Literature Review on Effect of Particle-Size and Air Flow Rates on the Ignition Temperature of Coal

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Abstract— Spontaneous ignition and combustion of coal are the major problems for its mining, transportation and usage. The temperature of ignition or combustion of the coal mainly depends upon its rank. Generally, coals having lower ranks are more prone to the spontaneous ignition or combustion than the coal having higher ranks. But many times, as an exception, as the rank increases, the coal becomes more susceptible to spontaneous ignition. As we reduce the particle size, the susceptibility to ignite more efficiently increases. But reducing the size of the coal particle may also increase the volatility. In pulverized combustion, the coal is ground in fine particles and then heated directly. To check the variables which affect the susceptibility of the ignition of the coal, practical experimentation can be carried with some proper combustion setup.

Key words: Coal, Bituminous Coal, Sub-bituminous Coal, Volatile Material, Particle Size, Pulverised Combustion, Ignition Temperature

I. Literature Review

Spontaneous ignition and combustion of coal are the major problems for its mining, transportation and usage. The temperature of ignition or combustion of the coal mainly depends upon its rank. Generally, coals having lower ranks are more prone to the spontaneous ignition or combustion than the coal having higher ranks. But many times, as an exception, as the rank increases, the coal becomes more susceptible to spontaneous ignition.

To check the variables which affect the susceptibility of the ignition of the coal, practical experimentation can be carried with some proper combustion setup. Bituminous coal is generally used in many applications. But to reduce the use of it, sub-bituminous coal may be examined.

A. *Different Methods used for combustion*

We have Initiated Spontaneous Ignition, FTIR, DSC, TCA and EPR measurements to accumulate data which can be used to propose mathematical models for spontaneous ignition of stored and pneumatically conveyed coals, said V. M. Malhotra, J . C. Crelling[1]**.** The author performed the tests by using spontaneous ignition and FTIR methods. 2gms of coal sample was used in both the experiments. In spontaneous ignition tests, air temperature was decided by doing trial and error method, by increasing the temperature gradually considering the result of previous values. In FTIR method, various vibrational bands were observed. Thirteen different types of coal from the different countries were studied by C.K. Man, J.R. Gibbins[5]. The Pittsburgh Research Laboratory (PRL) 20 L ignition chamber was used for the experimentation.

Many of the tests include Pulverized fuel combustion. Philip G. Sweeny, Dana T. Grow, and Donald P. McCollor[2] also did their experimentations using pulverized coal combustion and then they measured the products with CO and CO_2 analyzers. The production of CO and CO_2 was measured as a function of time, whereas Jack B. Howard, Robert H. Essenhigh(1966)[3] measured the volatile matter, fixed carbon, and ash content subjected to the time and temperature. Ray W. Arms(1922)[4] also used the same operation. He initially studied two different methods of coal combustion.

B. *Method of Sinnatt and Moore[4]*

The apparatus, as shown in the fig.1, consists of a heavy cast iron vessel in which an enclosed nickel crucible may be raised to any desired temperature. The whole apparatus is enclosed in an asbestos-lined box to eliminate the influence of drafts. Before entering the combustion chamber the oxygen or other gas traverses the U-shaped tube bored into the casting. The oxygen is dried by passing it through concentrated sulphuric acid. In certain experiments nitrogen was used to sweep out the crucible and a three-way tap was attached to the ignition meter so that nitrogen or oxygen can be passed into the combustion chamber as required. Pulverized fuel was used in all these experiments and in each case a measured amount was dropped into the nickel crucible by means of a dropper made of glass tubing.

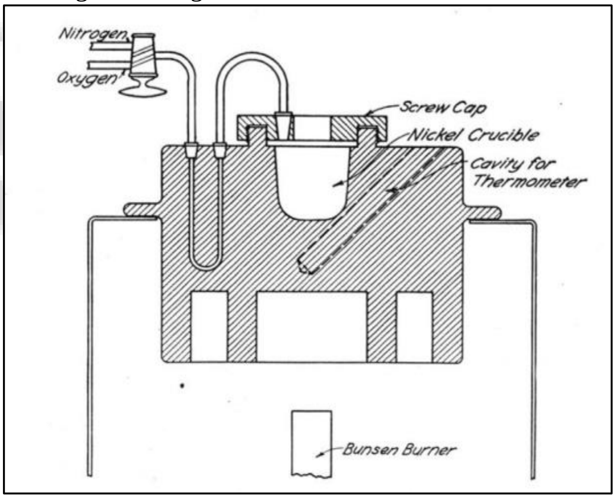

Fig. 1: Method of Sinnatt and Moore

C. *Method of Wheeler[4]*

The apparatus, as shown in the fig.2, consists of a tube holding the sample of coal, and an electrically heated sand bath surrounding the sample tube. Air is drawn through the sample at a constant rate, the temperature of the coal mass itself and the external sand bath being taken simultaneously. Experiments were made on 40g. samples of 150-mesh and 240-mesh coal. The temperature of the sand bath was slowly raised at a uniform rate and the temperatures inside and outside the coal taken at intervals.

