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THE EFFECT OF CARBONACEOUS MATERIALS AS MOULD ADDITIVE ON WHITE CAST IRON

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ABSTRACT: Carbonaceous materials as mould additive on white cast iron were studied. Two different carbonaceous types which were animal and plant sources were pulverized and some micron sizes were prepared such as below 53, 75-53 and 106-75 microns. Their effects on moulding sand were analyzed and compared. The caking potential of each material was considered through swell index test. The cast samples were prepared for metallographic analysis and the results were compared. Hardness and abrasion resistant test were equally performed on the samples. It was observed that the microstructure shows clear colony of cementite matrix, this invariably indicate high increase in hardness of 42.50HRC and wear resistant of the 75-53 charcoal which appears to be the highest while the lowest value of 29.24HRC was recorded for 75-53 of burnt cow bone.
KEYWORDS: Carbonaceous materials, microstructure, abrasion resistance, hardness, white iron

INTRODUCTION

White cast iron derives its name from the white, crystalline crack surface observed when a casting fractures. After fractured, cracks pass straight through due to its carbide impurities. An improved form of white cast iron is chilled cast iron [1].

White cast iron is hard and brittle and cannot be machined easily. It is the only member of the cast iron family in which carbon is present as carbide. Most white cast irons contain less than 4.3% carbon, with low silicon contents to inhibit the precipitation of carbon as graphite. As a result of graphite absence, it has a light appearance. The presence of different carbides makes white cast iron extremely hard and abrasion resistant, but very brittle [2].

The microstructure contains massive cementite (white) and pearlite. It also contains interdendritic cementite (white), which sometimes has a Widmanstiitten ("spiky") appearance. Austenite forms as the proeutectic constituent before the eutectic reaction (liquid transforms to austenite and cementite) and later transforms to pearlite and cementite upon cooling below the eutectic temperature [2].

Carbonaceous materials are materials that are very rich in carbon content, at least, about sixty to eighty per cent (60-80%) of carbon. The carbonaceous materials being used, which are burnt bone and charcoal are gotten from animal and plant respectively. Graded coal is the term given to ground coals with the fines (particle size below 75 microns/200#) effectively removed or reduced considerably [3]. If coals are used for over 60% below 75 microns/200# they lose some of the activity, simply because the release of volatile is quick and at this very fine particle size they are often removed by extraction systems.

A well graded coal is characterized by zero percentage above 1mm (such particles may cause surface gas blows) and around a maximum of 30% below 75microns/200#. This is only consistently achieved by considerable investment in cyclone type extraction processing allied to screening technology [4]. The ideal coal grading is dependent on the casting weight and configuration, coupled with the type of moulding plant and the metal analysis. As a general rule, the finer the details required, the finer the coal grading. High pressure moulding plants, either vertical or horizontal, tend to use the coarser grades as this will aid permeability and the slow release of volatile is a major advantage in these systems [4]. These coarser grades has the ability to re-cycle and therefore have a positive effect, as well as the important coke forming stage which helps increase the total carbon in the system.

A lot of researches have been done on this topic where much was said on the particle size of the carbon. Also some mentioned the low ash content and volatile matter. Not too many researchers have focused on the surface hardness effect of the carbonaceous additives on the surface of the metal due to the carbon diffusion from the mould. Particle size of the carbonaceous additives (75microns/200#) is called a graded carbon. This research work is to give an insight to the effect of graded carbon on the surface properties of the metal other than just surface finishing.

EXPERIMENTAL PROCEDURE

Experimental heats were obtained by remelting cast iron engine block, foundry returns, ferro-alloys and pure metals in a cupola furnace at the melting temp of cast iron which is 1300^{0}C, but in other to ensure total melting of material charge, 1700^{0}C temperature was ensure before tapping. System sand was used but more bentonite was added to improve its bonding strength. Carbonaceous additives of different sizes of micron and concentration for both charcoal and burnt grinded cow bone (53 below micron, 53-75 micron, 75-106 micron) and in proportion of 15kg of sand to 2kg of each micron of carbonaceous additive to 1 litter of water. Sieve analysis was carried out in respect with the particle size of coal to achieve a reasonable graded size of coal. The sieve sizes used are 600micron, 425micron, 300micron, 150micron, 106micron, 75micron, 53micron.

