Wall Pressure during Cokemaking

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Abstract
Pressure exerted by the coal plastic layer during coking largely determines the density of the coke formed and hence its other physical properties. Coke density is observed to increase with depth in the oven suggesting the pressure is dependent on static load as well as initial coal bulk density.

Introduction
Pressure develops on the walls of slot-type coke ovens as the coal charge is coked. Normally it can only be directly measured in pilot-scale ovens equipped with a "moveable" wall and a load cell. Using coal blends typical of those used by the Canadian steel industry it is observed that the coking pressure rises quickly after charging and then maintains a fairly constant value until the plastic layers meet at the oven centre when a peak is observed. This peak is often the maximum pressure recorded and hence is important in considering the safety of the blend for industrial use. During the short-lived peak pressure only the porous "tar-end" of the coke lumps are formed which has little effect on coke quality. However, the pressure during the bulk of the coking cycle is related to the physical properties of the coke being made and is the subject of this paper.

Experimental
Three series of experiments were carried out- two in a 450-mm wide, 325 kg capacity test oven, and one in a 310-mm wide, 250 kg test oven.

In the first series the coke cake was pushed out of the test oven into a box and quenched by spraying water externally. This allowed the coke in the cake to be divided into top, middle and bottom samples that were large enough to be tested for coke size, strength (stability and hardness factors) and apparent specific gravity. Figure 1 shows that the coke density is higher at the oven bottom and that the top to bottom gradient in density decreases as the initial coal bulk density increases. Similar plots were obtained for stability and hardness factors.

The second series of tests was carried out at the same initial coal bulk density however, the amount of low-volatile coal in a high/low-volatile coal blend was varied from 0 to 40%. Again coke properties improved from the top to the bottom of the oven and this time the variation decreased as the amount of low-volatile coal increased. Figure 2 shows the results for the coke hardness factor. Similar trends were obtained for coke stability and density.

The top to bottom gradient in coke properties observed in these two series could be interpreted as the result of an initial gradient in coal bulk density that is obtained on charging the oven. However the gradient is also seen to decrease with increased bulk density and the amount of low-volatile coal in the blend both of which increase the average coking pressure. Therefore it was concluded that the gradient was largely caused by the different static loads on the coal as it was being coked.

To determine the effect load has on coking pressure and coke properties a typical Canadian industrial coal blend was carbonized in a 310-mm wide, 250 kg capacity oven with an added load. This was accomplished by placing steel blocks on a steel sheet covering the top of the coal bed shortly after charging. The load on the coal was 7 kPa. It is considered that a charge loaded and coked in this manner simulates more closely coking of coal 1-2 m down in an industrial oven. Tests were carried out at different bulk densities with and without the load. Figure 3 shows that loaded charges increase the average coking pressure and that the increase is larger the higher the initial coal density. Figure 4 shows that the coke density is influenced by both the initial coal bulk density and the applied load. However coke densities from both unloaded and loaded tests fall on the same line when plotted against the average coking pressure, Figure 5. This demonstrates

that for a given coal blend it is the average coking pressure that determines the coke density which in turn determines other physical properties such as the coke hardness factor, Figure 6.

Discussion
Figure 2 shows that coke density increases with depth in the test oven and similar behaviour has been previously found in industrial oven samples collected by cages placed in the coal(1). The increase in coke density with depth in the test oven is higher the lower the initial coal bulk density. Hence at large depths the density of coke made from low coal bulk density will approach that made from high coal bulk density. This confirms findings of previous work showing that equations for coke properties were much less dependent on coal bulk density for industrial ovens than for test ovens(2).

Results also suggest that while the test oven may be expected to rate the coke quality of coal blends in the correct order for industrial use it does not necessarily reveal how much better one blend is than another because of the top to bottom gradient in coke properties. For example consider the addition of low-volatile coal to the blend to increase coke quality. In the second series of tests increasing the amount of low-volatile coal in the blend from 10 to 40% changed the coke stability from 55.4 to 59.6% a difference of 4.2%. However the stability was higher at the oven bottom in both cases, the difference being greater for the 10% low-volatile coal. If we consider the test oven represents the top quarter of an industrial oven and avoid extrapolation of the results by assuming the bottom three quarters of such an oven produces coke with a stability the same as that at the bottom of the test oven then industrial stabilities will differ by 2.1% rather than 4.2%. In this case test oven data overestimates the advantages of increasing the low-volatile coal in the blend to increase coke quality.

