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CARBURIZING OF CARBON STEEL SAE1020 USING BIOMASS ASHES OF SUGARCANE

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Abstract. *Carburizing is the thermochemical treatment consisting of introducing carbon to the steel surface by the atomic diffusion mechanism in order to increase the surface hardness of the material after it has been suitably tempered. This paper presents the use of residues from the burning of sugarcane bagasse as a solid source of carbon in the cementation process and the hardness variation obtained by the process is analyzed by Hardness Rockwell C measurement. Results indicate that the cementing process with sugarcane ash promotes the diffusion of carbon in the steel structure and increases the hardness in the steel around 19.3%*

Keywords: *thermochemical treatment, carburizing, hardness*

1. INTRODUCTION

Surface engineering represents a technically attractive and economically viable method for improving the surface layer of materials. For many applications the surface of the material controls its shelf life, so the aim is to develop a wide variety of functional properties that are different from the base substrate. Thermochemical treatment employs thermal diffusion to incorporate metallic or nonmetallic atoms on a surface of material to modify its chemical composition and microstructure (Fig. 1). The process may be carried out in solid, liquid or gaseous medium with one or more active chemical elements simultaneously (Czerwinski, 2012).

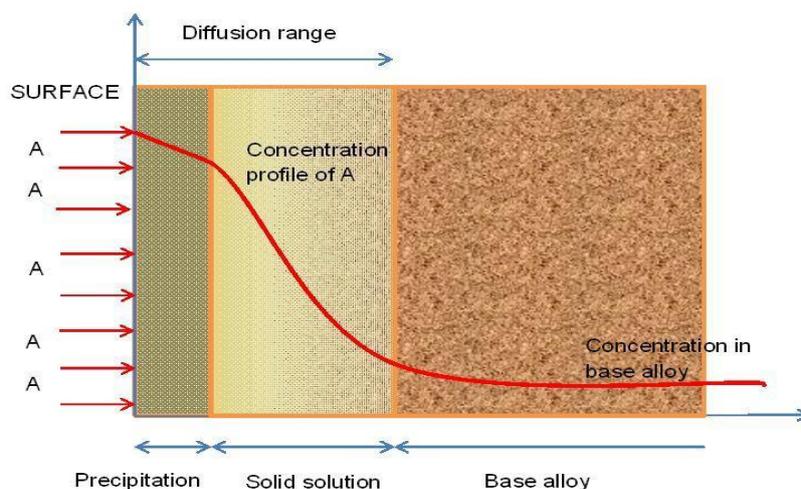


Figure 1. Principles of thermochemical treatment showing a distribution of the chemical element A inside an alloy along with typically modified sub-surface areas. (Czerwinski, 2012)

For a long time the thermochemical treatment was limited to machined parts, forged and cast with application in machinery, automotive, tooling, well drilling, mining and defense (Pye, 2003). Now the application of thermochemical treatments has expanded to alloys with exotic chemicals (Yeh et. al. ,2004), non-ferrous metals such as aluminum (Yoshida et. al, 2009) and also refractory metals. Numerous hybrid processes have been developed where thermochemical diffusion is a part of the multi-step treatment involving coating, coating, laser processing, etc. While conventional applications still dominate, there is an expansion of thermochemical treatment for new manufacturing techniques such as scale manufacturing, fuel cells (Brady et. al. 2001) or electronics (Singaravelu, 2011).

Carburizing is the thermochemical treatment consisting of introducing carbon to the steel surface by the atomic diffusion mechanism in order to increase the surface hardness of the material after it has been suitably tempered. When iron or steel is rapidly cooled by quenching, the higher carbon content in the outer surface becomes hard by transforming austenite into martensite, while the core remains soft and resistant as a ferritic and / or perlite microstructure. (Oberg, Jones and Ryffel, 1989)

To achieve sufficient carbon solubility and depth of penetration, the treatment is performed at relatively high temperatures of 900-950°C. As a result, steels, which do not have sufficient carbon content within their volume, get the hard surface (Czerwinski, 2012). The part has its hard surface and its ductile interior, making the steel can have many benefits that being previously totally ductile would not have (Barra, 2013).

