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MICROSTRUCTURE AND MECHANICAL PROPERTIES OF PACK CARBURIZED AISI 1020 STEEL USING NA_2CO_3 AND $CACO_3$ CATALYST

(MIKROSTRUKTUR DAN SIFAT MEKANIK BAJA AISI 1020 HASIL KARBURISASI PADAT DENGAN KATALIS NA_2CO_3 DAN $CACO_3$)

Abdul Karim[1], Ilham Azmy[*], Silviani Qotrunnida Khoiriah[2], Carolus Bintoro[3]
[1]*Department of Mechanical Engineering, Bandung State of Polytechnic*
[2]*Department of Manufacturing Process, Bandung State of Polytechnic*
[3]*Department of Aeronautical Engineering, Bandung State of Polytechnic*
*Corresponding author: ilham.azmy@polban.ac.id

ABSTRACT

AISI 1020 steel is categorized in low carbon steel which widely used for automotive parts industry and construction because its characteristic like high ductility, relatively low hardness value, and high formability. In continuously usage for long time, this steel tends to be worn down because its low surface hardness value. The surface hardness is congruity to wear resistance of AISI 1020 steel. In this research, the experimental method of pack carburizing process was carried out by heating AISI 1020 steel samples packed along charcoal with catalysts variation of Na_2CO_3 and $CaCO_3$ till temperature 900 °C and hold it for 4 hours to effect diffusion carbon mechanism in surface treatment. Thereupon, AISI 1020 steel samples was fast cooled by using distilled water. The selection of different catalyst variation according to diffusion capability which will be expected to enhance AISI 1020 steel's microstructure and mechanical properties. From this research, it obtained that pack carburized AISI 1020 steel using Na_2CO_3 possesses significant microstructure transformation which will affect to the highest hardness value increment (505,4 HV) and the lowest wear rate decrease (0,00821 mm^3/minute). Thereby, pack carburized AISI 1020 steel using Na_2CO_3 also exhibits good wear resistance characteristic so that can be used in long lifetime.

Keyword: AISI 1020 steel; mechanical properties; microstructure; pack carburizing

ABSTRAK

Baja AISI 1020 tergolong ke dalam baja karbon rendah yang secara luas digunakan pada industri komponen otomotif dan material konstruksi karena karakteristik khususnya seperti sifat keuletan yang tinggi, nilai kekerasan permukaan yang rendah, dan sifat mudah dibentuk. Dalam pengunaan secara kontinyu dalam waktu yang lama, baja ini sangat mudah untuk aus karena nilai kekerasan permukaannya yang rendah. Kekerasan permukaan tersebut sangat erat kaitannya dengan ketahanan aus dari baja AISI 1020 tersebut. Pada penelitian ini, metode eksperimen proses karburisasi padat dilakukan dengan memanaskan spesimen baja AISI 1020 yang dipack dalam campuran arang dengan variasi katalis Na_2CO_3 dan $CaCO_3$ hingga temperatur 900 °C dan ditahan selama 4 jam untuk proses difusi karbon selama perlakuan permukaan. Setelah itu, spesimen *baja AISI 1020 didinginkan secara cepat dengan menggunakan air distilasi. Pemilihan variasi katalis yang berbeda berdasarkan kapabilitas difusi yang diharapkan akan berefek pada peningkatan struktur mikro dan sifat mekanik baja AISI 1020. Dari hasil penelitian ini, didapatkan bahwa baja AISI 1020 hasil karburisasi padat menggunakan Na_2CO_3 memiliki transformasi mikrostruktur yang signifikan sehingga berpengaruh terhadap peningkatan nilai kekerasan tertinggi (505,4 HV) dan penurunan laju aus terendah (0,00821 mm^3/menit). Dengan demikian, baja AISI 1020 hasil karburisasi padat menggunakan Na_2CO_3 juga memiliki karakteristik ketahanan aus yang baik sehingga bisa digunakan dalam umur pakai yang lebih lama.*

Kata Kunci: Baja AISI 1020; mikrostruktur; pack carburizing; sifat mekanik

INTRODUCTION

Steel is one of typical material which widely used in industrial applications such as engine components, construction, and another work materials in the form of pipe sheets, profile rods, plates and so on. Low carbon steel has good ductility, however it still remains low hardness. The hardness of this steel depends on the chemical composition specifically on the carbon content. The higher of carbon content will improve the hardness of steel.