The fundamental relationship between coke density and pressure during coking was investigated with this coal blend in a sole-heated oven which other workers have used to show that coke density is only dependent on the load applied to the coal and is not influenced by the coal's initial bulk density(3). Loads used were 15.2, 7.6, 3.5 and 0.7 kPa and expansions ranged from -12% to 40%. (At the conclusion of the tests the cokes had been heated to about 900°C at their bottom surface and 500°C at their top surface. To compare with test oven cokes they were heated to 1100°C in a retort before their density was measured). Figure 7 shows coal coked in either the sole-heated oven or the test oven has the same relationship between coke density and load or average coking pressure. Measuring coke density of industrial samples, either average or made in specific locations, appears a good way of estimating industrial average coking pressures.

Conclusion
Static load of the coal charge affects coking pressure so that it varies with depth in the oven together with coke properties. This explains the relative lightness and poor abrasion resistance of test oven cokes compared with industrial cokes made from coal at the same bulk density. Coke density is related to average coking pressure. It is argued that test oven data may in some instances be misleading in predicting industrial coke strength. Work is continuing on a coking model that includes static loading and appropriate coking conditions for test ovens.

Acknowledgement
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References
1. J. F. Gransden, J. T. Price and M. A. Khan "Coking pressure and coke quality at different locations in an industrial oven", Ironmaking Proc., ISS/AIME Vol. 47, 1988, pp 155-162
2. J. F. Gransden, M. A. Khan and J. T. Price, "Comparison of industrial and pilot oven coking pressures and coke quality", Ironmaking Proceedings, ISS/AIME Vol. 44, 1985, pp 305-312.
3. J. B. Gayle and W. H. Eddy, "Use of sole-heated oven for studies of coal expansion and coke formation", US Bureau of Mines Report RI 5464, 35pp, 1959.
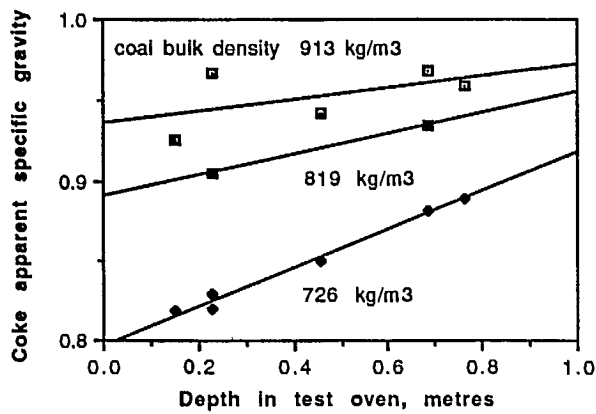
Figure 1   Variation of coke density with depth at three different coal bulk densities.
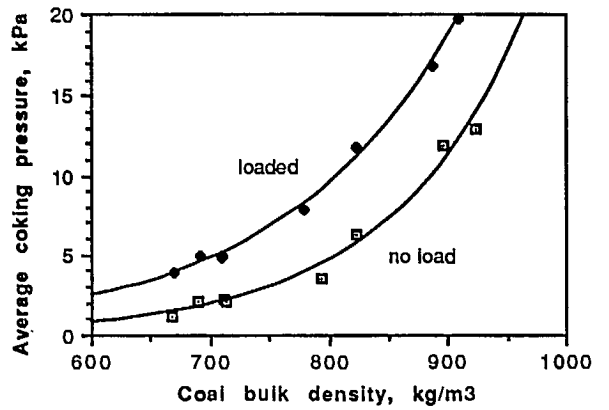

Figure 3   Effect of coal bulk density and load on the average coking pressure.
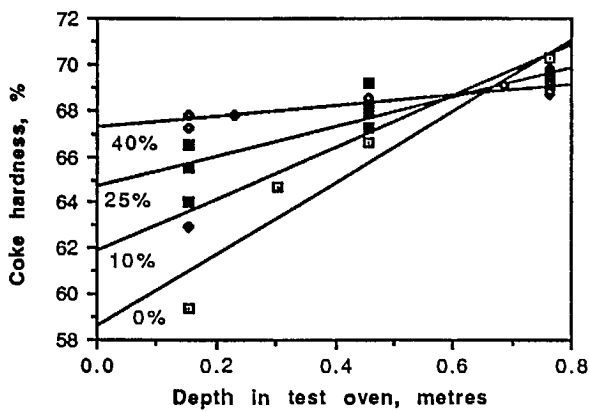