Solid-state carburizing consists of placing the part inside a metal box together with carbon-rich substances (charcoal, coke, calcium carbonate and linseed oil) and elevates it to high temperatures. Thus, the whole will form carbon dioxide, which will combine with a carbon monoxide previously placed in the box, which will cause it to form the cementite, responsible for the transformation of steel. After that, the piece is cooled quickly so as not to lose its new composition (Fraga, Lima and Silva, 2017).

A possible source of carbon is the sugarcane bagasse ash obtained from boilers of sugar and ethanol plants. The largest mass-produced by-product from the processing of sugarcane in sugar and alcohol mills is the sugarcane bagasse (in this text also referred to as biomass). In order to serve as fuel for the production of energy, the bagasse is burned in boilers resulting in ash. In the 2017/2018 harvest 633.26 million tons of sugarcane were harvested. Considering that all bagasse was used as fuel, 3.8 million tons of ashes were generated. These ashes are discarded in the soil, intended to serve as fertilizer, but present low nutrient content and contribute to contamination of soil and groundwater resulting in negative environmental impacts (Castro and Martins, 2016; CONAB, 2018).

In order to compare the surface hardening, a method commonly used is the measurement of surface hardness, it is a measure of the resistance of a material to a localized plastic deformation (for example, a small indentation mark or a scratch) the softer the material, the higher and the deeper the retreat. Generally, the Rockwell hardness test is the method used to measure the hardness of a material, due to its simple execution. The Rockwell Hardness method is represented by the symbol HR (Hardwell Rockwell) and when followed by a letter, this letter indicates the scale that was used, "C" indicates normal hardness test (Callister, 2008).

This paper presents the use of residues from the burning of sugarcane bagasse as a solid source of carbon in the cementation process and the hardness variation obtained by the process is analyzed by Hardness Rockwell C measurement.

2. RELATED WORKS

Pulverized bone was utilized by Aramide et al (2010) as a carbon source for carburizing of a mild steel (0.1999% C). The researchers carburized the workpieces at 850°C, 900°C and 950°C, during 15 minutes and 30 minutes, after quenched in oil and tempered at 550°C. They concluded that the sample carburized at 900°C and soaked for 15 minutes, and the one carburized at 850°C soaked for 30 minutes, both followed by oil quenching and tempering at 550°C, were better because they showed a trend of hard case with softer core.

Baumgartem and Costa (2005) utilized activated charcoal residue from the soft drink industries to produce a grainy for solid carburizing that was mixed with calcium carbonate (CaCO_3) and employed to carburization of samples of steel ABNT 8620. The treatment was performed under a temperature of 930 °C and periods of 4 and 8 hours. After, some specimens were air-cooled and others were oil-cooled at 50 °C. The researchers concluded that this method is capable of producing the desired results regarding the carburizing treatment, as well as producing less environmental impact when compared to the traditional process that uses charcoal (not its residues) and barium carbonate (BaCO_3) which is a heavy metal.

A carburizing mixture composed of charcoal and commercial carburizing powder (Cimentox) was produced by Freitas et al (2016). The mixture was used to carburize SAE1020 steel samples at a temperature of 950 °C for 120 minutes, then air-cooled. This mixture is capable of producing carburized layer and has a lower cost than using only commercial powder, however there is no reduction of environmental impact. The surface microhardness of the samples was increased to 49 HV relative to the core (the microhardness of the surface is 180 HV and the one of the core is 131 HV).

Gentil, Santos and Cintra (2019) analyzed the use of biomass, obtained as waste from the sanitary paper industry, in the solid carburizing process of AISI 8620 steel. Usually this cellulose biomass is destined for landfill or incineration.

The authors also replaced barium carbonate, which presents toxicity, with calcium carbonate, as a catalyst element. The samples were carburized at 900 °C during 4 hours, then, they were quenched in water at 25 °C. Using a mixture of 80% in mass of biomass and 20% in mas of calcium carbonate, it was possible to obtain a surface hardness increase of 365 HV and a core hardness increase of 263 HV (the core is at a distance of 8 mm from the surface).

