Correlation of Compressive Strength of Coal Pellets with Wet Weight of Coal Powder Agglomerates

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Abstract - The aim of this research is to determine the effect of weight of coal powder agglomerates on compressive strength of the agglomerates. Coal agglomerates of 0.015-0.0277m were produced and the weight and crushing strength of the agglomerates were determined. Kerosene (paraffin oil) was used as a bridging liquid. The relationship between the crushing strength of coal agglomerates and agglomerates weight clearly shows that the compressive strength decreases with increase in weight of agglomerates. The decrease in compressive strength was attributed to decrease in pore saturation leading to decrease in bonding force between particles.

Keywords: - Sub-bituminous coal agglomerates, Compressive Strength, Wet Weight.

I. INTRODUCTION

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].

Consequently, there has long been a desire for extraction of oil from coal. 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[2].

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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 $\pi D^2/4$ which implies

$$\sigma_c = \frac{L}{\frac{\pi D^2}{4}} \equiv \frac{4L}{\pi D^2} \qquad (1)$$

as the compressive strength, σ_c, generated during the crushing of the agglomerates.

The crushing strength factor of wet ball-shaped agglomerates held together with paraffin oil can generally be represented by the equation of the form[3]:

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

$$K = \frac{L/D^2}{S_o \gamma l_v} \qquad (3)$$

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 compressive strength depends on the agglomerate diameter (D), particle specific surface area (S_0), porosity of the agglomerate (ε), and the wetting characteristics of particles/bridging liquid ($\gamma_{LV}\cos\theta$)

II. EXPERIMENTAL

A. Materials/Method

The coal powder used to form the agglomerates is sub-bituminous coal, obtained from coal mine Enugu State, Nigeria and ground dry with a milling machine into powder form. The coal powder was then mixed with paraffin oil. The density of the coal powder was calculated. Paraffin oil was used as bridging liquid throughout the study.

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B. **Table I: Material and Quantity**

S/N	Materials	Quantity
1	Mass of powdered coal	413.8g
2	Volume of powered coal	500ml
3	Volume of oil	100ml

C. **Table II:** Chemical / Physical Properties

S/No.	Property	Value
1	PH Value	4.03 (Acidic)
2	Density	0.705 g/ml
3	Transmittance	0.00
4	Absorbance	1.51

D. Strength Measurements

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.

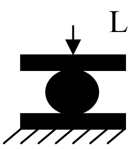
Balling disc speed was employed as required. Each pellet diameter was determined by averaging the diameter measured in three directions at right angles to each other using a vernier caliper. The load L (N) required to break each agglomerate was measured with WP 300 Universal Material Tester. The number of agglomerate tested for a given powder/liquid system varied.

Each agglomerate was weighed after breakage to determine the weight. Typical curve of compressive strength versus weight of the agglomerates was drawn

.

III. WET COMPRESSIVE STRENGTH TEST

When the limit of compressive strength is reached, materials are crushed[4-6]. This was done to determine the crushing strength of different samples of the agglomerate made. It was also done to determine the effect of weight of agglomerates on the compressive strength. Also six agglomerates were formed and subjected to compressive strength test. This was done by subjecting the agglomerates one after another to end loading, which produced crushing action.



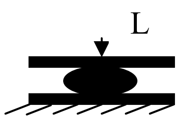


Fig1: Before Compression **Fig 2:** After Compression

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.

IV. THE EFFECT OF WET WEIGHT (THE WHOLE SAMPLE) ON CRUSHING STRENGTH

A. **Table III:** EXPERIMENTAL RESULTS

DIAMETER (m)	LOAD (N)	WET WEIGHT (N)	COMPRESSIVE STRENGTH. Ơc (N/m²)
0.015	2050	0.027	11,595959.6
0.01632	2100	0.05	10,034,929.8
0.0184	2130	0.053	7,007,174.8
0.021	2300	0.102	6,637,806.6
0.02702	3200	0.158	5,578,464.1
0.0277	3300	0.198	5,473,810.4

