Pertanika J. Sci. & Technol. 3(2): 203-209 (1995)
ISSN: 0128-7680

Effect of Particle Size on Young's Modulus of Carbon from Oil Palm Bunches

Mohamad Deraman and Mohamad Pauzi Ismail[1]

Physics Department
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor, Malaysia

[1]Malaysian Institute for Nuclear Technology Research
Kompleks PUSPATI Bangi
43000 Kajang, Selangor, Malaysia

Received 15 June 1994

ABSTRAK

Dalam usaha untuk menggunakan serabut tandan kosong buah kelapa sawit sebagai bahan pemula untuk membuat produk karbon, ia telah dihancurkan dan dijadikan pelet. Pelet telah dikarbonisasikan dalam vakum sehingga suhu 1000°C, menggunakan kadar pemasanan kira-kira 200°C/jam. Modulus Young karbon pelet yang dihasilkan diukur menggunakan teknik ultrasonik. Data menunjukkan bahawa modulus Young amat bergantung kepada saiz serbuk yang digunakan untuk menyediakan jasad hijau. Modulus Young bagi pelet karbon yang disediakan daripada serbuk yang lebih halus (70% serbuk dengan saiz $\leq$ 50 μm dicampur dengan 30% dengan 50 μm $\leq$ saiz $\leq$ 150 μm) dan serbuk yang lebih kasar (100% serbuk dengan 50 μm $\leq$ saiz $\leq$ 150 μm) adalah masing-masing 1.02 GPa dan 0.78 GPa. Nilai-nilai ini kelihatan lebih kurang 5 hingga 6 kali lebih kecil daripada sampel karbon yang disediakan langsung daripada kelapa endokap babasu dan 9 kali lebih kecil daripada produk karbon keluaran Syarikat General Electric.

ABSTRACT

In an effort to use oil palm empty fruit bunches (EFB) for making carbon products, EFB was ground and pelletized. The pellets were carbonized *in vacuo* up to 1000°C, using a heating rate of about 200°C/h. Young's modulus of the carbon pellets was measured using the ultrasonic technique. The data shows that Young's modulus is significantly dependent on the particle size of the powder used in the preparation of the green body. Young's modulus of carbon pellets made from smaller particles (70% powder with size $\leq$ 50 μm plus 30% powder with 50 μm $\leq$ size $\leq$ 150 μm) and larger particles (100% powder with 50 μm $\leq$ size $\leq$ 150 μm) was 1.02 GPa and 0.78 GPa respectively. These values appear to be about 5 to 6 times smaller than those of the carbon samples directly prepared from the endocarp of babassu coconut and about 9 times smaller than that of the carbon product from General Electric Company.

Keywords: oil palm empty fruit bunches, carbon pellets, powder particle sizes, ultrasonic technique, Young's modulus

INTRODUCTION

Oil palm empty fruit bunches (EFB) are waste materials produced in very large quantities by palm oil mills. In Malaysia, the annual production of EFB is about 2 million tonnes (Shaari *et al.* 1991). Studies on the utilization of EFB have been reviewed by Mohamad Deraman (1992a). EFB is currently used as mulch, fertilizer (after burning) and boiler fuel. The use of EFB for making roof tiles, pulp and paper is still in the research stage. Recently there have been studies on the use of EFB for the production of carbon pellets (Mohamad Deraman 1993a, 1993b, 1993c, 1994, 1995; Mohamad Deraman *et al.* 1995). Carbon products derived from other highly cross-linked polymers such as phenolic resin (Choe *et al.* 1992; Sastri *et al.* 1993), cellulose (Davidson and Losty 1963), lignocellulose (Emmerich and Luengo 1993), polyfurfuryl alcohol (Sonobe *et al.* 1990), and polyarylacetylenes (Economy *et al.* 1992) have been studied.

In Malaysia, the value of imports of carbon products (excluding granular carbon and carbon black) over the past five years amounted to over RM100 million (Mohamad Deraman 1993d). Carbon products are widely used as electronic or electrical components, pipes and filters in the chemical industry, crucibles and susceptors in crystal growth. In many applications the products are subjected to mechanical stress. Therefore, mechanical properties of this product have been widely studied.

The present work was performed in order to determine Young's modulus of carbon pellets prepared from EFB and compare the values obtained with those of commercially produced carbon samples. Comparison was also made with Young's modulus of carbon samples prepared from the endocarp of babassu coconut (Emmerich and Luengo 1993).