Ihom (2013) mixed cow bone and charcoal in different proportions to produce a carbide element. The mixture was used to carburizing a steel with 0.13% C, in an electric furnace at 900 °C, during 8 hours. The result showed that 60 wt% charcoal / 40 wt% cowbone had the highest effective case depth of all the carburizing compounds used. With this proportion, a hardness of 950 HV was achieved in the surface and a hardness of 550 HV was achieved in 2.32 mm depth. The presence of CaCO₃ in the cow bone plays the role of an energizer, speeding up the reaction.

Umunakwe et al (2017) used a palm kernel shell/coconut shell mixture as carburizers for low carbon steel (0.16% C) at 950 °C. The carburizers were washed, dried, milled and sieved to 150µm particle size. They were mixed in various compositions to serve as carburizers. In each composition, 20wt% of calcium carbonate (CaCO₃) was added as energizer. The specimens were subjected to pack carburization and thereafter quenched and tempered at 450oC for forty five minutes in a heat treatment furnace. The surface hardness was increased obtained the best values when a mixture composed of 20 wt% palm kernel shell powder and 80 wt% coconut shell powder, in this case, the hardness was increased in 20 HRA relative to the control sample.

3. METHODOLOGY

To realize the first tests, four workpieces were prepared using a steel rolled cylindrical billet SAE 1020. First the specimens were machined to acquire the desired dimensions (diameter of 20 mm and height of 15 mm), and then, they were rectified to obtain a better surface finish.

Table 1. Chemical composition of steel SAE 1020 in percentage

C	Mn	P max.	S max.
max. 0,27	0,60 / 0,90	0,040	0,05

For the heat treatment treatments was used the muffle oven Scientific GP with maximum heating temperature of 1200°C, as Figure 2.



Figure 2 – Muffle oven used in heat treatments.

All workpieces were tempered, being heated for 1h in oven at 900°C and cooled inside the oven.

The solid carburizing mixture was prepared with 80% in mass of biomass ash from sugarcane and 20% in mass of potassium carbonate (K₂CO₃), which acts as a catalyst, accelerating the carbonation reaction (Chiaverini, 1984). The ashes used as carbon source were acquired in a sugar and ethanol plant in the interior of São Paulo / SP. The carburizing was carried out in an electric oven at a temperature of 900 ° C for 9 hours in two workpieces, the other two will serve as a basis for comparison.

The samples were radially cut and mounted with polyester resin, sanded, polished and attacked with 2% Nital acid for 5 seconds and its analyzed microstructure and made the measurements of microhardness, as Figure 3.



Figure 3. Sample cut, sanded, polished and attacked.

In order to verify the carbon diffusion on the surface and thus verify the success of the experiment, a metallographic analysis will be made for carbon rich steel microstructure and a microhardness test will be performed on the HMV-2000 Shimadzu microhardness from the edge to the inside of the material 0.5mm pitch, as Figure 4.

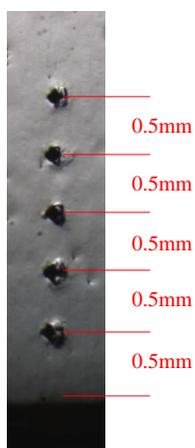


Figure 4 – Microhardness measurement scheme

4. RESULTS

The results of the metallography are presented in Figure 4. In the non-carburizing workpiece we can observe a higher proportion of ferrite (light phase) in relation to pearlite (dark phase), in the carburizing workpiece there is a greater amount of dark phase (pearlite), evidencing the carbon diffusion process due to the carburizing process.



non-carburizing workpiece



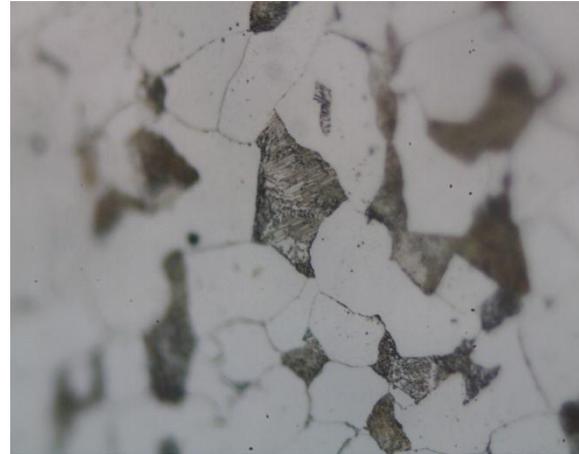
carburizing workpiece

Figure 4. Metallography with a 200x increase and attacked with 2% Nital acid for 5 seconds.

