FAST AND ECONOMIC APPROACH OF COALS AND COAL BLENDS IN TERMS OF COKE QUALITY AND COKING BEHAVIOR BY PILOT-SCALE COKING TESTS[1]

Drazen Gajic[2]
Helenio Resende Silva Junior[3]
Manfred Kaiser[4]
Wolfgang Kern[5]

Abstract
The pilot-scale coking test retort permits less time consuming investigations with limited quantities of coals in comparison to the semi-industrial scale coke oven. DMT collect coke qualities and carbonization behavior data from coal and coal blend carbonization tests, which done parallel in the pilot-scale coking test retort and semi-industrial coke oven as well as in industrial coking plants, since 15 years. The pilot-scale coking test retort was dedicated for the fast and economical test for the determination of the CRI and CSR of coking coals. The evaluation of this bulk of coal and coke data shows also a high transferability of other important values from the retort test to the industrial coke ovens. DMT will present the comparison between semi-industrial coke oven and the pilot-scale coking test retort in terms of CRI/CSR, mechanical strength and internal gas pressure.
Key words: Cokemaking; Pilot-scale coking test retort; Semi-industrial coke oven; Coke quality; Internal gas pressure.

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2 *Dr., Coal & Coke Researcher, DMT Cokemaking Technology, DMT GmbH & Co.KG, Germany; drazen.gajic@dmt.de.*
3 *Process Department, Paul Wurth do Brasil, Belo Horizonte, MG, Brazil*
4 *Dr., Head of Cokemaking Technology, DMT Cokemaking Technology, DMT GmbH & Co.KG, Germany*
5 *Head of Sales, DMT Cokemaking Technology, DMT GmbH & Co.KG, Germany.*

1 INTRODUCTION

Coke oven operators search for reliable test methods to optimize their blends in relation to coke quality and coke oven safety. DMT has supported coke oven operators with simultaneous tests in industrial coke ovens and semi-industrial movable coke ovens since decades. Also, DMT has implemented the pilot-scale coking test retort since 15 years. Its use as a cost effective and time saving investigation for coke quality has established the pilot-scale coking test retort as a suitable practical application.

The comparison of the pilot-scale coking test retort and the semi-industrial scale coke ovens indicates a sufficient correlation concerning coke quality. The unreliability of the determined maximum internal gas pressure in the pilot-scale coking test retort required a new approach for this issue. The results of the new approach show that the pilot-scale coking test retort is a fast and cost effective test method to consolidate the measured internal gas pressure in the industrial coke oven and to increase the reliability of the optimization of the coal blend in relation to coke oven safety.

This paper will describe the development of the pilot-scale coking test retort from a research facility to a suitable practical application.

2 TECHNICAL FACILITIES AND METHODS

The origin of the pilot-scale coking test retort was in the eighties. Development and installation of the pilot-scale coking test retort occurred during the investigation of the needed energy for a carbonization process, a research program conducted by DMT. Figure 1 displays the primary design of the pilot-scale coking test retort.

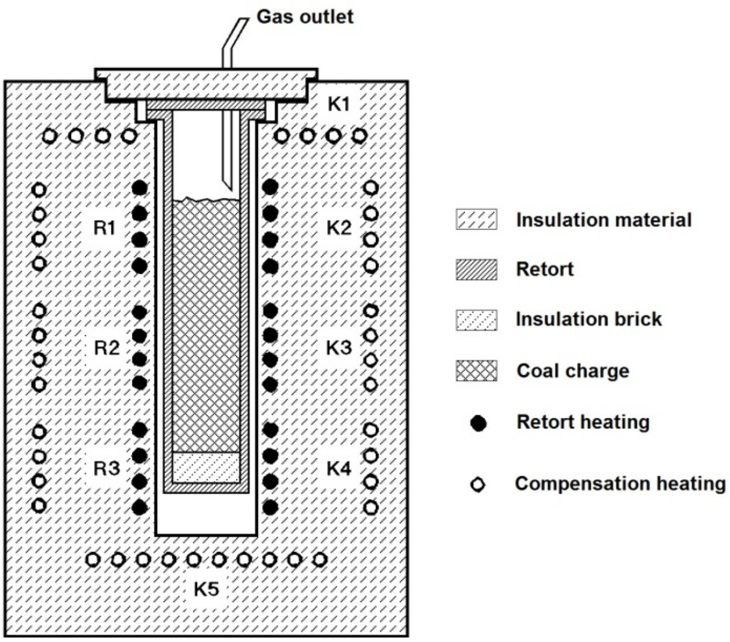

Figure 1. Electrically heated carbonization retort furnace.

