Hence, increasing the NiCr content in the alloy led to increased hardness.

4. CONCLUSIONS

Various NiCr contents were successfully added to the alloy. Presenting NiCr in the alloy of around 0.434 g leads to an increase in hardness and corrosion resistance. Increasing NiCr content in the alloy resulted in an increase in hardness and a decrease in corrosion resistance. The presence of a certain amount of Ni contributes to the formation of lower transformation phases, including martensite. The incorporation of Cr plays an important role in promoting the formation of acicular ferrite. Hardness increases due to martensitic formation in the welding layer, but this could result in a micro-galvanic effect, which decreases corrosion resistance. This research outcome could be utilized on excavator blades to enhance their hardness and corrosion resistance, which would lead to an increase in their remaining lifespan.

5. ACKNOWLEDGMENT

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