Chromium Enrichment on P11 Ferritic Steel by Pack Cementation

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ABSTRACT

The future thermal power plant is expected to operate at higher temperature to improve its efficiency and to reduce greenhouse gas emission. This target requires better corrosion properties of ferritic steels, which commonly used as materials for superheater and reheater of boiler tubes. In this work, chromium enrichment on the surface of ferritic steel is studied. The deposited chromium is expected to become a reservoir for the formation of chromia protective layer. Chromium was deposited on the substrate of steel by pack cementation process for two hours at the temperature of 850ºC, 950ºC and 1050ºC, respectively. XRD analysis indicated that chromium was successfully deposited at all temperatures. Somehow, SEM cross sectional image showed that continuous layer of chromium was not continuously formed at 850^{o}C. Therefore, this research clarify that chromium enrichment by pack cementation may be conducted at the temperature above 950^{o}C.

Keywords: Ferritic steel, pack cementation, chromium enrichment.

INTRODUCTION

Nowadays, world is facing environmental impact caused by the greenhouse gasses emission from fossil fuel combustion. The awareness of public on global climate change leads to the growing concern on the need to reduce emissions of carbon dioxide and reductions in the range 60-80% may be needed [1]. The reductions can be done by using low- or zero-carbon energy sources such as renewables energy: wind, hydro and others [2], but for the current stage, fossil fuel power plant is very important in power generation. The fossil fuels that used to generate power included coal, oil and gas mainly covered the energy consumption[3, 4]. Therefore, in order to reduce the emissions of greenhouse gases from fossil fuel power plant, increasing thermal efficiency will be one of the solutions [5].

The improvement of thermal efficiency of power plant may be realized by increasing its operating temperature. This condition may lead to more excessive corrosion, especially in boiler components which exposed to high pressure and high temperature steam. Ferritic steel is a common material that used as boiler tubes in superheater and reheater area. Many researchers have reported that oxidation rate of this steel in steam condition was faster that dry atmosphere [6-8]. This is due to retardation of chromium formation and or evaporation of chromia protective layer [9, 10]. Therefore, improvement of corrosion resistant of this steel is important in order to use this material at higher operating temperature.

In this work, chromium enrichment on ferritic steel is studied by using pack cementation process. This chromium addition is expected to become a reservoir for the formation of chromia protective layer when the steel exposed to high temperature oxidation. This work was objected to study the relation between cementation temperature and homogeneity of chromium diffusion.

EXPERIMENTAL PROCEDURE

Sample Preparation

The sample used for this study is a P11 steel. The samples were cut into small pieces of specimens with the dimensions 10x10x2 mm^3 as shown in Figure 1. The surface of specimens were manually polished to a 2000grit-grade finish using SiC abrasive papers and washed with acetone in an ultrasonic bath to remove its surface rust and greasy dirt.

Figure 1: Sample of P11 steel

For the pack cementation process, chromium powder as the masteralloy, alumina powder as inert filler and NH_4Cl as the activator, were mixed homogenously inside ball milling for 30 minutes, according to a predetermined ratio shown in Table 1. The samples were embedded in the pack mixtures inside alumina crucible and then covered by alumina lid and glued by alumina based cement. The crucible then put into horizontal tube furnace, and loaded with argon gas. The pack cementation was conducted at 850°C, 950°C, and 1050°C for two hours.

Table 1: composition of pack mixtures (wt%)

Cr	NH_4Cl	Al_2O_3	Temperature, °C	Time, h
10	5	85	850	2h
10	5	85	950	2h
10	5	85	1050	2h

Characterization method

After the diffusion coating, surface of the samples was investigated with x-ray diffraction (Rigaku Miniflex X-Ray Diffractometer) with Cu-Kα radiation in angular range of 10-90° in 0.010° steps with 2s per step. In addition, the cross section of the samples was investigated by using SEM with EDX (Tabletop SEM TM3030Plus). Before SEM investigation, sample was mounted into epoxy resin and polished by SiC abrasive paper until 2000-grit continued with diamond paste 0.3 micron, and then cleaned with acetone.

RESULTS AND DISCUSSION

Pack cementation of chromium was carried out on P11 at the temperature 850ºC, 950ºC and 1050ºC to find the suitable condition for the formation of continuous chromium layer. Figure 2 show XRD pattern of each cementation temperature. The star (*) indicator shows the impurities that affected from the carbon that were placed at the holder plate of the samples during the XRD process was running. The peak in the energy spectrum line for element Cr is clearly different in the three layers. The energy spectrum line peak for element Cr in the temperature 950ºC and 1050ºC has a higher intensity as compared to 850^{o}C, which may indicate that chromium content or thickness was higher. This result is strengthened by the cross sectional image of the steel from SEM investigation in Figure 3 until 5.

