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BEHAVIOR OF LOW CARBON STEEL MECHANICAL PROPERTIES DUE PACK CARBURIZING MEDIA CHARCOAL BUFFALO BONE

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Abstract
Pack Carburizing is one way to increase the hardness of a material but still gained a strong material. This study aims to determine the effect of variations in the percentage of media carburizing with buffalo bone charcoal powder as carbon in the carburizing process on mechanical properties of low carbon steel. Temperatures used in carburizing process takes place is 900ºC with a holding time of 60 minutes. In this process the carbon obtained from buffalo bone charcoal made into a fine powder and combined with $BaCO_3$ as energizer. Percentage of buffalo bone charcoal powder as carburizing media at 65% BBP + 35% $BaCO_3$, 75% BBP + 25% $BaCO_3$, 80% BBP + 20% $BaCO_3$ weight of buffalo bone charcoal powder used in the process of carburizing. In this study, the steel will be added to the barium carbonate and buffalo bone charcoal powder is heated in the furnace at a temperature of 9000C. Then testing hardness Vickers and tensile strength.Results of research material hardness for normal or without treatment equal to 74.333 kg / mm2 and a tensile strength of 636.94 N / mm2. Meanwhile, after being subjected to the hardness carburizing pack will increase, and the largest in percentage 80% BBP + 20% $BaCO_3$ namely 91.667 kg / mm2. The tensile strength after pack carburizing process and the greatest increase in the percentage of 80% BBP + 20% $BaCO_3$ ie 1233.78 N / mm2. By looking at the results of the study can be in the know that the percentage of buffalo bone charcoal powder as the media pack carburizing hardness and tensile strength of low carbon steel.

Introduction
Pack carburizing is a heat treatment process in which the process of heating and cooling the metal (figure 1) in the solid state to change the properties of the physical and mechanical metal.Through appropriate heat treatment, the voltage can be reduced, the grain size can be enlarged or reduced, enhanced toughness or produce a hard surface around a resilient core.The cooling rate is the controlling factor, where cooling faster than the critical cooling will produce a hard structure while slow cooling will produce a softer structure.To allow for proper heat treatment, the chemical composition of the steel must be known due to changes in the chemical composition, particularly the carbon element can result in changes in the physical properties and mechanical properties.In general, in addition to the element carbon steel containing nickel (Ni), chromium (Cr), manganese (Mn), molybdenum (Mo), tungsten / wolfram (W), silicon (Si), vanadium (V), copper (Cu), sulfur (S), tin (Sn) and phosfor (P) with different levels.

When a piece of steel with a carbon content of 0.20% is heated evenly with slow and the temperature recorded at specified intervals, will obtain the curve as shown as follows :

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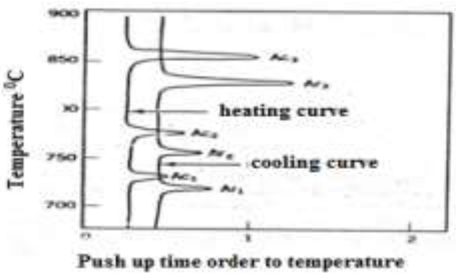

Figure 1. The rate curve - inverse to Baja SAE 1020 (Amstead, B.H., et al, 1992).

Changes that occur at the point - a tipping point is an allotropic change. By definition, an allotropic change is a change that is capable of turning or reversible on the atomic structure of a metal which is followed by a change in the nature.Changes the points is to be known, given the heat treatment of steel include heating above this area. Hardened steel can not be heated above except under the critical areas and sometimes above the upper critical area.

Suppose a piece of steel 0.20% carbon steel is heated at a temperature of 870ºC, above the Ar_3 point of steel is a solid solution of carbon in iron-gamma and called austenite. Atom - iron atoms form a cubic lattice concentration side (face centered cubic) and is non-magnetic. When cooled to a temperature below the point Ar_3, atoms will form a cubic lattice convergence space (body centered cubic). This new structure called ferrite or iron -alpha and a solid solution of carbon and iron - alpha. Solubility of carbon in iron - alpha is much lower than when the carbon in the iron - gamma. At the point Ar_2 steel is magnetic, and when the steel is cooled until the line Ar_1, ferrite formed will increase.In line Ar_1 remaining austenite will be transformed into a new structure called pearlite. Perlite appear as a layer consisting of ferrite and iron carbide plates alternately.