MATERIAL AND METHODS

Oil Palm Empty Fruit Bunches (EFB)

Information on several properties of EFB can be found, for example, in the study by Mohamad Deraman (1993b). Fresh EFB contain about 34% dry matter, 3% oil and 63% water, and represent about 20 to 22% of weight of fresh fruit bunches. EFB are stringy and flexible, and consist of fibres or bundles of fibres. The individual fibres have an average size of about 1 mm in length, 25 μm in width and 3 μm thickness. EFB contain 45-50% cellulose, 25-35% hemicellulose and 25-35% lignin. Chemical composition is estimated as: ash (6.3%), oil (8.9%), C (42.8%), N_2 (0.8%), P_2O_5 (0.22%), K_2O (2.9%), MgO (0.3%) and CaO (0.25%).

Sample Preparation

EFB were cut, oven dried, ground and sieved in order to obtain powder with two different ranges of particle sizes: (i) size ≤ 50 μm and (ii) 50 μm

≤ size ≤ 150 μm. The powder was pressed into pellets of about 2.53 cm in diameter and 0.25-0.30 cm thickness. The compression pressure used was about 150 kPa. This value was chosen according to the procedure proposed by Mohamad Deraman (1992b).

Three sets of samples were prepared for ultrasonic measurements. The first set consisted of 18 pellets made from a mixture of 70% of powder '(i)' plus 30% of powder '(ii)'; the second set of 18 pellets were made from powder '(ii)'. Samples of the first and second sets were labelled A and B respectively (Table 1). Eighteen of the EFB pellets (nine from sets A and B) were carbonized *in vacuo* up to 1000°C, using a heating rate of about 200°C/h. Three samples in the third set were carbon products obtained from General Electric Company(GEC).

Young's Modulus Measurement

Young's modulus of the samples A, B and GEC was measured using the ultrasonic method. The time of flight of the longitudinal wave (transit time) through the sample was recorded using a pulse echo ultrasonic nondestructive tester (PUNDIT) together with 20-mm diameter transducers (PUNDIT). The frequency used was 150 kHz and the couplet used was ultrasound transmission gel (Aquasonic 100). The sensitivity of the instrument was 0.1 microsecond. The velocity of the longitudinal wave V was calculated using the standard formula.

In the case of one-dimensional forms of wave equation for isotropic and homogeneous material, Young's modulus Y is given by

$$Y = \rho V^2$$

where ρ is the apparent density of the material (see, e.g. Bray 1989). The above case was considered in this experiment since the samples were isotropic and homogeneous and the small size of the sample used is also within one dimensional-measurement. The ultrasonic wave-forms for samples A and B are shown in *Fig. 1*.

RESULTS AND DISCUSSION

The density and Young's modulus obtained from samples A, B and GEC are listed in Table 1. The results show that after carbonization the density of the green bodies decreased while the Young's modulus of the carbon samples increased because the chemical structure and microstructure of the samples underwent changes during carbonization. The weight loss and volume shrinkage due to the carbonization process for the two sets of samples were about 71% and 65% respectively. After carbonization it is known that the inter-particle physical bonding of the powder in the green bodies changes to some extent to a chemical bonding which is eventually the bonding between carbon-carbon atoms.

