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Research paper

Husk rice used in the pack carburizing process of the AISI 1020 steel

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Abstract

Carburizing is a heat treatment used to increase the carbon concentration on the surface of specimen of steel, in order to obtain a high hardness and a toughness core. One of the methods used to achieve these characteristics is the pack carburizing using charcoal or mineral coal. In this work, the heat treatment of pack carburizing on the SAE 1020 mild steel (disks 75 mm in diameter and 10 mm thick) is carried out using rice husk as a carbon source. The heat treatment was carried out at a temperature of 950° C with a soaking time of 7 hours. In addition, the results of the experimentation were compared with the results obtained with the traditional charcoal. In general, it was observed in the microstructural analysis and in the surface hardness that the charcoal, unlike the rice husk, provides better characteristics in terms of a greater penetration of the carbon in the piece and in the achievement of greater hardness.

Keywords: *AISI 1020 Steel; Hardness; Husk Rice; Pack Carburizing.*

1. Introduction

The Most of the pieces that are part of the different machines are manufactured in steel (especially low and medium carbon steels), ensuring that their mechanical properties are as uniform throughout the section of the piece. However, for certain applications it is necessary that the parts present surfaces with high hardness that make them resistant to wear and a core sufficiently ductile to absorb the impacts to which this is subjected.

The different combinations of mechanical properties required in a piece of steel are usually obtained by the application of heat treatments. Carburizing is one of the most used treatments to obtain in low carbon steels unique characteristics of high hardness and toughness in a piece at the same time (surface-core) [1-6]. This treatment consists in heat up the piece of steel for a certain time at a temperature higher than Ac_3, in a medium that provides carbon. Medium that can be liquid, gaseous or solid. Traditionally, pack carburizing is carried out using charcoal or mineral coal as materials that provide carbon to the surface of the piece of steel. These raw materials are mixed with carbonates ($BaCO_3$, Na_2CO_3, K_2CO_3, $CaCO_3$), which are called energizers and are products that accelerate the carburizing reaction, the carbon potential and the transport rate of the carbon from the carburizing medium to the surface of the piece.

Recent literature reports the use of other types of substances that also provide carbon as well as the aforementioned carbons. Various residues (organics) have been shown to be competitive alternatives to traditional carburizing medium as well as to different energizers (carbonates). Oluwafemi et al [7] carried out pack carburizing in SAE 1020 steel, using as carburizing substance palm-shell carbon. During the execution of this treatment temperatures between 800° C and 950°C were used with soaking times of 60, 90 and 120 minutes, the carburized parts were quenched in oil and were tempered at 500°C for 60 minutes and then cooled in air. The results showed the formation of microstructures typical of a hardened steel in the treated steel specimens, also the hardness value obtained in the surface is greater than the value obtained in the core, confirming that there was an increment of carbon in the surface, expected behavior in the heat treatment of carburizing.

Putra Negara et al [8] performed pack carburizing at a temperature of 950°C with a soaking time of 240 minutes in low carbon steel (0.17% C), using different proportions of a carburizing mixture constituted by charcoal produced from the stem of bamboo and goat bones and barium carbonate as energizer, the results obtained showed the production of case depth with the consequent increment of hardness in the surface of the piece, which decreases when approaching the core. The case depths obtained with the different mixtures oscillate between 0.5 and 1 mm, the maximum case depth reached (1 mm) is achieved with the mixture consisting of 20% of barium carbonate, 60% of goat bone coal and 20 % bamboo stem charcoal. Putra Negara et al [9], carry out a heat treatment of carburizing using charcoal produced from coconut shell fibers mixed with barium carbonate as energizer in an 80/20 proportion respectively, in order to evaluate the wear resistance obtained in a steel with 0.17% of carbon. In the treatments carried out, temperatures of 950°C were used with soaking times of 120, 240 and 360 minutes, after carburizing the specimens were quenched in water. The results obtained showed greater hardness and wear resistance in the specimens treated during 360 minutes. The specimens showed a progressive decrease in hardness from the surface towards the core, in which the hardness corresponded to that of the metal in the condition without heat treatment. Istiroyah et al [10], used charcoal obtained from coconut shell and rice husk at a temperature of 600°C, in the carburizing of AISI 316L steel. The specimens were heated to 400°C with a soaking time of 480 minutes. The results indicated that there was a better distribution of the carbon in the carburized steel with the coconut shell charcoal than in the carburized steel with rice husk charcoal. The behavior of the hardness obtained was greater (by 40%