AISI 1020 steel is classified as low carbon steel which requires an engineering process in order to improves the mechanical properties. During load-applications, AISI 1020 steel structure will usually be affected by external forces like shear stresses that can raise deformation process (Marulanda-Cardona et al. 2017). Thus, it is necessary to increase adequate mechanical properties value so that AISI 1020 steel becomes stronger, harder, and durable. One of the efforts to improve the mechanical properties is utilizing surface treatment process of pack carburizing to add carbon content on the steel surface (Abidah and Drastiawati 2019).

The surface treatment process aims to obtain the required mechanical properties by controlling the parameter which occurs during the surface treatment process. One of the most widely-used surface treatment processes is the pack carburizing process. Pack carburizing aims to add carbon content on the steel surface with a solid carbonization process through the addition of a catalyst so that carbon can diffuse on the steel surface. After the pack carburizing process, it is usually followed by a rapid-cooling process (Darmo, Sinarep et al. 2021).

The addition of catalyst in pack carburizing process is very useful to accelerate the diffusion process of carbon atoms onto the steel surface so it can be resulted the increment of mechanical properties (Aji, A.B. et al. 2019, Dewangan 2021). On the other hand, a quenching process is urgently needed to increase mechanical properties such as hardness and strength which distributed continuously throughout the steel. When viewed on a micro basis, the increase in mechanical properties occurs due to the phase transformation of austenite to martensite.

Therefore, in this research, a pack carburizing process was carried out with different energyzers (Na_2CO_3 and $CaCO_3$) followed by rapid-cooling (quenching) through variations in the cooling media of pure water and oil. The choice of catalyst's variations of catalysts and cooling media aimed to improve the mechanical properties of AISI 1020 steel. Both catalysts used have a fairly high carbon atom content, so it is expected to increase the hardness value (Mandal 2016, Utami et al. 2019). In addition, variations of the cooling medium with different viscosities were carried out to observe the increase in the strength value. Thus, the results of the study are expected to show a significant improvement on the mechanical properties of AISI 1020 steel.

MATERIALS AND METHODS

Commercial steel of AISI 1020 were used in this experiment. Prior to pack carburizing process, the composition of steel was truly examined by Spectrometry to compare with the fixed standard AISI 1020 steel. Henceforth, the steel samples were machined to the appropriate dimension for the pack carburizing treatment and its characterization.

Pack Carburizing Treatment

Pack carburizing process was conducted to form carbon layer on the surface of low carbon AISI 1020 steel. Carburizing paste was used in various catalyst (Na_2CO_3 and $CaCO_3$) (PT. Bratachem).

Figure 1. Pack carburized samples

Samples (Figure 1) were treated in furnace with carburizing paste (PT. Bratachem) and heated until 900 ^oC for 4 hours holding times prior to rapid cooled by using distilled water. The as-prepared samples were subsequently characterized their microstructure and mechanical properties.

Microstructure Characterization

Microstructure characterization was carried out by using Optical Microscope Olympus BX51M. Prior to visual observations, samples were prepared according to metallography technique (ASTM E3). Preparation technique involved some processes like hot mounting, grinding with abrasive paper grade 400 to 1500 mesh, polishing with alumina paste, and ended by etching using nital (HNO_3 and methanol mixture). The prepared samples were observed by using microscope with different magnification.

Mechanical Test

Mechanical tests were carried out to assess hardness and wear resistance properties. Hardness properties were examined by using Vickers Microhardness Tester Mitutoyo HM-122. The hardness values were obtained by forcing a diamond indenter of 10 mm diameter onto the surface of the steel samples under a static load. Several hardness tests were performed on each steel sample to further determine the average value of hardness properties.

Wear resistance properties were investigated by using Force-Board Wear Tester with pin-on-disc method. This method can simulate the friction force between samples and disc which further implies wear resistance speed values of the samples. The wear test was evaluated on all samples with 2,45 kilograms load, rotary speed of 70 meter/minute with the time duration of 30 minutes.

RESULTS AND DISCUSSION

Chemical Composition

The chemical composition was examined by Spectrometry test to determine the congruity of sample steel with the standard AISI 1020 steel. Table 1 shows Spectrometry's data results of sample steel which used in this research.

Table 1. Data Results of Spectrometry Test

Element	Composition (%)
C	0,20
Si	0,24
Mn	0,17
P	0,025
S	0,024
Fe	99,34

From this table 1, the sample steel possesses the main chemical composition of ferrous (99,34 %) and carbon (0,20 %). Therefore, the resulted spectrometry test of sample steel has equal to standard AISI 1020 which classified as low carbon steel(Ebraheem and Fairouz 2019).