If levels exceed 0.20% carbon steel where ferrite begins to form and precipitate from austenite. Carbon steel yield 0.80% called eutectoid steel and the structure is 100% perlite. At the eutekoid point is the lowest temperature in the metal where there is a change in a state of solid solution, and is the lowest equilibrium temperature where austenite decomposes into ferrite and cementite (Amstead, B.H. et al, 1992).

Austenisasi temperature hardening temperature and recrystallization temperature of a steel, is determined by to the percentage of carbon content. Guidelines for determining the temperature of hardening can be used several ways such as diagrams iron - iron carbide (Fe - Fe_3C) for carbon steel (Fig. 2), the temperature of hardening is at 30°C - 50°C above the critical temperature (see shaded area) standard treatment hot materials (eg AISI) and by using the product catalog. Steel with a carbon content below 0.35% can not be hardened unless additional carbon elements prior to the material to be hardened through carburizing processes (carburizing).

Components and structures made of steel have problems not only in terms of hardness, ductility or toughness, but also in terms of fatigue caused by wear surface as alternating voltage and voltage arcing. To overcome these problems need to give a hardness on the surface of the component, which can be done by carburizing, titers are high frequency current or flame and so on.

In the process of the pack carburizing in the box, using charcoal mixed with certain solutions such as $NaCO_3$, $CaCO_3$ or $BaCO_3$ which serves as the activator material and at the same time as the energizer element, then the mixture is inserted into the steel in the form of specimens that will harden. The box is then sealed to avoid air from the outside and then heated 750ºC-950ºC, and thus the steel surface will have a higher carbon content. Because the steel structure becomes rough due to the heating time, then after the first hardening at 750ºC-950ºC, then mashed with the second or the hardening-quenching at 800ºC (Figure 2), and in-tempering at 150-200ºC (figure 3) before used.

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Carburizing reaction can be explained as follows:

$2C + O_2 \longrightarrow 2CO$ (1)

Then CO dissociate into C_{at}:

$2CO \longrightarrow CO_2 + C_{at}$ (2)

The gas produced by the energizer can occur with reaction equation:

$BaCO_3 + panas \longrightarrow BaO + CO_2$ (3)

then carbon dioxide gas (CO_2) reacts with solid carburizer forming carbon monoxide gas (CO) with the reaction equation:

$CO_2 + C(arang) \longrightarrow 2CO$ (4)

where C dissolves into steel (Surdia, T. and Shinroku, 1992)

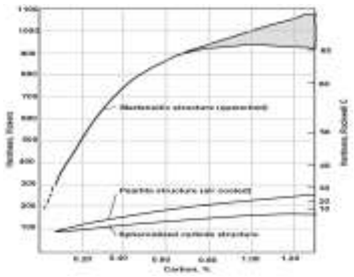

Figure 2. Hardness Due Quenching Process (Meyrick, G. and Wagoner, R. H., 2001)

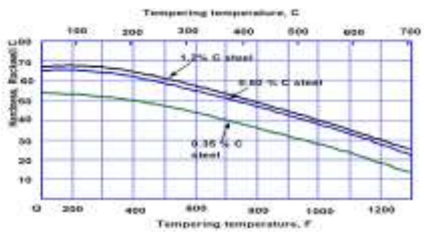

Figure 3. Temperature Tempering Vs Hardness (Meyrick, G. and Wagoner, R. H., 2001)

The heat treatment in low-carbon steel is based on the principle of thermochemical diffusion system, which is a way to change the surface properties of the substrate, it is necessary to add external materials and additional materials will be diffused into the surface of the substrate. Heat treatment of steel is also based on the principle of physical metallurgy associated with the processing, properties and microstructure. In the heat treatment process, the entire process of using heat to change the structure of the steel. To change the properties of the steel surface can be done by changing the structure and shape of the surface with a *thermomechanical treatment*.