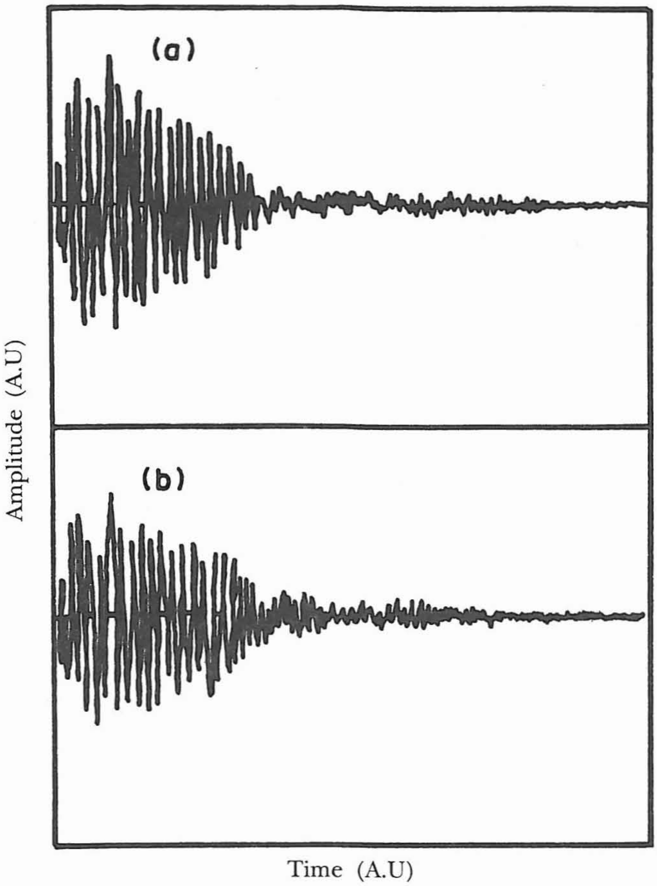

Fig. 1: Typical ultrasonic pulse through (a) sample A and (b) sample B

The results in Table 1 also show that the particle sizes of the powder affect Young's modulus of the samples. Carbon samples prepared from smaller particles seem to have a higher Young's modulus. Optical microscopic examination found that carbon produced from smaller particles has smaller shrinkage cracks between particles and a smaller number of pores, which obviously contributed to a higher Young's modulus.

It was found that Young's modulus of EFB-carbon (shown in Table 1) differs from that of the carbon samples prepared from the endocarp of babassu coconut, which is about 9 GPa (Emmerich and Luengo 1993). The main reason for such a difference is that particles in the latter samples are naturally bonded together whereas those of the former samples are made by compacting the powder. It should be noted that the densities of the green body in both samples were about the same and the carbonization procedures used were identical.

TABLE 1
Density and Young's modulus of pellets

Samples	Before/ Carbonization		After/ Carbonization	
	Density (g/cm^3) ± 0.01	Young's modulus (GPa) ± 0.03	Density (g/cm^3) ± 0.01	Young's modulus (GPa) ± 0.03
A1	1.20	0.79	0.96	1.12
A2	1.20	0.83	0.99	1.12
A3	1.24	0.91	1.00	1.14
A4	1.20	0.78	0.99	1.00
A5	1.19	0.65	0.99	1.01
A6	1.21	0.61	1.00	1.00
A7	1.20	0.69	0.98	1.08
A8	1.21	0.58	0.97	1.07
A9	1.22	0.79	0.91	0.89
Average	1.21	0.69	0.98	1.02
B1	1.14	0.60	0.89	0.84
B2	1.11	0.52	0.94	0.84
B3	1.10	0.53	0.94	0.73
B4	1.12	0.62	0.97	0.80
B5	1.12	0.50	0.93	0.73
B6	1.12	0.57	0.93	0.68
B7	1.12	0.60	0.93	0.74
B8	1.11	053	0.89	0.73
B9	1.14	0.58	0.89	-
Average	1.12	0.57	0.92	0.78
GEC1			1.59	4.50
GEC2			1.60	4.81
GEC3			1.60	4.80
Average			1.60	4.72

It was also found that Young's modulus of the EFB-carbon pellets was smaller than that of the carbon products from General Electric Company. This suggests that the preparation method of the EFB-carbon pellets must be improved in order to enhance Young's modulus. The high values of the weight loss and volume shrinkage seem to suggest that an improvement can possibly be made if part of the volatile matter is removed by pre-carbonizing the raw fibres, followed by grinding them into powder and compacting the powder into shapes for further carbonization. By doing this it is expected that the density of the carbon product would be significantly improved because the green bodies that contain less volatile matter would produce fewer and smaller cracks and pores. The pre-carbonization of the raw fibres must be carried out at a suitable carbonization temperature, otherwise the powder will not stick together even under a high compaction pressure. When phenolic resin was used as a precursor, the optimum temperature for pre-carbonization was found to be about 350°C (Jenkins and Kawamura 1976).

CONCLUSIONS

Young's modulus of carbon products prepared by carbonization (1000°C) of pellets made of ground fibres of oil palm empty fruit bunches was measured. It was found that particle sizes of the powder seem to affect Young's modulus of the samples, i.e. smaller particle size gave a higher value of Young's modulus of the carbon pellets. This study also demonstrated that the compacting raw powder method (even using a rather smaller particle size, i.e. of the order of 50 μm) of preparing the green bodies gave very poor mechanical properties of the carbon produced.