Figure 2   Variation of coke hardness with depth for a high-volatile coal blended with four different amounts of a low-volatile coal.
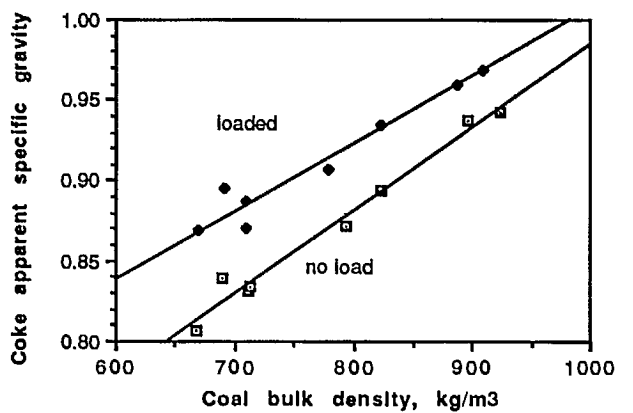

Figure 4   Effect of coal bulk density and load on the coke density.
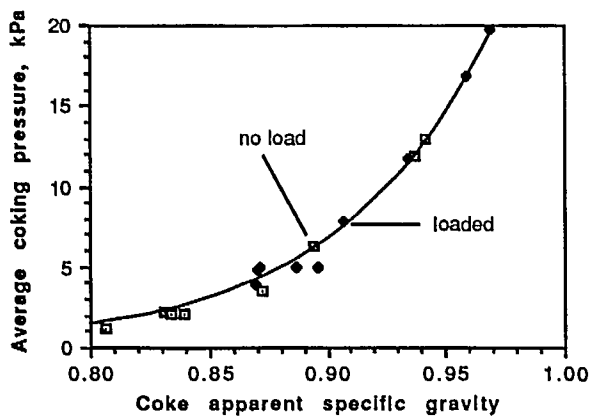
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Figure 5 Coke density is related to average coking pressure for both unloaded and loaded charges.
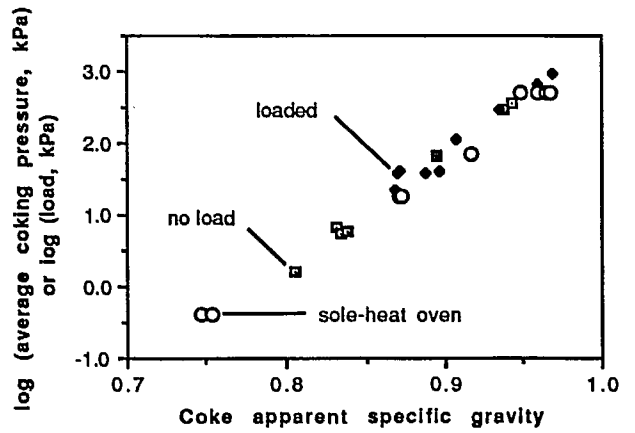

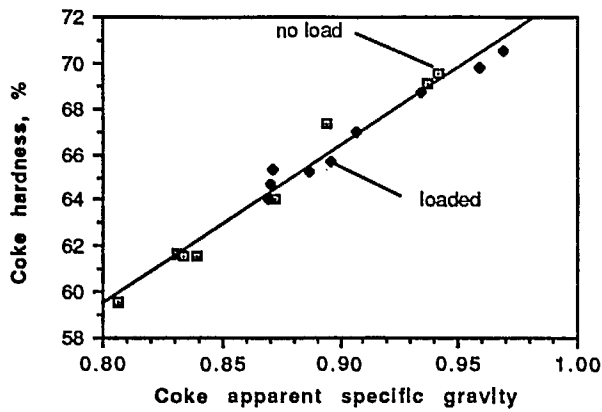Figure 7 Coke density depends on load in the sole-heated oven and average coking pressure in the test oven.

Figure 6 Relationship between coke density and hardness.

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