Chemical heat treatment on steel is the steel heating process by adding certain substances when heated, then cooled. Chemical heat treatment can be either (1) carburizing, (2) nitriding, (3) cyaniding or carbonitriding, and (4) diffussion coating. Carburizing is a coating process with carbon steel surface by heating the steel at a temperature of 750ºC-950ºC. Carbon powder used to form a solid, liquid or gas. Thick layer of carbon formed on the surface depending on the length of heating is done, which varies from 0.5-2 mm with a coating rate of 0.1 mm / hour. The carburizing process will increase the carbon content of the steel surface layer of about 0.75 to 1.20%.Carburizing process can not be done on any steel, depending on the level of carbon contained in the steel and carburizing process is generally carried out on low carbon steel (> 0.35% C). "Carburizing process is often done to harden the surface of the gear and the cam or cam (Malau, V., 1999)". To accelerate the penetration of carbon into the specimen during pengarbonan process, it is necessary to add other elements such as $BaCO_3$, $NaCO_3$ and others. "Research on the effects of pack carburizing process to fatigue steel ST60 using charcoal and barium carbonate ($BaCO_3$) plus sodium carbonate ($NaCO_3$), 950ºC temperature of 850°C and held for 5 hours.

The results show that the surface hardness increased from 220, 856 HVN to HVN be 417.139 and fatigue life is also increased from 2,017,451 into 4,154,577 cycles (Yasa, I.N., 2000) ". "Research on the relationship between the case depth of carbon due to the carburizing process fatigue strength steel SAE 8620. carburizing process is carried out with 940ºC temperature was held for 45 minutes, 3 and 5 h followed by quenching at a temperature of 850°C detained 15, 30 and 60 minutes. The result indicating that the longer the hold time the case depth and fatigue strength of carbon steel SAE 8620 higher (Asi, O., et al, 2007) ".

Research on the effect of holding time dense to the surface hardness carburizing steel AISI - SAE 1522 with coconut shell charcoal and $NaCO_3$ by 20% as the activating substance. The result is 570 HV (2 hours), 753 HV (3 hours) and 773 HV (4 hours) (Sudarsono, 2003) ". "Research on the effects of media composition carburizing wood charcoal powder barium carbonate to abuse and wear of low carbon steel. Barium carbonate ($BaCO_3$) varied 15%, 20%, 25% and 30% with the treatment temperature 850°C, 900ºC and 950ºC and held for 2 hours. The results obtained are the highest surface hardness, which is 667% and resistance to wear by 816% driven primarily by the carburizing process at a temperature of 950ºC with the addition of 20% barium carbonate (Suryanto, H. et al, 2005) ".

Carburizing process at ST37 steel lathe chisel with a temperature of 950ºC media charcoal arrested 2 hours followed by quenching. The result concludes that the steel ST37 is subjected to carburizing process can be used to cut steel or other material that is softer (Rumendi, U. and Purnawarman, O., 2006) ". "Research on the effect of carburizing process against the notched fatigue behavior of austenitic stainless steel AISI 316. The results show that the fatigue resistance of the sample carburizing increased compared with that of the untreated sample (Akita, M. and Tokaji, K., 2006)".

Hardness

Hardness is a material's ability to resist scratching, abrasion, wear, indentation, penetration and able to withstand loads up to the occurrence of plastic deformation. Hardness testing aimed at evaluating the heat treatment, and detect hardening or softening due to overheating, decarburization or surface hardening.

Hardness measurement method, which is carried out by way of indented material mengguanakan indenter on the surface of the specimen at a certain load then the former emphasis formed was measured. "Indentor usually made of hardened steel, tungsten carbide and diamond-shaped pyramid with a square mat apex angle between the two opposite sides of 136º.

