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Structural and Mechanical Properties of Carbon-Carbon Biocomposites

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Abstract. Carbon-carbon composites (C/C composites) have been synthesized from organic sawdust as a carbon filler material and carbon asphalt as matrix of composites. The structural and mechanical properties of carbon-carbon composites from sawdust-asphalt are focused in this experiment. The structural has been characterized by using FTIR, XRD and XRF. The mechanical properties has been resulted from hardness, strength, and attrition testing. According to XRF data, CaO is the main content from carbon filler in composite decrease with increasing carbon asphalt matrix and vice versa for SO_3 as the main content from carbon tar as a matrix. Changing structure of C/C composites indicated sawdust as carbon has been bound to asphalt as carbon composites. Beside this, adding carbon to carbon composites shows increasing hardness from 6,57 to 9,27 kg/mm^2, strength of sample from 11,90 to 18,56 N/mm^2, and decreasing attrition of material from 1,64 to 0,28 gr. According to the data shows that adding sawdust to asphalt makes increasing hardness and strength of C/C composites. It means that the C/C composites from organic material sources has a good material composites which has low degradation under high temperature, economically, and eco-friendly to apply in asphalt as material of road construction. It means that organic material very potential as a carbon-carbon composite materials for various applications.

1. Introduction

Carbon-carbon composites (C/C composites) are a family of composite materials which composed of fibrous substrates and chemically vapor deposited matrices [1]. The properties of this carbon are low density, high thermal conductivity and shock resistance, low thermal expansion and high modulus [2-4]. Carbon/carbon is mostly used in aerospace applications, mainly for aircraft disc brakes, and parts of rocket [1]. On the other hands, C/C uses as material coating to protective layers which will be impermeable to oxygen at 1000^{o}C and above. Applying C/C composites to silicon carbide [5] and boron nitride [6] give incomplete oxidation protection. It has been shown that C/C composites are affective in protecting against oxidation in air at temperatures up to 1000^{o}C. The large strength-to-weight ratio and the retention of strength at high temperature make C/C composites attractive at high temperature structural materials.

The unique properties of C/C composites have attracted attention from many researchers to develop and deeply study of carbon-carbon composites, including developing a material sources of C/C composites. Several researcher have used a different material sources of C/C composite because it tolerated by other materials [7], such as coal tar pitches [8] and carbon nanotubes in a polystyrene matrix [9].

The aim of this work is to produce C/C composites using organic as material sources that has higher hardness and strength, and low degradation. The characterization of C/C composites using by X-Ray Fluorencence (XRF), Fourier Transform Infra-Red (FTIR) and X-Ray Diffraction (XRD). The mechanical properties identified by hardness, strength, and attrition. In this experiment, we present a sustainable, inexpensive and eco-friendly approach of C/C composites.

2. Experimental

2.1. Preparation C/C composites

Firstly, C/C composite makes from wood waste (C) as material source of carbon and tar (CC) as material source of carbon composite. In this experiment, there are 3 different composition of C/C composite. The ratio of C/C composite 80:20 where 9 gram of C and 3,5 gram of CC, 70:30 means 8,75 gram of C and 3,75 gram of CC, 60:40 where 8,5 gram of C and 4 gram of CC.

2.2. Characterization

C/C composites have identified from structure and mechanical properties.

2.2.1. Structure of C/C composites. Characterized of physical properties by using X-Ray Fluorescence (XRF) to determining chemical composition, Fourier Transform Infra-Red (FTIR) to identifies chemical compounds and X-Ray Diffraction (XRD) to identification of a crystalline material and provide information on unit cell dimensions.