compared to untreated steel) in the specimen carburized with coconut shell charcoal, with rice husk charcoal the hardness had an increase of 26%. Ihom et al [11] used as carburizing sources: charcoal obtained from melon shell, rice husks, sugarcane bagasse, plastics such as polyethylene, palm flowers and egg shells as energizer; the steel used for carburizing presented in its composition 0.25% of carbon and a hardness value of 30 HRC. The treated specimens were heated to 920°C for a time of 300 minutes, under two conditions; in one condition carburizing medium was used only and in the other condition a mixture of carburizing medium with egg shell (50 g) as energizer. Then, the pieces were quenched in water. The results showed that the highest hardness reached was approximately 56 HRC with the mixture of palm flowers and egg shell, with case depth of 0.7 mm. The potential of the egg shell as energizer is demonstrated in this work, due to its high content of $CaCO_3$

Ihom et al [12] also used charcoal as carburizing medium and cow bones as energizer (taking advantage of its high content of calcium carbonate) in different proportions for carburizing of a piece of RST 37 steel (with 0.13% C) with 16 mm in diameter and 30 mm in length. The mixtures used for the carburizing process were: 100% charcoal, 75% charcoal and 25% cow bones, 70% charcoal and 30% cow bones, 60% charcoal and 40% cow bones. Carburizing process was carried out at 900°C with a soaking time of 480 minutes. At the end of the heat treatment it was obtained that the best results achieved with the mixture formed by 60% of charcoal and 40% by pulverized cow bones, where the case depth obtained was of 2.32 mm.

Darmo et al [13], used in the carburizing of SS400 steel (SAE 1020) a mixture of teak wood charcoal and powdered snail shells (Pomacea Canalikulata Lamarck-PCL) as energizer in proportions of 10, 20 and 30%. Carburizing process was carried out at 950°C with soaking times of 3, 5 and 7 hours. As a conclusion it was obtained that the best carburizing results were achieved using a 20% of PCL. Arthur EK et al [14], carried out carbonitriding of SAE 8620 steel using powdered cassava tree leaves mixed with $BaCO_3$, in a 4: 1 ratio, the heat treatment was carried out at 900°C, with a soaking time of 5 hours. The results showed changes in the microstructure and hardness of the original material compared to the treated specimens. The microstructural changes are evident after the hardening of the specimens. In the untreated specimens, the present phases are ferrite and perlite, with predominance of ferrite. In the treated specimen ferrite and martensite are observed, the presence of martensite indicates that there was an increment in the percentage of carbon and consequently an increase in hardness.

The aim of this study was to establish the carburizing potential that the rice husk can offer, as an agricultural residue, to provide carbon to the surface of a specimen of SAE 1020 mild steel when it is heat treated by pack carburizing.

2. Experimental procedure

2.1. Carburizing steel

The material (specimens) used to carry out the heat treatment of pack carburizing were SAE 1020 mild steel disks. Specimen's dimensions were 75 mm of diameter and 10 mm in thickness, the chemical composition is shown in Table 1.

Table 1: Chemical Composition of AISI 1020 Steel

C	Mn	P	S	Si
0.199 %	0.586 %	0.045 %	0.059 %.	0.154 %

2.2. Carburizing materials and energizer

Charcoal and rice husk were used as carburizing mediums and calcium carbonate ($CaCO_3$) as energizer. The chemical composition of the carburizing mediums obtained by elemental analysis is shown in table 2.

Table 2: Chemical Composition of Carburizing Sources

Elemental analysis (%)					
	C	H	O	N	S
Rice husk	41.13	3.37	35.3	0.33	-
Charcoal	72.31	2.43	-	1.16	1.05

2.3. Equipment

The equipment used were: electric furnace type muffle (maximum temperature 1200° C), with a 40x40x40 cm hearth, universal hardness tester model HBRVU 187.5, Olympus BX51R optical microscope with software for image analysis Stream Basic, metallographic double disc polisher model GP-2, Metallographic cutter of frontal action lever model Q-3A, pack carburizing boxes manufactured in austenitic stainless steel 304, SEM Phenom pro X.