In general, the Vickers hardness testing method with micro scale (micro hardness) which dlakukan based on ASTM standards. On testing Vickers, given loading slowly without any shock loads and held 10-15 seconds. After the indenter raised, both former stamping diagonally measured and averaged, then the Vickers indentation hardness (HV) is calculated by the equation:

$$HV = \frac{2.P.\sin(\theta/2)}{d^2} \quad (5)$$

$$d = \frac{d_1 + d_2}{2} \quad (6)$$

$$HV = \frac{1,854P}{d^2}\left(\frac{kgf}{mm^2}\right) \quad (7)$$

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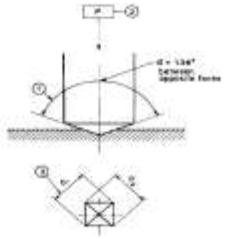

Figure 4. Micro Vickers Hardness TestingMethods(ASTM E-92)

Table 1 Vickers Hardness Testing Variables

Number	Symbol	Designation
1	...	Angle at the vertex of the pyramidal indenter (136°)
2	P	Test force in kilograms-force
3	d	Arithmetic mean of the two diagonals d^1 and d^2

Table 2 Hardness Relationship Layers With Carbon Content

The carbon content (%)	**Coating hardness (HR_C/HV)**
0,28 – 0,32	35/345
0,33 – 0,42	40/392
0,43 – 0,52	45/446
≥0,53	50/513

Source : Boyer & Gall, 1985

Strength Tensile

The tensile strength (ultimate tensile strength) is the ability of a material to withstand tensile loads. It is measured from the load / maximum force inversely proportional to the cross-sectional area of test material.

Tensile test was done by giving a load on both ends of the test specimen is slowly increased until the test specimen broke. This can be ascertained by testing tensile strength, yield load and modulus of elasticity (Young's modulus) strength, a reduction in cross-sectional area and the length.

The test aims to determine the strain and stress of particle board that has been made. The results of this testing is the graph of load against extension (elongation). Strength (σ) can be formulated into:

$$\sigma = \frac{P}{A_0} \qquad (8)$$

Strain (ε) can be formulated into:

$$\varepsilon = \frac{\Delta L}{L_0} \qquad (9)$$

where P is the applied load (N), A_0 is the initial cross-sectional area (mm), L_0 is the initial length (mm), ΔL is the length(mm).

Modulus of elasticity (E) can be formulated into:

$$E = \frac{\Delta\sigma}{\Delta\varepsilon} \qquad (10)$$

where Δσ is the stress (MPa), ΔƐ is strain (%), E is the modulus of elasticity (GPa).

Strength and Strain Curves

The line shows the deformation in a tensile test specimens as shown in Figure 5. When the load is applied to the first, stretched specimen is proportional to the load, this effect is hereinafter referred to as linear elastic properties. If the load is removed, the object back to its original shape.

Nominal strength or strength technique, described as the ratio of the load applied to the initial cross-sectional area of the test specimen. When the load starts to increase at a certain strength level, the specimen experience permanent deformation (plastic). At that rate, the strength and strain is no longer proportional as in the elastic region, where the incident occurred is known as the yield stress. The term yield strength is used to determine the point where the stress and strain is no longer comparable.

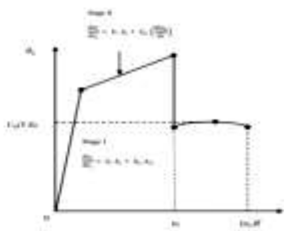

Figure. 5 Strength-Strain Curves Pull

The maximum tensile strength (ultimate tensile strength) is the maximum strength that can be borne by the composite material prior to the fracture. The maximum tensile strength values are determined from the maximum load divided by the initial cross-sectional area

$$\sigma_{max} = \frac{P_{max}}{A_0} \qquad (11)$$

where σ_{max} a maximum tensile strength (N / mm^2), $P_{max}$is the maximum tensile load (N), A_o is the initial cross-sectional area(mm^2).

FacilitasAnd Methods

In this research using the kitchen heater (furnace) as a place to warm up with the steel box carburizing made of steel plate 5 mm with a resistance to temperatures of up to 1500°C., Hardness tester micro methods Vickers (micro hardness), test equipment tensile (stensile strength), the handle grip electric drill to the sample when sanded, saws for cutting material, and spring scales.

Materials used in this study was low carbon steel in accordance with in accordance with ASTM E-466.

With the percentage of media carburizing varies bone charcoal buffalo and Barium carbonate ($BaCO_3$), which is 65% BBP + 35% $BaCO_3$, 75% BBP + 25% $BaCO_3$, 80% BBP + 20% $BaCO_3$ where decision-bone buffalo on traditional party and home cut animals in Toraja. Cleaning of buffalo bone and followed by drying, buffalo bone cutting for charcoal, refining the mesh 30 buffalo bone charcoal as an energy source pack carburizing.