2.2.2. Mechanical properties. Mechanical properties of C/C composites contains three testing are:

- Hardness testing performed by using equipment based Brinell method. The result of this testing calculated by using formula below.

$$\mathrm{BHN}=\frac{2\mathrm{P}}{(\pi.\mathrm{D})(\mathrm{D}-\sqrt{D^2-d^2})} \quad (1)$$

- Strength testing was tested using tensile machine based pressure formula.

$$\mathrm{P}=\frac{\mathrm{F}}{A} \quad (2)$$

- Attrition testing conducted compositely on disc rotating. Attrition can be seen from the mass changed. Changing of mass obtained by weighing the mass of the C/C composite before and after testing.

3. Result and Discussion

3.1. Structure of C/C composites

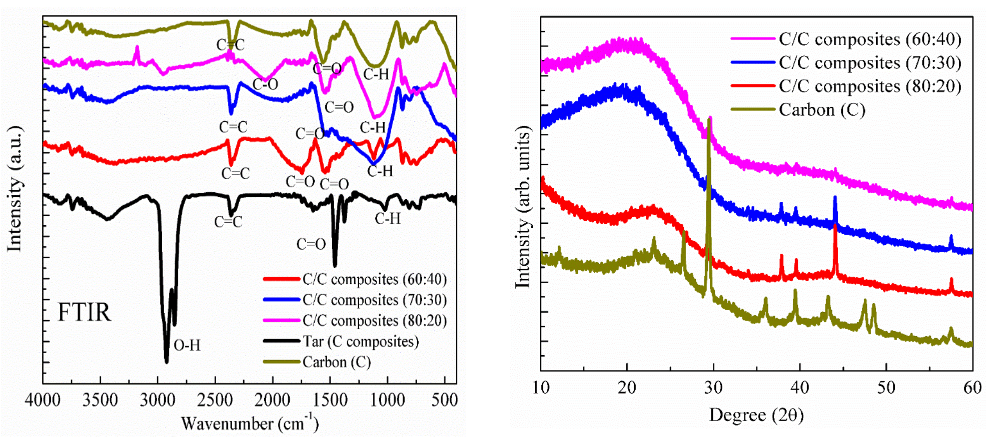
X-ray Fluorescence (XRF) spectrometry is a technique to determination of many major elemental compositions of earth materials. The composition of C/C composite determined by XRF shows on table below.

Table 1. Effect of carbon to carbon composite by X-ray Fluorescence spectrometry data.

Oxide (wt. %)	Sample				
	Wood Waste (C)	C:CC (80:20)	C:CC (70:30)	C:CC (60:40)	Tar (CC)
CaO	58.16	29.13	26.37	23.12	0.00
K_2O	24.08	23.75	22.42	20.25	0.00
SiO_2	6.57	4.95	4.52	2.87	0.00
P_2O_5	4.09	1.84	1.64	3.97	1.15
Fe_2O_3	5.18	3.39	2.25	2.83	0.03
SO_3	0.00	36.33	42.26	45.74	98.49
LOI	1.92	0.61	0.54	1.22	0.33

Wood waste as material source of carbon contains 58,16% of CaO and 24,08% of K_2O. Tar as material source of carbon composite contains 98,49% of $S0_3$. Adding carbon composites to carbon makes decreasing composition of CaO and K_2O but increasing SO_3. It can be seen on different ratio of C/C composite respectively. Compositions of SO_3 on material C/C composites are 36,33%, 42,26%, and 45,74% on ratio 80:20, 70:30, and 60:40 respectively. Composition of CaO and K_2O on material composites are 52,88%, 48,79%, and 43,37% with ratio 80:20, 70:30, and 60:40 respectively. This data shows that addition of carbon composites has impacted to the properties of carbon and vice versa. It indicated a material C/C composites can reduce degradation of tar properties. In the other side, composition of SiO_2 of carbon has decreased from 6,57% to 2,87% on ratio 60:40 of C/C composites.

