Measurement of Crushing Strength of Coal Agglomerates

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Abstract- The aim of this research is to produce coal agglomerates 15-27.51mm and to determine the crushing strength of the agglomerates for good handling of fine (coal-liquid mixture) to improve fugitive dust control, decrease in transportation losses, reduce risk of coal freezing, lower risk of spontaneous combustion in iron and steel industries, railway corporations and coal corporations. Kerosene (paraffin oil) was used as a binder and the agglomerated coal oil mixture was pelletized using balling technique (disc). Mechanical and physical tests were carried out. The relationship between the crushing strength of coal agglomerates and agglomerates diameters show that coal diameters have effect on its compressive (crushing) strength. As the coal agglomerate diameter increases, the coal strength decreases which implies that crushing strength is dependent on the agglomerates diameter and crushing strength is indirectly proportional to agglomerates diameter.

Keywords- Sub-bituminous coal agglomerates, Compressive Strength, Crushing Strength, Material handling.

I. INTRODUCTION

It cannot be denied that, although coal has many virtues, it has one or two disadvantages. Principal among them are its mineral content, especially the sulphur – bearing component, and the problems created in the handling and storing of coal, such as dust and reclamation systems. By contrast, liquid fuels are naturally low in mineral content, can be freed of their sulphur compounds, and are easily handled and stored[1]. On the other hand, coal is abundant, widespread, and fairly cheap to produce; while oil reserves are much smaller and are concentrated in politically unstable areas, and the commodity can become very expensive indeed, regardless of production costs.

Consequently, there has long been a desire for extraction of oil from coal.

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The conversion of coal to true liquids has been investigated and practiced for over fifty years.

Optimum crushing strength is the maximum compressive strength (stress) a material can withstand under crush loading.

In capillary state agglomerate, the wetting liquid completely fills the void space between the particles to form a continuous network within the agglomerates. The negative pressure within the pellet, developed as a result of the multitude of capillaries formed by the system of particles at the agglomerate surface, is responsible for strength. The maximum negative pressure[2], or entry suction Pe, is given by eqn. (1) and the tensile stress by eqn. (2)

$$p_e = So\left[\frac{1-\varepsilon}{\varepsilon}\right]\gamma l_v \cos\theta \qquad (1)$$

where γl_v is the liquid surface tension, θ is the contact angle, S is the specific surface area of the particles, and ε is the porosity of the agglomerate.

The tensile stress, σ_t , required to cause pellet failure must overcome the capillary pressure generated in the saturated pellet .

$$\sigma_t = sP_e \qquad (2)$$

where s is the saturation.

When compressive test is carried out, the peak load is determined and the strength value σ_c is obtained by dividing the load, L by the cross – sectional area which implies

$$\sigma_c = \frac{\pi D^2}{4}$$

Therefore, $$\sigma_c = \frac{L}{\frac{\pi D^2}{4}} \equiv \frac{4L}{\pi D^2} \qquad (3)$$

as the compression stress, σ_c, generated during the crushing of the agglomerates.

Corrections to account for the increase in cross – sectional area are negligible if rupture is reached before 2 – 3 % strain.

While the normalized compressive strength factor Kc and tensile strength factor Kt are given thus[3];

$$K_c = \frac{4}{\pi}\frac{L}{D^2}\frac{1}{S}\left[\frac{\varepsilon}{1-\varepsilon}\right] \qquad (4)$$

and

$$K_t = S_o \gamma l_v \cos\theta \qquad (5)$$

The compressive stress at failure is known[4] to exceed the tensile stress due to the additional interparticle frictional effects which must be overcome in compressive failure. Hence;

$$\sigma_c = \alpha\sigma_t \qquad (6)$$

Therefore, $$\alpha = \frac{\sigma_c}{\sigma_t}$$

where α is greater than unity. Combining equations (1) and (6)

$$K_c = \alpha S_o \gamma l_v \cos\theta \qquad (7)$$

The crushing strength of wet ball – shaped agglomerates held together with paraffin oil can generally be represented by the equation of the form[5]:

$$L/D^2 = KS\frac{(1-\varepsilon)}{\varepsilon} S_o \gamma l_v \cos\theta \qquad (8)$$

$$K = \frac{L/D^2}{S_o \gamma l_v} \qquad (9)$$

[As defined in nomenclature; where L is the crushing load, D is the agglomerate diameter, ε is agglomerate porosity, S is the pore saturation, γl_v is the surface tension of the bridging liquid, S_o is the specific surface area of the particles and θ is the contact angle between the particles and liquid.] The factor K depends upon the mechanism of agglomerate failure but can be considered constant for the present discussion.

From equation (8) linear relationships can be expected in the graph of L/D^2 versus $S_o \gamma l_v$ and = $\frac{L/\frac{\pi D^2}{4}}{} \frac{1}{S}\frac{\varepsilon}{1-\varepsilon}$ versus $S_o \gamma l_v \cos\theta$ only if S , ε and $\cos\theta$ are all constant for a given powder system.