Bones of cows are gathered together and burnt to charcoal. Wood is gathered and also burnt to charcoal. The burnt materials are then pulverized for further grading. The pulverized carbonaceous additives are sieved properly with sieves of different mesh sizes, using the sieve shaker. The particle sizes are: 106-75µ, 75-53µ and 53below. The pattern is of a wooden material. The pattern is a cuboid 100mm in length, 50mm in breath and 10mm thick. The pattern is well grafted. The shrinkage value of white cast iron (21mm) is put into consideration.

Moulding sand is properly sieved to remove very coarse particles. The sieved sand is mixed with Bentonite for proper binding. Little percentage volume of water is added to the mix to give the mixture a good green strength. The facing sand is further sieved for a finer particle size then the facing sand is mixed with carbonaceous materials from the two different sources. The moulding sand composition is a per cent volume of the total mixture. Silica sand contains 85%vol; bentonite contains 10%vol, and moisture of 5%.

Metallography

Sectioning of the cast iron material involves the cutting of the material into smaller pieces for proper handling of the material during grinding and polishing and also for proper mounting. Grinding stage is a primary stage of smoothing the surface of the sample to be examined. The grinding grits of emery papers are (60, 220, 320, 400, 800, 1000, and 1200). Polishing is the secondary surface smoothing done to get a shiny mirror like surface. The polishing cloth is impregnated with diamond paste. Mounting involves placing the sample on a hold able resin material; in case the material is not handy Etching involves the addition of a Nital reagent to reveal the microstructure better on the microscope.

Swell Index

The pulverized carbonaceous materials (burnt bones and burnt wood) are mixed with a little amount of bentonite. They are packed into the moulding machine and pressure of about 700N is excreted on the material to attain a compacted form of the carbonaceous material. The compacted form is cylindrical due to the shape of the mould. The microstructure is examined under a microscope, and the examination is noted. This is first done to be able to compare the former with the latter. The compact is them fired in the furnace up to 700^{0}C for 45mins. This brings about change in the colour of the materials and also some loss of volatiles and also the swelling of each of the material. The microstructure is then checked again. On analyzing the boundaries of the grains, the fusion of the particles determines the caking of the carbonaceous substance.

Hardness test

Hardness test was carried out with the use of indentech (indentation testing machine).The flat surface of the sample is put at the pointer of the machine. The sample is held together by tightening of the knob. As the grip on the sample increases, indications will be seen on the digital reader. At the final gripping, the machine gives a final sign, and the sample is left at the mouth. The machine displays the hardness value and it is recorded. The procedure is repeated five times for each sample, picking five different points on each sample.

Abrasion resistance

Abrasive test were also carried out by using precision surface grinding machine [conventional machine], model TH – M3270. The machine adopt concealed structure of grinding heat motor, the configuration is elegant and natural. Longitudinal movement of worktable of machine adopts hydraulic nonpolar transmission and also can be transmitted by hand wheel. Transverse movement of worktable not only can be transmitted by motor, but also by hand wheel which uses clutch gear to realise the interlocking of manual and power evaluation and ascendance of wheel are controlled, work piece is place on the worktable size 320 x 700mm and the spindle grinded is made to move horizontally on the fixed work piece at a constant feeding rate of 0.01mm/sec. the grinding stone is made of corundum carbide with speed of 1440/1747 rev/min.

RESULTS AND DISCUSSION

The micro structure shown in Figure 1(a) of 53µ below charcoal carbonaceous mould additives [CMA] shows clear colony of cementite matrix formed, this invariably indicate high increase in hardness value. The eutectic formed is endogenous dendrite formation with more retain austenite *present which transformed to pearlite at room temperature. Figure 1(b) of 75-53 μ charcoal appears that solidification starts from austenitic dendrites formation while as the temperature decreases cementite matrix evolved. Austenitic phase decompose on cooling but some still precipitate in the eutectic cell which form pearlite. This has effect on the hardness of the material and it is endogenous dendrite formation. In Figure 1c of 106-75μ charcoal, there is an increase in size of CMA; gas released is minimal which affect carbide matrix formation. The microstructure reveals fine cementite morphology formed. At Figure 1(d), 53 below micron burnt cow bone CMA, the structure reveals little precipitate of austenite with colony of carbide precipitating to cementite morphology. It shows spiking inter-dendrite carbide morphology which grows into cementite matrix. This can be attributed to the gas evolved from the CMA and its properties (denser). Figure1(e) of 75-53 μ cow bone CMA, shows features of white carbide of the matrix of eutectic cementite, however, untransformed austenite is much which is retain in pearlite, this will soften the metal a little. The morphology of cementite matrix is interwoven with clear carbide dendrite growth.*