Characterization of FTIR spectroscopy was used for identification of functional groups in material carbon from wood waste, C/C composites, and carbon composites from tar. As figure 1 shown, the curve carbon have a strong absorption peak at around 2924 cm^{-1} [10] which is the absorption peak of O=H and nothing on curves of C/C composites. This is mainly due to H_2O molecules involved in the process of synthesis carbon from waste wood. The peak in 2363 cm^{-1} is attribute to C=C absorption peak of aromatic ring and C=O stretching vibration appear between 1456 cm^{-1} [11] and 1561 cm^{-1} [12] The peaks around at 1100 cm^{-1} are attributed to aromatic C-H bending vibrations. However, the aromatic C-H absorption peak 1018 cm^{-1} from carbon and at 1141 cm^{-1} from C/C composites with ratio 60:40 are smaller than other curves. There may be having a polymerization reaction of compounds from carbon and carbon composites to form a multi-fused ring material [13]



(a) (b)

Figure 1. Physical properties of C/C composites by (a) FTIR and (b) XRD data.

The effect of carbon composites for carbon that identified by FTIR on Figure 1a shows changing intensity at surface state area but not changed a moleculer bonding. FTIR data for C/C composites with ratio 80:20 shows instability condition at peak 2300 cm^{-1} changing a moleculer bonding become C-O at

2062 cm^{-1} due to the several carbonaceous particle not bonding with tar particle forming unstable bonding.

Figure 1b shows that carbon from wood waste has peak degree at 29,5 and 43,3. C/C composite with ratio 80:20 has peak degree at 29,2 and 44,0. C/C composite with ratio 70:30 has peak degree at 29,4 and 44,0. C/C composite with ratio has peak degree at 29,6 and 44,0. The intensity peak in XRD decreased with the increase of ratio carbon composite on carbon. Carbon from waste wood indicated a domination of amorphous structure than a crystallite. It impacts to structure of carbon as amorphous fully. It can be seen from peak of carbon reduce become amorphous structure for high amount of tar in C/C composite. This is not surprising due to the structure of tar is amorphous.

3.2. Mechanical properties of C/C composites

The characterizations of mechanical properties consist are hardness, strength, and attrition. Purpose of this experiment to identify a physical and mechanical properties from material composite from organic sources.

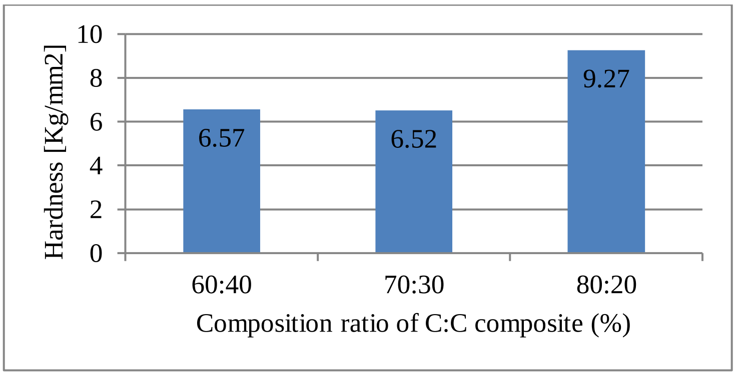


Figure 2. Graph of hardness testing result for C/C composites.

Changing composition of carbon-carbon composites impacts to hardness value. The result of hardness tenting of C/C composites shows on Figure 2. Composition ratio 60:40 has 6,57 kg/mm^2, 70:30 has 6,52 kg/mm^2 and 80:20 has 9,27 kg/mm^2. According to the diagram shows that increasing a composition of carbon comparable to hardness value. It means that a dominant materials from carbon wood waste more hardly than other less composition of carbon.

Decrease of hardness of mechanical properties on C/C composite caused by cracking core of material is not come out on the surface materials. A mechanical properties a materials composites was not depend on reinforcing and adhesive materials, but the characteristic of bonding between carbon and the composite that using on the material C/C composites. Interaction of their component impacts to mechanical properties for system carbon composites. The effect of surface treatment is significant on the mechanical properties of the resulting composites [1]

Result of strength testing shows that 11,90 N/mm^2, 12,02 N/mm^2, and 18,56 N/mm^2 with ratio composition are 60:40, 70:30, and 80:20 respectively. According to the graph below, it shows increasing composition of carbon comparable to the compressive strength of C/C composites.