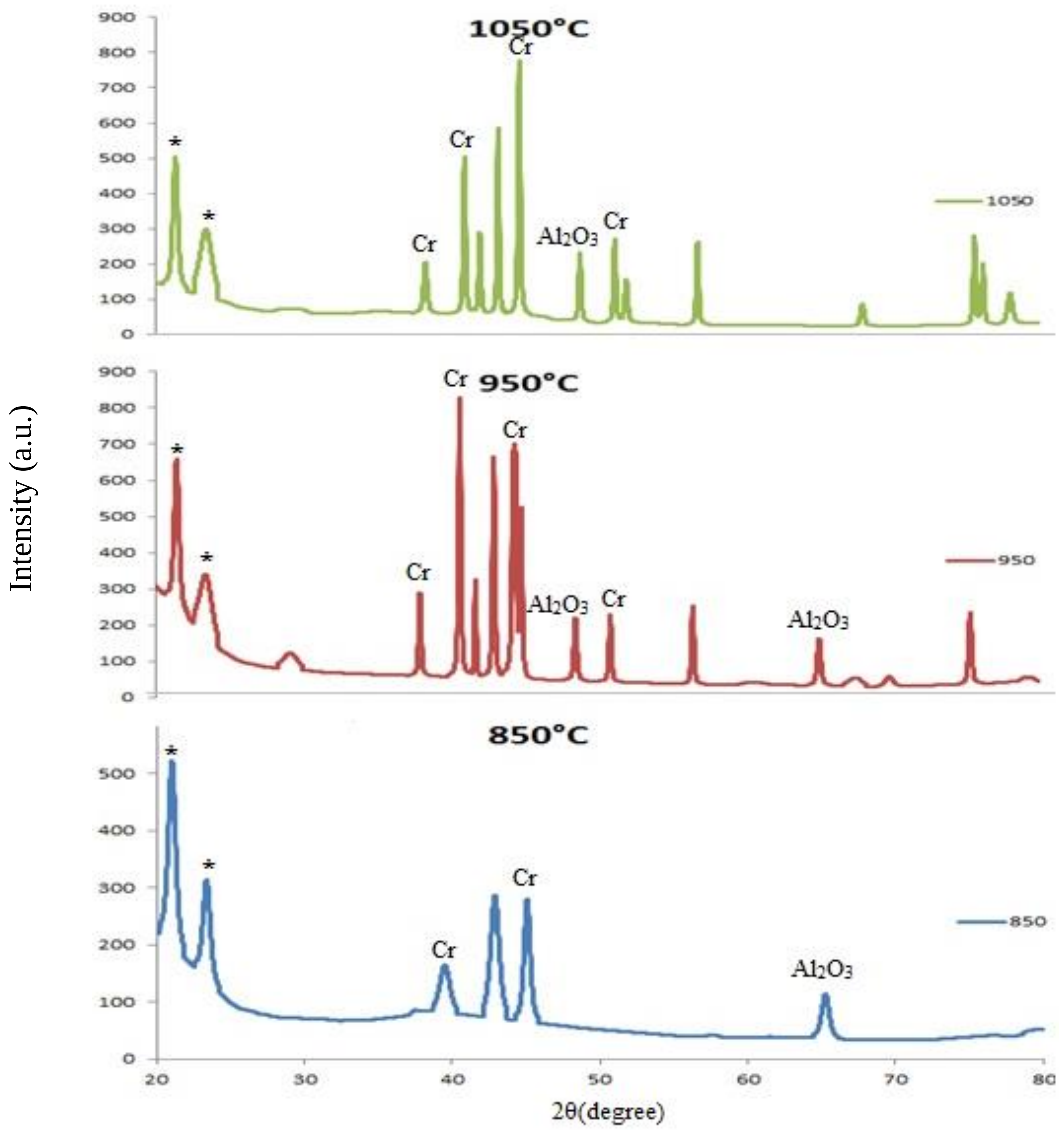

Figure 2: The XRD spectrum for different temperature for pack cementation coating process.

Figure 3 shows the cross sectional image of pack cemented steel at 850^{o}C. The thickness and formation of the Cr is not continuous and non-uniform. The inhomogeneity in the oxide will cause the non-uniform distribution of the grain size of Cr[7]. This first approach using 850ºC for the deposition of Cr using pack cementation process show a thin layer of Cr on top of the steel. Chromizing is generally thin in coating thickness because the pack continues to undergo depletion [11]. We can see from the figures, the thicknesses are very thin, which is less than 1 µm.