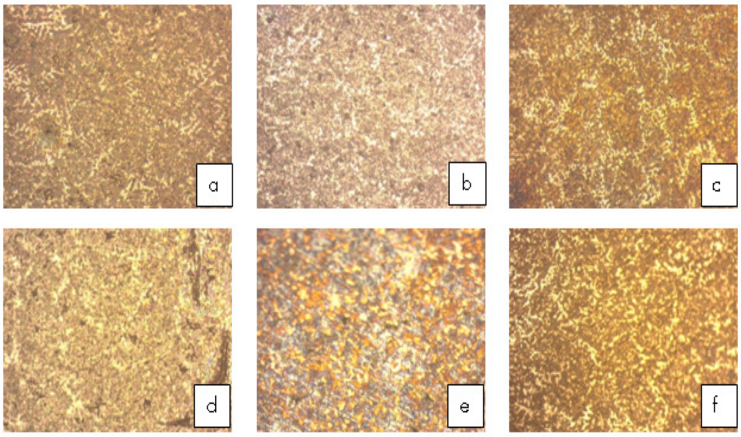

Figure 1. Microstructure of varying graded charcoal (a-c) and burnt cow bone (d-f)

The particles of the burnt cow bone before firing is well compact. The grain boundaries are noticeable, also the sizes of the particles are small and there is easy recognition of one particle from the other. After some minutes of firing, the particles fused together, thereby increasing the surface area of each particle, indication the caking ability of the additive and expected lustrous carbon formation. The caking ability of the different carbonaceous additives were compared, it was quite obvious that the caking ability of the charcoal is much more than that of the cow bone. The charcoal swells more and also fuses more than the burnt cow bone, although, the cow bone also made some noticeable swellings. This could be explaining that the charcoal has more fixed carbon than the burnt cow bone [5].

Figure 2(a) shows that the optimum hardness is obtained at the sample with 106-75μ having 39.32HRC. The softness gotten at 75-53 μ for burnt cow bone with 29.24HRC could be as a result of the eutectic formation of the honey comb ledeburite, which gives the insight of where there is less strength, there is less hardness [6]. For a moderate hardness burnt cow bone with 75-53 μ could be use as mould additive while 106-75 μ is recommended for maximum hardness. Generally, increase in hardness could mainly be as a result of refinement of structure from pearlite to martensite. When there is reduced hardness, then plastic deformation will increase [7].

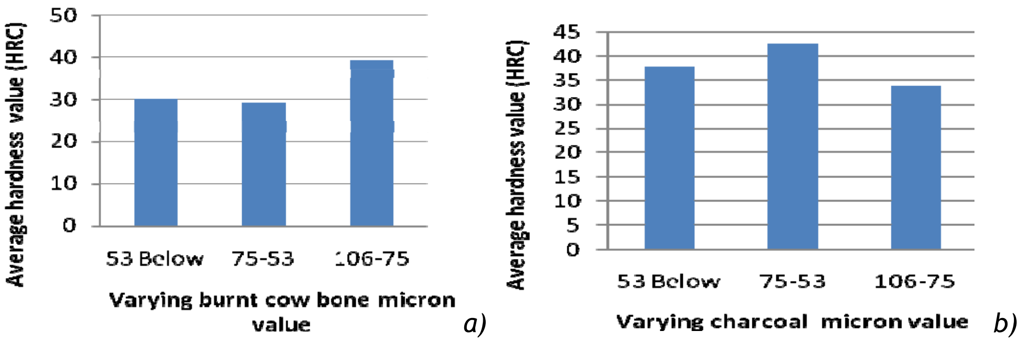

Figure 2. Average hardness value of burnt cow bone (a) and charcoal (b)