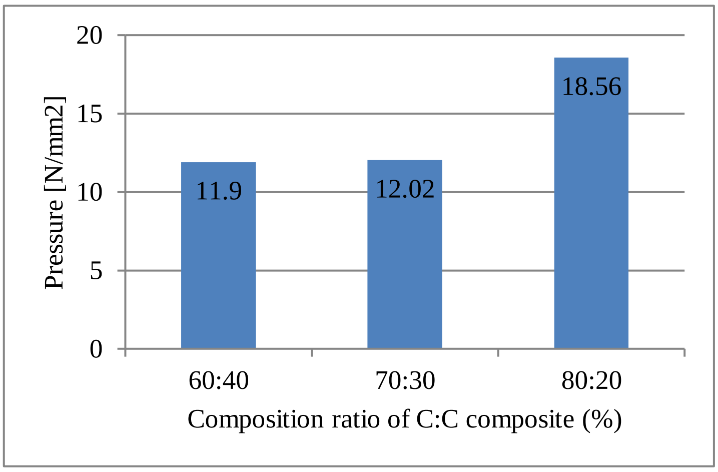


Figure 3. Graph of strength testing result for C/C composites.

The compressive strength not only depends to a micro-structure of material, such as pore and crack that occurs on carbonization process. The properties of carbon powder and deformations of materials on carbonization effects to the strength carbon composites. This caused likely other experiment that has reported [1, 14].

The attrition of sample was seen from mass changing before and after testing. Results of attrition testing with different ration of composition carbon-carbon composite at 60:40, 70:30, and 80:20 are 1.64 gram, 1.24 gram and 0.28 gram. It show on figure below.

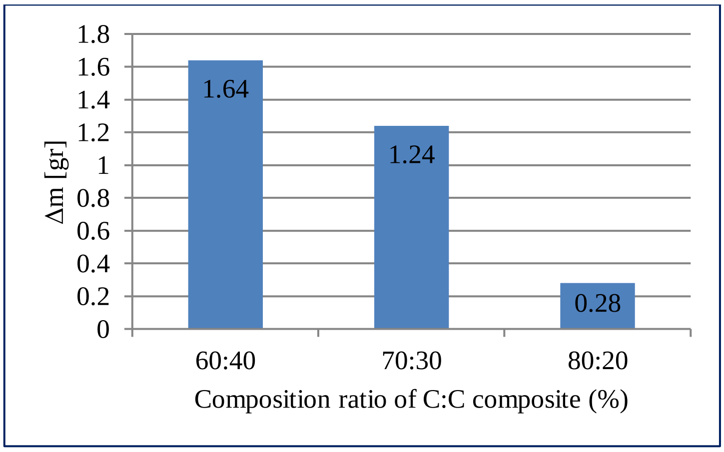


Figure 4. Graph of attrition testing result for C/C composites.

C/C composite with ratio 80:20 has low attrition at 0,28 gram. Changing micro structure of matrix carbon from densification process and thermal effect causes low attrition of material. Strong chemical bonds at the interface cannot provide a release mechanism, a weak interface adhesion resulted a crack. The processing cracks interphase initiated path from the interlaminar crack propagation [8].

4. Conclusions

Carbon-carbon composites based organic as material sources has been synthesized. According to analytical data from physical and mechanical properties shows that the level absorbance of molecule C/C composite increasing significantly. It has impacts to instability of moleculer bonding at C=C bonding and C-H bonding of C/C composites. Even thought detects a different of wavenumber from FTIR data, but still shows same bonding. On the other hands, mechanical properties of C/C composites shows that increasing composition of carbon comparable to increase hardness and strength value but

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decrease of attrition value. It indicated that organic material as material source of carbon is very potential to be C/C composites. This finding will lead to further research on applying C/C on industries.

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