D. *Effect of Coal Type on combustion*

The classification of coal is generally based on the content of volatiles. Other deciding contents in the coal are Carbon, Hydrogen, Oxygen, Sulphur and its heat content.

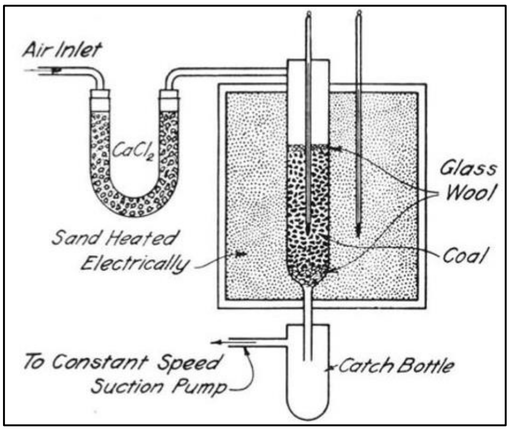

Fig. 2 Method of Wheeler

Other than these, maceral content in the coal is also a deciding parameter resulting in the difference in the oxidation potential[1]. Examples of maceral are inertinite, vitrinite, exinite etc.

From the study done by V. M. Malhotra, J. C. Crelling[1], the coal in the particle size range of 1mm < particle size < 6 mm is most susceptible to spontaneous combustion. The results indicate that there is a sudden jump in runaway temperature at Tg > 493 K for particle size < 106 µm. As the particle size increases, the Tg value required to induce a sudden jump in runaway temperature value also increases. In fact, for particle size > 850 µm no jump in runaway temperature is observed at 290 K < T < 700 K with or without inert gas preheat treatment. The influence of particle size upon the concentration required for a lower-limit mixture diminishes as particle size decreases, and below about 60 microns, the effect of particle size becomes inappreciable[3]. If the surface temperature of a particle initially at 100°C should suddenly reach 1100°C, about 0.02 seconds would be required for the centre to reach 1090°C in the case of a 100 micron particle, and less than 0. 001 seconds would be required if the particle size was 30 microns[3]. Different types of coal from different parts have different glow-points[4]. They also have different ash and moisture content. The glow point is probably affected by the oxygen content of the coal. Particle size appears to have a small effect on coal ignition. Overall, the <53µm fraction behaved very similar to the whole coal. However, the large size fractions (>53µm) of a coal were generally slightly more difficult to ignite and always resulted in a significantly lower weight loss compared to its corresponding small size fraction (<53µm).

To find out the effect of coal particle size on the combustion properties, the TG, DTG and DSC data were compared by Dunxi Yu, Yun Yu[6]. They found the peak temperatures of the three coal particles <63 µm, 63 - 100 µm and 100 - 200 µm are 514, 530 and 561°C, respectively. The exothermic heats for the particles <63 µm and 63 - 100 µm in the temperature range of 300 - 450°C are higher than that for 100 – 200 µm because of the heterogeneous reactions of volatiles and char.

6.3, 9.5 and 12.5mm sized coal particles were studied by M. Brikci-nigassa, E. S. Garbett, A. B. Hedley[7]. The combustion efficiency was observed to increase with bed temperature for the 6.3 and 9.5 mm coals. The 12.5 mm results show only a slight sensitivity to bed temperature (1043 K - 1193 k, 20% excess air). The highest carbon combustion efficiency of 95% is achieved with the 9.5 nun at a bed temperature of 1193 K

E. Effect of air flow and Air Temperature on Combustion

To determine the effects of air flow temperature, T = 493 K was chosen since a sudden jump in runaway temperature was observed at this temperature. The runaway temperature shows a parabolic dependence on the air flow rates[1]. Increasing the gas temperature dramatically decreased the ignition delay time for both the Pittsburgh #8 vitrain and the Beulah vitrain. Philip G. Sweeny, Dana T. Grow, and Donald P. McCollor[2] concluded from their research that, ignition delay depends strongly on the gas temperature.

Ray W. Arms[4] considered three different cases of air supply to observe the effect of air and oxygen on coal ignition. In the first case, the coal was heated in an ordinary manner by of a very small stream of oxygen. In the second case, the stream was cut off at 300°C and in the third case; the blast of the oxygen was played on the sample. It was observed that the glow point is largely dependent upon the air supply, but that the actual temperature of the glow point, no matter how it is approached, is not altered.

C.K. Man, J.R. Gibbins[5] concluded from their study that, almost all the coals ignited in O_2 in CO_2 at some point. The concentration of O_2 in CO_2 that gave a similar ignition comparable to that in air was established to be between 30 and 35%. This is consistent with recent data reported by CANMET, which concluded that the heat flux from oxyfuel experiments between 28 and 35% O_2 in CO_2 was comparable to that carried out in air.

M. Brikci-nigassa, E.S. Garbett A.B. Hedley[7] studied three different samples of coal of 6.3, 9.5 and 12.5mm. To determine the effect of airon the coal ignition, excess air between 6 and 47% was supplied to the samples. An increase in carbon combustion efficiency is achieved with the increase of air up to about 20-25%, a further increase in excess air beyond this value does not improve the carbon combustion efficiency significantly.

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