Procurement of low carbon steel is done by first measuring and cleaning of low-carbon steel by washing with asethon. Manufacture of low carbon steel specimens for hardness test and tensile test, before being subjected to, the manufacture of test specimens for experiments testing hardness and tensile test experiment after being treated with pack carburizing.

Material Low carbon steel test specimen after capture data on violence and early strength, the test object is wrapped with steel wire as a hook to facilitate the process of appointment of the specimen in hot conditions.

Low carbon steel test specimen is put into the box cementation, backfilled with carbon (charcoal buffalo bone and barium carbonate ($BaCO_3$) to cover the whole surface.

Enter cementation box into the furnace and then shut down. Turn on the furnace, and then see the initial temperature 27-30ºC. Wait until the end of the heating temperature of 850ºC, with a holding time of 60 minutes. Then turn off the furnace and open the furnace, remove the cementation of the box by using forceps.

Lift the carbon steel test specimen from inside the box cementation using gancu and enter into a cooling medium such as distilled water, leave to cool. Then, remove the test specimens of low and medium carbon steel on the inside of the cooling medium. Clean up of the remnants of carburizing process, then sandpaper one side until the net for hardness testing process as well as the tensile strength.

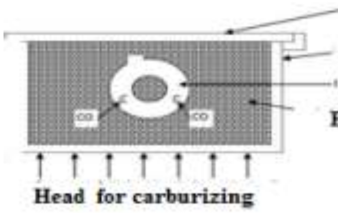

Figure 6. Tool of Carburizing Process

This research was conducted at the Laboratory of Physical Metallurgy and Mechanical Technology. Department of Mechanical Engineering, Faculty of Engineering, University of Hasanuddin Makassar in September and October 2017.

Results and discussion

Hardness

The result showed that the hardness of low carbon steel that is treated with a pack carburizing process at temperatures up to 850ºC with a variation of the composition of buffalo bone charcoal carburizing media and $BaCO_3$ can be seen in Table 3 following :

Table 3 Table hardness low carbon steel due to pack carburizing.

No.	Percentage media carburizing	specimen	D (cm)	HV (kg/mm^2)	Average HV (kg/mm^2)
1	Normal	1	1.588	72	74.333
		2	1.588	76	
		3	1.588	75	
2	65%BBP+35%$BaCO_3$	1	1.588	82	81.667
		2	1.588	80	
		3	1.588	83	
3	75%BBP+25%$BaCO_3$	1	1.588	86	86.667
		2	1.588	87	
		3	1.588	87	
4	80%BBP+20%$BaCO_3$	1	1.588	92	91.667
		2	1.588	91	
		3	1.588	92	

Based on the above table can be illustrated in a graph in Figure 7 below:

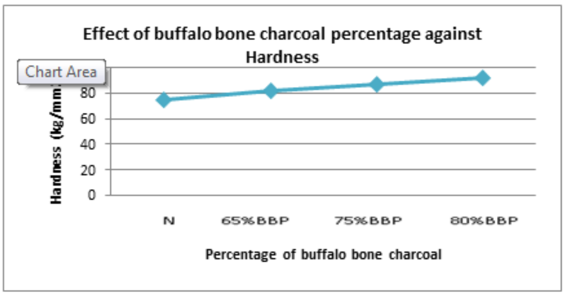

Figure 7. Graph of buffalo bone charcoal percentage effect on low carbon steel hardness

According to the table and chart above shows that the higher the percentage of bone charcoal buffalo provided in the material of low carbon steel the hardness increases from material hardness normal 74,333 kg/mm^2, and an increase in hardness at a percentage of 65% BBP + 35% $BaCO_3$ amounted to 81,667 kg/mm^2, hardness at a percentage of 75% BBP + 25% $BaCO_3$ amounted to 86,667 kg/mm^2, hardness at a percentage of 80% BBP + 20% $BaCO_3$ amounted to 91.667 kg/mm^2. Can be concluded that the heat treatment of materials of low carbon steel at a diameter of 1,588 cm with the pack carburizing at heating temperature 850°C with long lasting 30 minutes on the size of the mesh 30 and the load used for the suppression of 60 kg with the variation of the percentage of bone charcoal buffalo effect on the hardness, which the greater the percentage of the hardness of this increasing due to the more carbon that enters the material which causes the material harder and other wise.