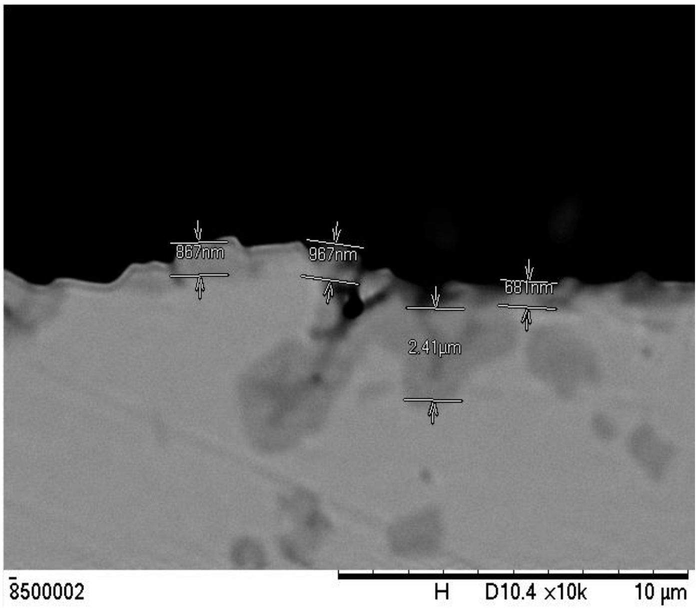

Figure 3: The image of Cr coating at temperature 850ºC under BSE-SEM image

The cross sectional image of pack cemented steel at 950ºC is shown in Figure 4. The Cr at this temperature starting to be more continuous and homogenous compare to Figure 3. The thickness of the Cr is increasing as the increasing in the temperature. The SEM-BSE image shown there are more pores are visible in the diffusion zone. The high activity of activator, chloride at the metal surface the iron in the substrate will react with the halide and cause the evaporation from the substrate. The influence of the pores to the in the diffusion zone soon will be investigated.

The result of pack cementation at temperature 1050ºC is more likely the same with 950ºC, as it shown in Figure 5. The chromium thickness at this temperature was slightly thicker due to the more Cr diffused into the steel.

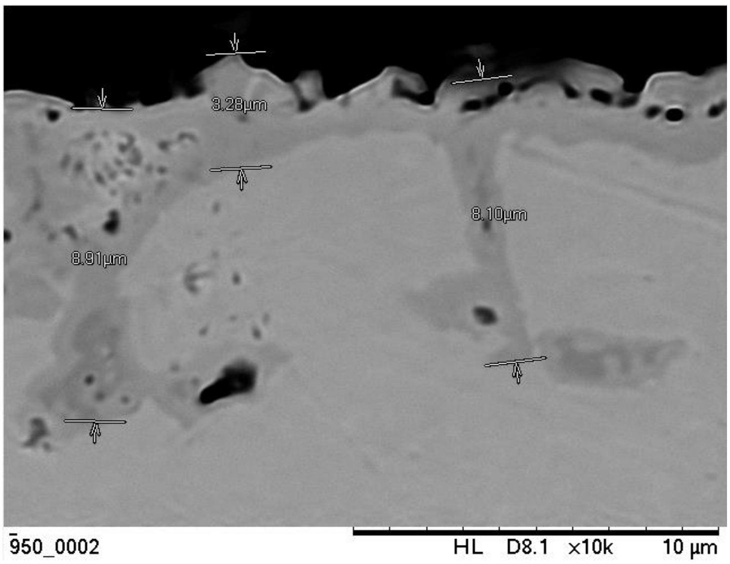

Figure 4: The image of Cr coating temperature 950ºC under BSE-SEM image

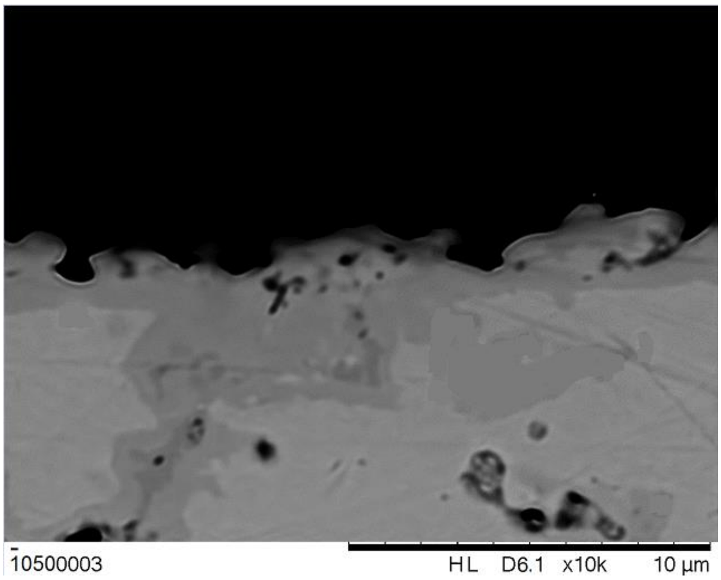

Figure 5: The image of Cr temperature 1050ºC under BSE-SEM image

CONCLUSIONS

Enrichment of chromium on the surface of P11 ferritic steel was conducted by pack cementation process at different temperature, starting from 850^{o}C until 1050^{o}C. From the investigation of cross sectional image by SEM, it was clarified that continuous layer of chromium formed when the enrichment process conducted above 950^{o}C. This continuous chromium layer is expected to become the reservoir for the formation of chromia protective layer when the steel exposed to boiler environment.

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