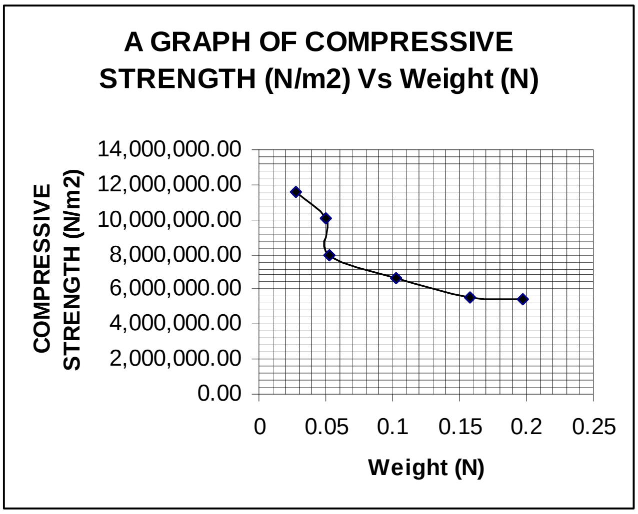


Fig 3: Relationship between the crushing strength Ơc and Weight Ww, of coal powder agglomerates.

V. RESULTS AND DISCUSSION

Fig. 3 illustrates the effect of changes of agglomerate weight on the compressive strength of the agglomerate. It is clear from the graph that the compressive strength of coal powder agglomerate decreases with increasing weight of the agglomerate.

The weight of an agglomerate Ww depends on individual particle size (r = d/2), number of particles (N), agglomerate size (D), particle density (ρ_ρ), agglomerate porosity (ε), pore saturation (S) and density of bridging liquid (ρ_l) , thus, the agglomerate weight can be given by:

$W_A = NW_\rho + W_L$

Where

$NW_\rho = N(4\pi^3/3)\,\rho_\rho$;

$W_L = S(\rho_l)$., if S is given in m^3

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Note that theories and experiments have shown that the crushing load *(L)* is proportional to square of agglomerate diameter *(D)*, i.e., $L \sim D^2$ as can be deduced from eq.(l). The compressive strength depends on the agglomerate diameter *(D)*, particle specific surface area *(So)*, porosity of the agglomerate *(ε)*, pore saturation (S) and the wetting characteristics of particle/bridging liquid represented by the expression $\gamma_{LV}\cos\theta$ in eqn. 2.

Thus, to explain the effect of agglomerate weight on compressive strength, it may be wise to keep agglomerate diameter *(D)* constant. Under this condition, if agglomeration compaction pressure is increased, more particles will get compacted within the agglomerate (D), i.e., N increases while S reduces, as it is only these two parameters (and of course the porosity) that can change {with *D* kept constant}. Reduction in S (quantity of bridging liquid) will affect the capillary forces existing within the agglomerate leading to change in compressive strength.

It can be seen in Fig. 3 therefore that as the agglomerate weight increases while the compressive strength of the agglomerate decreases. When the agglomerate diameter is fixed, the increase in agglomerate weight can only occur when the number of particles in the agglomerate is increased. Such an increase in number of particles will lead to a decrease in agglomerate porosity and hence a decrease in pore saturation. Decrease in pore saturation will reduce the number of individual particles in the agglomerate wetted by the bridging liquid leading to possible particle-to-particle direct contact. This will surely lead to a weak bond between particles, and hence a reduction in compressive strength.

In the data of Fig. 3 however, the agglomerate diameter was not kept constant. The data of Table III show that the agglomerate diameter ranges from 0.015m to 0.028m. Within this narrow diameter range, the explanation given above appears to hold. The sharp deviation in slope of fig. 3 around the agglomerate weight of 0.05 N may probably be attributed to the fact that the agglomerate diameter was not held constant, or possibly that there was some experimental error.

VI. CONCLUSION /RECOMMENDATION

The relationship between the crushing strength of coal agglomerates and agglomerates weight clearly shows that the compressive strength decreases with increase in weight of agglomerates. The decrease in compressive strength was attributed to decrease in pore saturation. Decrease in pore saturation led to decrease in capillary force bonding the particles together.

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