Tensile strength

The result showed that the tensile strength of a low carbon steel that is treated with a pack carburizing process at temperatures up to 850°C with a variation of the composition of buffalo bone charcoal carburizing media and $BaCO_3$ can be seen in Table 4 below:

Table 4 Table Tensile Strength Low carbon steel due to pack carburizing

No	MediaCarburizing	Specimen	A_0 /mm^2	Load max (N)	Strength Tensile N/mm^2	Average Strength Tensile (N/mm^2)
1	Normal	1	28,26	18000	636,94	636,94
2	65%BBP+35%$BaCO_3$	1	28,26	24200	856,33	966,03
		2	28,26	28300	1001,41	
		3	28,26	29400	1040,33	
3	75%BBP+25%$BaCO_3$	1	28,26	29600	1047,41	1060,40
		2	28,26	30400	1075,72	
		3	28,26	29900	1058,03	
4	80%BBP+20%$BaCO_3$	1	28,26	38800	1372,96	1233,78
		2	28,26	33600	1188,96	
		3	28,26	32200	1139,42	

Based on the above table can be illustrated in a graph in Figure 8. below:

[*Nitha * et al., 4(12): December, 2017*]
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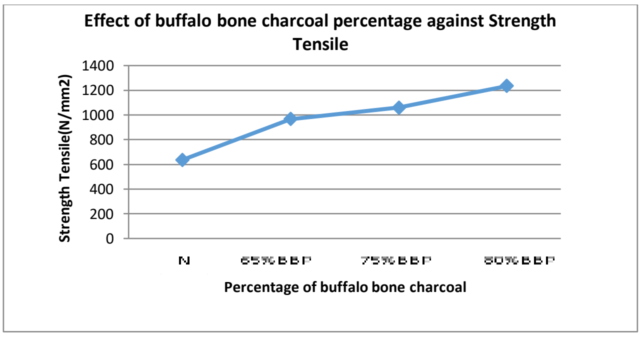

Figure 8. Graph buffalo bone charcoal percentage influence on the tensile strength of low carbon steel

According to the table and chart above shows that the higher the percentage of bone charcoal buffalo provided in the material of low carbon steel the strength of its increasing of tensile strength of the material normal 636.94 N/mm^2, then an increase in the value of the tensile strength at a percentage of 65% BBP + 35% $BaCO_3$ amounted to 966.03 N/mm^2, tensile strength values at a percentage of 75% BBP + 25% $BaCO_3$ amounted to 1060.40 N/mm^2, tensile strength values in percentage 80% BBP + 20% $BaCO_3$ amounted to 1233.78 N/mm^2. Based on the above results it can be concluded that the heat treatment of low-carbon steel material in the cross sectional area of 28.26 mm^2. Pack carburizing process at a temperature of 850°C with a durable heating 30 minutes at 30 with a mesh size variase the percentage of buffalo bone charcoal may influence the tensile strength of carbon steel lower, it means that the process karburizing besides increasing the hardness value can also increase the value of low-carbon steel tensile strength.

So that low-carbon steel material treated carburizing process with buffalo bone charcoal media can be used as an alternative material on the use of materials that require harsh but strong material, ie, material that is able to withstand penetration, scratches and friction but strong against a large load.

Conclusion

Percentage of buffalo bone charcoal in the process affects the hardness carburizing low carbon steel in which the greater the percentage, but given the hardness is increased and otherwise.

Percentage of buffalo bone charcoal in the process of carburizing effect the tensile strength of low carbon steel in which the greater the percentage applied, the tensile strength increased and otherwise.

Low carbon steel that has undergone carburizing process with buffalo bone charcoal media with a percentage of 80% BBP + 20% $BaCO_3$ very well be used for the construction materials that require a hard material but remains strong.

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