2.4. Hardness and microstructural identification

The Brinell hardness method was used to measure the hardness along the surface layer through to 16 sweep indentations at the diametral direction as shown in Figure 1.

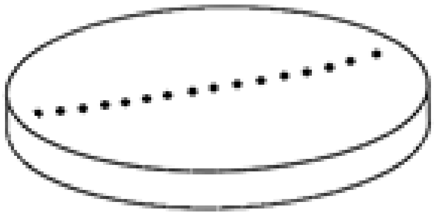

Fig. 1: Hardness Measurement Points in the Carburized Specimens.

The specimens for microstructural identification were mounted in polyester resin and initially were grinding with SiC abrasive grade paper (from 180 to 1000). The final polishing was made with alumina paste of 1 µm. All specimens were etched with picral (4 g of picric acid-100 ml of 96% methanol).

2.5. Heat treatment of pack carburizing

The heat treatment was carried out using carburizing mediums and energizer material (mixture) as indicated in table 3.

Table 3: Mixture Composition of the Pack Carburizing

Mixture code	Amount of carburizing source [g]	Amount of energizer [g]
MC1	500 g of charcoal	-
MC2	500 g of charcoal	333, 3 g of $CaCO_3$
MC3	500 g of husk rice	-
MC4	500 g of husk rice	333,3 g of $CaCO_3$

Before the introduction of the specimens submitted to the heat treatment(disks) in the boxes, it was uniformly spread on the bottom of these 100 g of the mixture used, then the specimen was introduced in the center of the box (one disk per box), which was filled with the mixture without compacting until it was completely covered. The boxes were sealed with refractory cement; this sealant was prepared using 830 g of cement and 200 ml of water. The sealed boxes were allowed to dry for 12 hours and then were placed in the electric furnace (one box at a time). The temperature for the heat treatment was set at 950°C with a soaking time of 7 hours. Carried out each pack carburizing treatment the specimens were removed from the furnace and cooled at room temperature.

3. Results and discussion

The figure 2 shows the micrographs of the SAE 1020 mild steel specimens used in the study, figure 2a corresponds to the steel in the state of supply, the structure observed is ferrite and pearlite; being the matrix constituent the ferrite and the dispersed constituent the perlite, characteristic constituents for the chemical composition indicated in table 1. Figures 2b to 1e correspond to the specimens with heat treatment using the carburizing mixtures indicated in table 3.
The figure shows from the core to the surface, a progressive increment in the amount of pearlite is observed, this amount remaining in the core equal to the amount observed in the image of the specimen without heat treatment (figure 2a). This progressive increment in the proportion of pearlite shows that both the rice husk and the charcoal allowed the introduction of carbon (diffusion) into the steel specimen, showing an increment in the amount of carbon until certain distance from the surface (case depth). Case depth that, as it can be seen, was greater in the specimens that contained energizer material in its composition (figures 2c and 2e), In this way, the stipulated in the literature [15] is contrasted with respect to the potentiating effect of the energizer in the increase of the diffusion rate of the carbon in heat treatment of pack carburizing. The results also showed that the carbon diffusion was more intense in the specimens that were heat treated with charcoal (figures 2b and 2c), the expected result, taking into account that the percentage of carbon in this, is higher by 43.11% to the percentage present in the rice husk.