ACKNOWLEDGEMENTS

The authors wish to thank Universiti Kebangsaan Malaysia for financial support for this project (code 20/92), and Khafiz bin Tahir, Azhar bin Mohd Sinin, Saini bin Sain and Zailan bin Mohd Yusof for their contribution to this work. We also acknowledge the Department of Civil and Structural Engineering, UKM for permission to use the ultrasonic equipment.

REFERENCES

BRAY, D.E. 1989. *Nondestructive Evaluation*, p.48-51. New York: Mc Graw-Hill.

CHOE, C.R., K.K. LEE and B.I. YOON. 1992. Effect of processing parameters on the mechanical properties of carbonized phenolic resin. *Carbon* **30**: 247-249.

DAVIDSON, H.W. and H.W. LOSTY. 1963. Impermeable cellulose carbon. *Gen. Elec. Co. J. (London)* **30(1)**: 22-30.

ECONOMY, J., H. JUNG and T. GOGEVA. 1992. One step process for fabrication of carbon-carbon composites. *Carbon* **30**: 81-85.

EMMERICH, F.G. and C.A. LUENGO. 1993. Young's modulus of heat-treated carbons: A theory for nongraphitizing carbons. *Carbon* **31**: 333-339.

JENKINS, G.M. and K. KAWAMURA. 1976. *Polymeric Carbons: Carbon Fibre, Glass and Char* p.41-44. Cambridge: Cambridge University Press.

MOHAMAD DERAMAN. 1992a. Pembuatan karbon glasi daripada serabut kelapa sawit. *Bull. S&T Kead. Pej. Malaysia* **2(1)**: 5-12.

MOHAMAD DERAMAN. 1992b. Pellet disediakan daripada serabut tandan kelapa sawit: Ciri ketumpatan pukal pelet lawan tekanan mampatan. In: *Pros. Sem. Tahunan ke IX Sains Keadaan Pepejal*, p. 128-134. Universiti Teknologi Malaysia.

MOHAMAD DERAMAN. 1993a. Carbon pellets prepared from fibres of oil palm empty fruit bunches. III. A comparison of weight loss and dimensional shrinkage with carbon from phenolic resin. *Solid State Science and Technology* **1(1)**: 41-49.

MOHAMAD DERAMAN. 1993b. Carbon pellets prepared from fibres of oil palm empty fruit bunches. I. A qualitative X-ray diffraction analysis. *PORIM Bulletin* **26**: 1-5.

MOHAMAD DERAMAN. 1993c. Penyediaan pelet karbon daripada serabut tandan kelapa sawit: Analisis struktur pada suhu karbonisasi 1000°C. In *Himpunan Kertas-Kerja Simposium Fizika Nasional XIV, Himpunan Fizika Indonesia (HFI)*, p. II(1-11). Medan: Universitas Sumatra Utara.

MOHAMAD DERAMAN. 1993d. Application of solid carbon products in Malaysia: Analysis of imports. *Bull. S&T Kead. Pej. Malaysia* **3(3)**: 95-98.

MOHAMAD DERAMAN. 1994. Resistivity of carbon from oil palm bunches: percolation theory. *J. Phys. D: Appl. Phys.* **27**: 1060-1062.

MOHAMAD DERAMAN. 1995. Estimation of compression pressure in the preparation of pellets from oil palm bunches. *PORIM Bulletin* **30**: 1-5.

MOHAMAD DERAMAN, MOHAMAD PAUZI ISMAIL and MA'ZAM MD SAID. 1995. Young's modulus of carbon from a mixture of oil palm bunches and latex. *J. Mat. Sci. Lett.* **14**: 781-782.

SASTRI, S.B., J.P. AMISTEAD and T.M. KELLER. 1993. Carbonization of high-temperature resins. *Carbon* **31**: 617-622.

SHAARI, K., K.K. CHOON and A.R.M. ALI. 1991. Oil palm utilization - reviewing research. Research pamphlet No. 107. Forest Research Institute of Malaysia.

SONOBE, N., T. KYOTANI and A. TOMITA. 1990. Carbonization of polyfurfuryl alcohol and polyvinyl acetate between the lamellae of montmorillonite. *Carbon* **28**: 483-488.