It can be noticed that among the several of charcoal additives, the graded additive is the most preferred for the white cast iron. It gives the highest hardness. If the desired property in the cast is hardness, then the addition of 75-53 μ charcoal amongst the particle sizes of the charcoal could be recommended. Also, for a low hardness, 106-75 μ addition of charcoal is preferred. The possible cause of low hardness in the 106-75 μ sample must have been an effect of larger particles not volatizing fast as smaller particles will. In general, the hardness effect of the charcoal addition as a carbonaceous additive to the surface of the samples has brought a considerable high hardness. This explains the plate-like cementite formation in the eutectic.

The analysis of the two carbonaceous additives gives a good comparison of the effect of the additives on the hardness of the cast samples. Figure 3 indicates that: at below53 μ, the hardness effects of the two different additives are almost apart which means hardness differs in the material *at that chosen micron. The optimum result is reached at the grading of 75-53 μ carbonaceous materials.*

From the swell index observation, it shows that there is more fixed carbon in the charcoal which could be given out to the surface of the metal, thus, making the surface hard. The same also applies to burnt cow bone where there is not much swelling and the material's surface is soft, due to little fixed carbon in the material. At the standard grading (i.e.75-53 μ), cow bone and charcoal displayed the lowest and highest hardness respectively i.e. 42.5HRC and 29.24HRC respectively. At the addition of the 106-75 μ, the balance range of hardness in the metal sample is about the same. The range displayed a balancing selection between the positioning of the softest and the hardest.

In these wear results; it is assumed that the microstructure plays an important role in the weight loss [8]. The carbon content of the cast irons is chosen to be identical and consequently the volume fraction of hard eutectic carbide is almost the same in the microstructures (Figure 1). The differences in the microstructures are the austenite decomposition products developed on continuous cooling after solidification

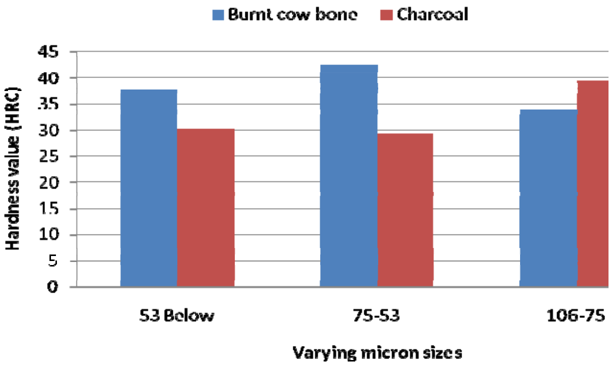

Figure 3. Comparison between cast samples from burnt cow bone and charcoal additives

This must have been the high hardness seen in the material, and the high hardness was caused by the carbon diffusion in the carbon-rich carbonaceous material [9-10]. This sample possess the highest hardness that can be found in all the samples and therefore, it was expected to have a high resistance to wear, which correlate with previous hardness result obtained. 106-75 μ graded carbon seems to be the least resistant of the carbonaceous additives of charcoal, as the percentage weight loss after 15 minutes is 1.26 as compared to 75-53 μ and 53 below micron with 0.61 and 0.77 respectively.

The results obtained from the wear resistance test correlates with the microstructure and hardness test. From the hardness test, 75-53 μ of charcoal proved to be the hardest and so it is with the wear resistance result obtained. Also, 75-53 μ for burnt cow bone proved to be the softest wore faster than others.

CONCLUSIONS

The effect of swell index property in carbonaceous additives has been brought to light by understanding that it is part of the qualities to consider if any carbonaceous additive is to be added to the mould. This could be explaining that the charcoal has more fixed carbon than the burnt cow bone, hence higher hardness.

It is concluded that the grading of the carbonaceous additive can effect change on the surface hardness and wear resistance of the white cast iron.

The optimum result is determined by the preferred desire of the foundry engineer. If the desire of the engineer is high hardness in the material, then 75-53μ charcoal could be recommended and also if softness is to be improved in the material, then the cow bone of 75-53μ is recommended. If on the average, the properties are to be maintained on a balanced level, 106-75μ of both carbonaceous additives can be used as substitute for one another.

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