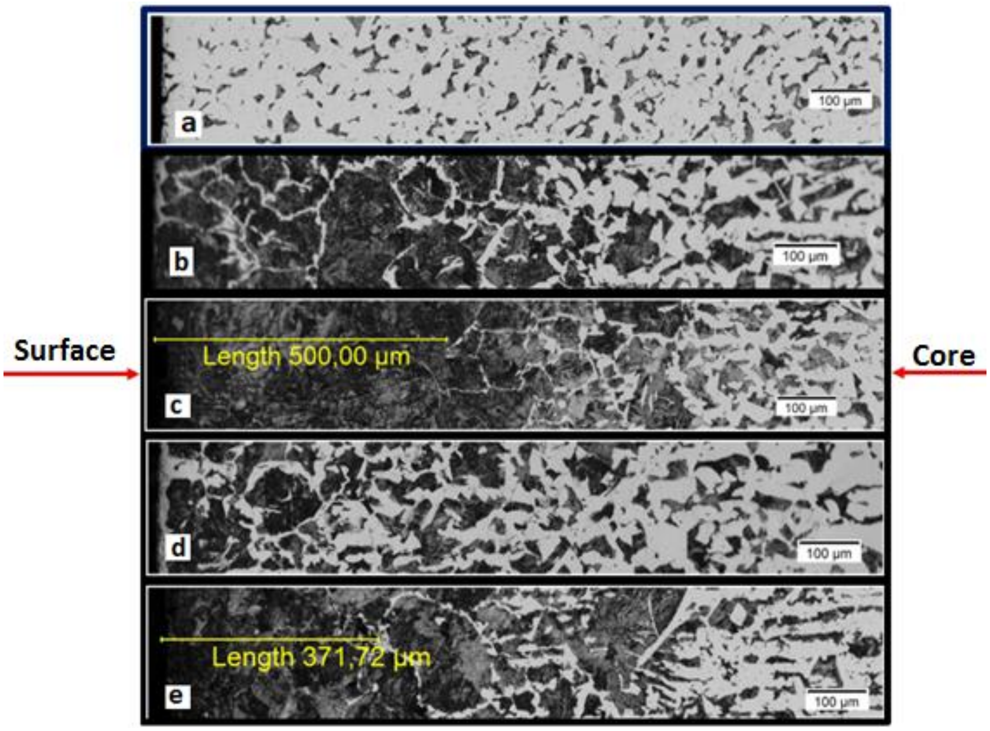

Fig. 2: Optical Micrograph of SAE 1020 Mild Steel Specimens: (A) Uncarburized (Base Material), (B) Carburized Specimen with MC1, (C) Carburized Specimen with MC2, (D) Carburized Specimen with MC3, (E) Carburized Specimen with MC4. Etched with Picral. 100X.

Likewise, the results indicated in table 4, make it possible to complement what was previously expressed (is observed in the table the percentage of carbon achieved in the carburized zone as a function of the carburizing mixture). It can be seen that in the specimens that were carburized with charcoal (MC1 and MC2) a greater percentage of carbon was obtained in this zone. Although, in the figures 2b and 2d, no uniform thickness of the diffused carbon is observed as that observed in figures 2c and 2e, it does not indicate that the carbon content has not increment on the surface of these specimens, it is sufficient to compare with figure 2a and the values given in table 5 to observe this increment. Increment that was higher in the specimen carburized with charcoal without energizer (figure 2b), being able to appreciate a greater amount of perlite there.

Table 4: Carbon Percentage Obtained at the Case Depth

Condition of the specimens	Carbon (%)
Carburized with MC1	46.85
Carburized with MC2	67.90
Carburized with MC3	37.81
Carburized with MC4	48.89

The data presented in table 5 show the hardness increment obtained when using a certain carburizing mixture in the heat treatment.

Table 5: Hardness Brinell Values Before and After Pack Carburizing Process

Condition of the specimens	Average hardness values without quenching [HB]
Uncarburized	171
Carburized with MC1	226.6
Carburized with MC2	254
Carburized with MC3	210.6
Carburized with MC4	233

In this work, no measurements of hardness were made along the enriched zone with carbon (case depth), these measurements were made on the surface of the carburized specimen (disk), as is illustrated in figure 2. The highest hardness was obtained when pack carburizing was made with charcoal and energizer (MC2 mixture), this hardness value was 254 HB, and the hardness value in the uncarburized specimen was 171 HB. When in the pack carburizing heat treatment were used the MC1 and MC4 mixtures, the hardness value obtained is very similar, being this hardness value greater than that of the uncarburized specimen. The similarity in these results can be explained with reference to the composition values (% carbon) indicated in table 4, it is observed that the percentages of carbon obtained in the pack carburizing heat treatment with these mixtures are very close to each other. Therefore, it is reasonable that hardness values are also similar too.

4. Conclusion

The results presented in this work show that the use of rice husk (agricultural waste) as a carburizing substance in the pack carburizing heat treatment, allows to be added carbon to the surface of the steel, achieving on this surface an increment of hardness with respect to the hardness presents in the steel without heat treatment. However, the results indicate that the carburizing potential of the rice husk is lower than that of traditional charcoal.

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