A perlite can be viewed in detail in Figure 5, it is possible to see in detail how cementite lamella (dark lamellas) at the base of ferrite (light) in the dark detached grains. Cementite contains 6.67% carbon and 93.33% iron, again showing the carbon increase due to surface diffusion.



non-carburizing workpiece



carburizing workpiece

Figure 5. Metallography with a 100x increase and attacked with 2% Nital acid for 5 seconds.

In Figure 6 we can see that the carburizing process had a higher hardness near the surface, a hardness close to or possibly higher than 160 HV, due to limitations of the measurement process, hardness measurements close to the edge cannot be made, the applied process has a satisfactory success up to a depth of 2.5 mm and that up to 1.5 mm a hardness close to 160 HV.

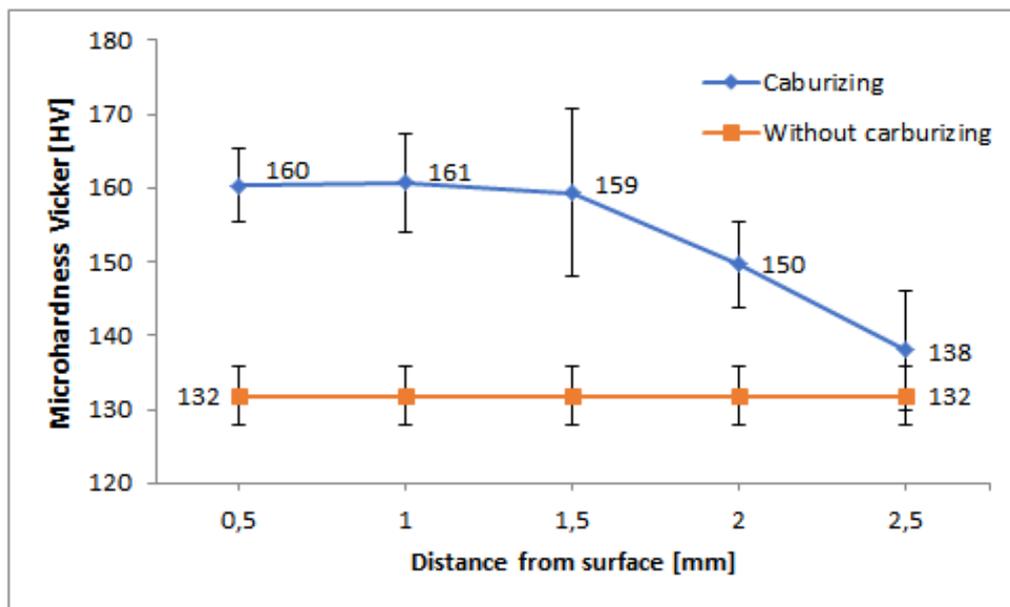


Figure 6. Microhardness Vicker. HMV-2000 Shimadzu microhardness tester and a Vickers pyramid-shaped diamond indenter, under loads of 0.2 kgf and a dwell time of 15s.

5. CONCLUSIONS

Analyzing the metallography we can observe that carburizing significantly increased the amount of pearlite on the surface of the material, proving the diffusion of carbon in the structure of the material.

If we analyze the increase of hardness in the surface up to 1,5mm deep we have an increase of 21.2%, and the carburizing process carried out succeeds up to a depth of 2,5mm in that it happens to have the hardness similar to non-carburizing.

The increase in steel hardness after chemical treatment was about 19,3% and shows that the use of sugarcane biomass ash may be promising for the field of thermochemical treatments.

For the next steps it is intended to perform tests with other types of steel as well as wear test.

6. ACKNOWLEDGEMENTS

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