II EXPERIMENTAL

A. Materials

The coal powder used to form agglomerate is sub-bituminous coal which was obtained from Okaba coal mine Enugu State and ground dry with a milling machine into powdered form and sized by screening with standard sieve. The coal powder was then mixed with paraffin oil with the use of mixer in the balling disc machine. The density and calorific value of the powder were measured. Paraffin oil was used as bridging liquid throughout the study.

B. Method

Agglomerates of different sizes of coal powder required for strength determination were formed using a balling disc of 20cm diameter with adjustable inclination to the horizontal. Balling disc speed was employed as required. Each pellet diameter was determined by averaging the diameter measured in three directions at right angles to each other using a vernier caliper. The load L (in kN) required to break each agglomerate was measured with an WP 300 Universal Material Tester. The number of agglomerates tested for a given powder/liquid system varied. Typical curve of compressive strength versus diameter was drawn.

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Chemical / Physical Analysis of Enugu Sub-bituminous Coal

PH Value	4.03 (Acidic)
Density	0.705 g/ml

The Calorific Value of Powdered Solid State of Coal

Transmittance	0.00
Absorbance	1.51

The Calorific Value of Wet Powdered Coal

Transmittance	0.00
Absorbance	1.51
Mass of powdered coal	413.8g
Volume of powered coal	500ml
Volume of oil	100ml

III. WET COMPRESSIVE STRENGTH TEST

Compressive strength is the capacity of a material to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed.

This was done to determine the crushing strength of different samples of the agglomerates made. It was also done to determine how strong the agglomerates will be after they had been wet. Also six agglomerates were formed and subjected to compressive strength test using universal material tester. This was done by subjecting the agglomerates one after another to end loading, which produces crushing action. The agglomerates were placed between fixed and moveable cross heads; compressive loads were read from the scale at breaking / crushing of the specimen to determine the crushing strength.

Table 1.1 EXPERIMENTAL DATA (RESULTS): The effect of diameter of agglomerates on crushing Strength.

Pellet Diameter, D(m)	**Crushing Load, L(N)**
0.015	2050
0.01632	2100
0.0184	2130
0.021	2300
0.02702	3200
0.0277	3300

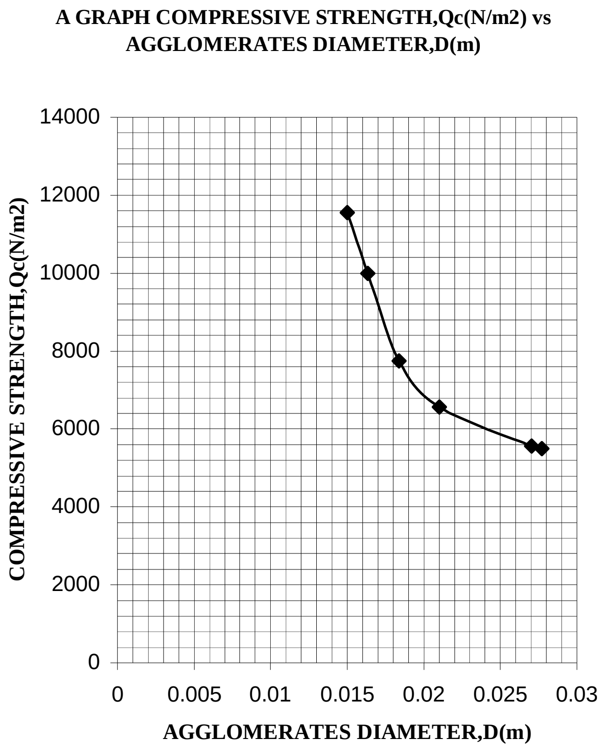

Figure1: Relationship between the crushing strength, σ_c and the agglomerate diameter, D for coal powder. Coal agglomerates diameter and crushing strength analysis

IV. RESULTS AND DISCUSSION

The effect of diameter on the agglomerates strength shows that the crushing strength of coal is dependent on the diameter D of agglomerates and the crushing strength is indirectly proportional to agglomerates diameter.

V. CONCLUSION /RECOMMENDATION

Research of this kind other than using coal has been done, but this study was done using coal to see the conformity/similarities/relationship/comparison with the previous research.

Agglomeration should be applied on coal powder system for good handling.

From this research, coal agglomerates of 15mm to 27.51mm should not be compressed beyond its compressive (crushing) strength.

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LIST OF SYMBOLS

D agglomerate diameter, mm

K constant factor

Kc normalized crushing strength factor N/m^2

Kt tensile strength factor m2Jkg^{-1}

σ_c Compressive stress for the crushing of agglomerates, N/m^2

Ơt tensile stress , N/m^2

L crushing load, N

S pore saturation

So specific surface area of particles, m^2kg^{-1}

ε porosity

γlν bridging liquid surface tension, J

γsν surface tension of solid(coal), J

γsl surface tension of unknown, J

ρ density,

θ contact angle

α factor relating tensile strength to crushing strength, defined by eqn. 6

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