Microstructure Observation

Microstructure observation was examined by using metallography technique for AISI 1020 steel. This process is very pivotal to study the alteration of microstructure caused by pack carburizing on the AISI 1020 steel. To compare the microstructure alteration, three samples of AISI 1020 steel's microstructure images were taken which consisted of uncarburized, carburized using Na_2CO_3 catalyst, and carburized using $CaCO_3$ catalyst AISI 1020 steels.

Figure 2 depicts microstructure of uncarburized AISI 1020 steel (as-prepared sample). This microstructure becomes a basis to look up main formation phases from the AISI 1020 steel sample prior to pack carburizing treatment.

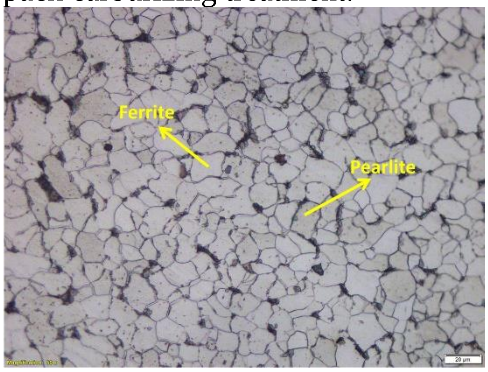

Figure 2. Microstructure image of uncarburized sample

As we seen in Figure 2, uncarburized AISI 1020 steel consists of several phases such as ferrite and light pearlite on austenite matrix. The structure of ferrite possesses body centered cubic (BCC) crystal formation which maximum carbon composition 0,025 % then affects to brittle and magnetic properties(Kurniyanto et al. 2022). This uncarburized sample considers as the most brittle compare than carburized samples.

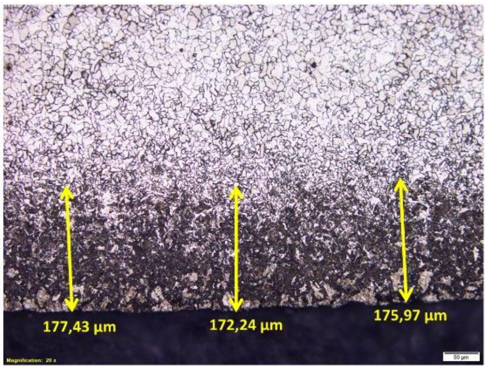

Figure 3. Microstructure image of carburized layer thickness

Figure 3 shows the layer thickness of pack carburizing surface in different locations which resulted by the deposition of carbon. The layer thickness observes approximately 175,21 µm which indicates pack carburizing process has injected the diffusion of carbon (C) atoms onto the surface of the steel(Nasution and Nasution, 2020). It also proves that the pack carburizing process has succeeded to treat on AISI 1020 steel.

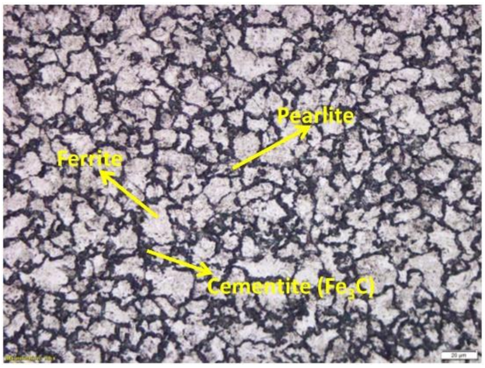

Figure 4. Microstructure image of carburized sample using Na_2CO_3 catalyst

Figure 4 depicts the microstructure image of pack carburized AISI 1020 steel using Na_2CO_3 catalyst. Pack carburizing treatment worked at austenite temperature of 900 ^oC with holding time 30 minutes and then followed by fast cooling using distilled water caused to microstructure change from austenite to pearlite. This pearlite structure is combination of ferrite and cementite (Fe_3C) phases (Juliansyah et al. 2019). In Figure 3, the dark part is caused by carbon diffusion. Martensite phase is not formed because less heat holding time and fast-cooling process so then no enough time for carbon atom to diffuse (Bahtiar et al. 2014, Haryadi et al. 2021). This structure alteration increases hardness value of carburized AISI 1020 steel using Na_2CO_3 catalyst.

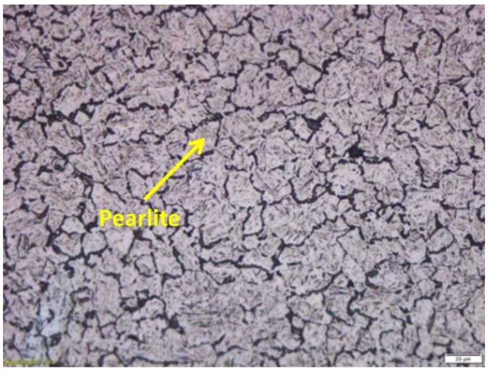

Figure 5. Microstructure image of carburized sample using $CaCO_3$ catalyst

Figure 5 portrays the microstructure of carburized AISI 1020 steel using $CaCO_3$ catalyst. The structure formation is not much different from carburized AISI 1020 steel using Na_2CO_3 catalyst which represented by the presence of pearlite. This phenomenon is affected by the same fast-cooling condition of both carburized AISI 1020 steel using Na_2CO_3 and $CaCO_3$ catalysts(Afriany, A. et al. 2017, Andika, R.A. et al. 2019). However, the pearlite structure is observed clearer in carburized AISI 1020 steel using $CaCO_3$ catalyst.

Mechanical Properties

To examine the mechanical properties of the prepared samples, hardness and wear resistance tests were investigated. The hardness value was taken on three different locations of samples which continues to calculate the average of hardness value. The comparison of AISI 1020 steels hardness average value is depicted in Figure 6.

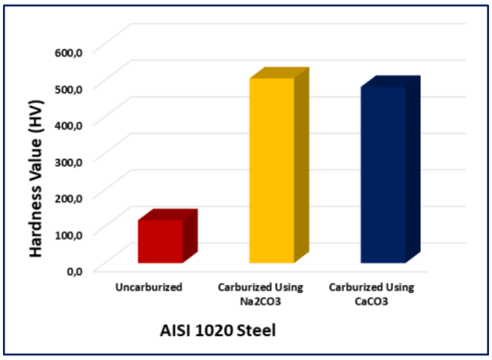

Figure 6. Hardness value of all samples

The uncarburized, carburized using Na_2CO_3, and carburized using $CaCO_3$ of AISI 1020 samples have average hardness value successively of 117,4 HV, 505,4 HV, and 482,2 HV. This hardness value difference illustrates the significant enhancement effect of carburized samples compare to uncarburized sample. Carburized AISI 1020 steel using Na_2CO_3 exhibits the highest hardness value (505,4 HV) which correlates to much formation of cementite (Fe_3C) on microstructure. This situation has portrayed that Na_2CO_3 capable to undergo interstitial diffusion on the pack carburizing process(Handoko et al. 2021). So, it concludes that Na_2CO_3 catalyst is more capable to assist diffusion of carbon onto the AISI 1020 steel.

The wear resistance is one of most important things to evaluate for determining the pack carburizing process's success. To get wear resistance data of all samples, the wear test was evaluated which resulted wear rate of all samples. Based on Figure 7, it depicts wear rate of uncarburized and carburized AISI 1020 steels using Na_2CO_3 and $CaCO_3$ catalysts.

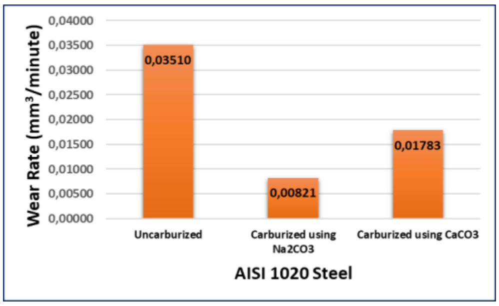

Figure 7. Wear rate of all samples

The uncarburized AISI 1020 steel exhibits the highest wear rate of 0,0351 mm^3/minute which indicates that the sample has atrocious wear resistance. Meanwhile, carburized AISI 1020 steels using Na_2CO_3 catalyst shows the lowest wear rate of 0,00821 mm^3/minute compared to carburized AISI 1020 steels using $CaCO_3$ catalyst of 0,01783 mm^3/minute. This fact demonstrates that AISI 1020 steels using Na_2CO_3 catalyst owns the highest wear resistance properties. The significant improvement occurs by the virtue of Na_2CO_3 catalyst to maximize pack carburizing process so that carbon diffusion on the surface will enhance wear resistance properties.

CONCLUSION

In summary, AISI 1020 steel was successfully fabricated via pack carburizing process using Na_2CO_3 and $CaCO_3$ catalysts. Carburized AISI 1020 steel using Na_2CO_3 catalyst has significant microstructure transformation and mechanical properties proven by highest hardness value (505,4 HV) and lowest wear rate (0,00821 mm^3/minute). These results started that carburized AISI 1020 steel using Na_2CO_3 shows intriguing characteristics which implicates to improve approximately 23% long lifetime for continuous usage.

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