Aside from the investigation of the energy consumption of a carbonization process, DMT realized the formation of an entirely closed plastic zone like an envelope during the carbonization process. The shrinking plastic layer constantly pushes the raw gas to pass through the hot coke before it reaches the gas free space. This leads to a maximum of cracking reactions in the pore structure of the incandescent coke similar

to the behavior in an industrial coke oven. DMT modified the pilot-scale coking test retort after the research program to evaluate coke quality and coking behavior data in comparison to the semi-industrial / industrial scale ovens.
DMT removed the compensation heating and fixed the electrical heating by a temperature of 1,050 °C in the oven. DMT placed a small tube at the top of the retort to measure the internal gas pressure in the coal charge during the carbonization. Figure 2 shows the pilot-scale coking test retort in their modified and current design. Figure 2 contains the most important data of the pilot-scale coking test retort.

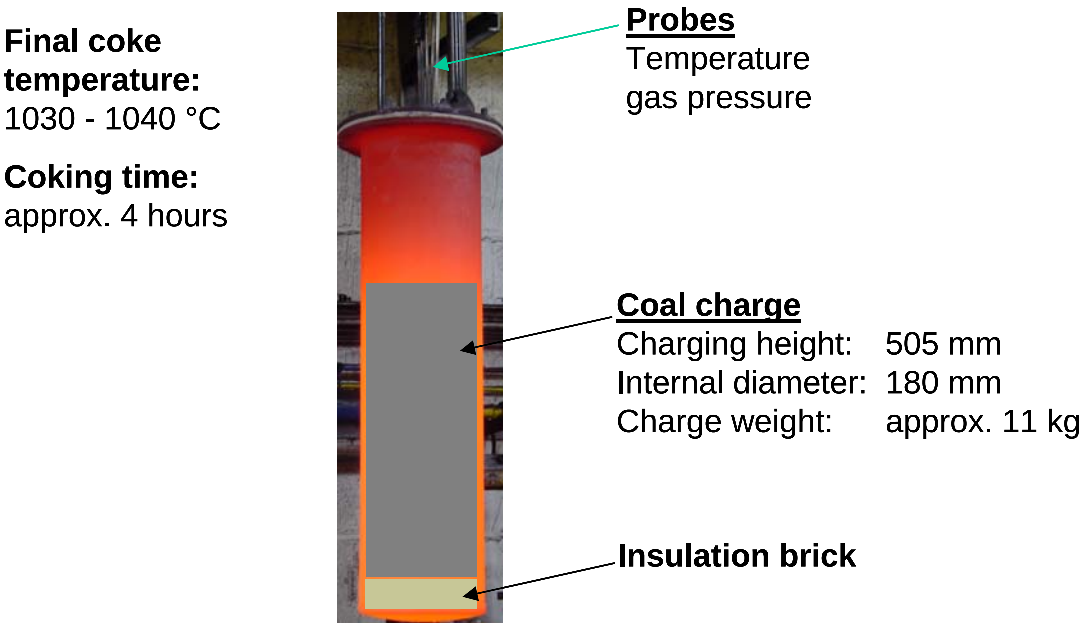

Figure 2. Pilot-scale coking test retort.

The adjustment of size distribution, moisture content and bulk density follows as given by the operating conditions of the industrial scale plant or semi-industrial movable coke oven at the DMT laboratory. The crane system removes the pilot-scale coking test retort from the electrical heating oven after 4 hours. The temperature in the middle of the charge reaches a final coke temperature between 1,000°C and 1,030°C.
The determination of the coke quality values follows after cooling and sieving of the produced coke. A portion of five kilogram of the produced coke, with a size distribution according to the sieve analysis, tumbles in the ISO drum for 100 and 500 revolutions. Sieving occurs after 100 and 500 revolutions in the drum to determine the residues of the 30 mm mesh sieve and residue smaller than 10 mm. The determination of the coke reactivity index (CRI) and the coke strength after reaction index (CSR) follows with the other portion of the produced coke.

3 EVALUATION OF TEST RESULTS

DMT has collected a bulk of data from the same single coal or coal blends that were simultaneously tested in the pilot-scale coking test retort and the movable semi-industrial coke oven as well as in the industrial coke ovens. Figure 3 shows the comparison between the obtained CRI and CSR values from the pilot-scale coking test retort and the semi- industrial coke oven. Also, Figure 4 shows the comparison between the generated CRI and CSR values of the pilot-scale coking test retort and industrial coke ovens.

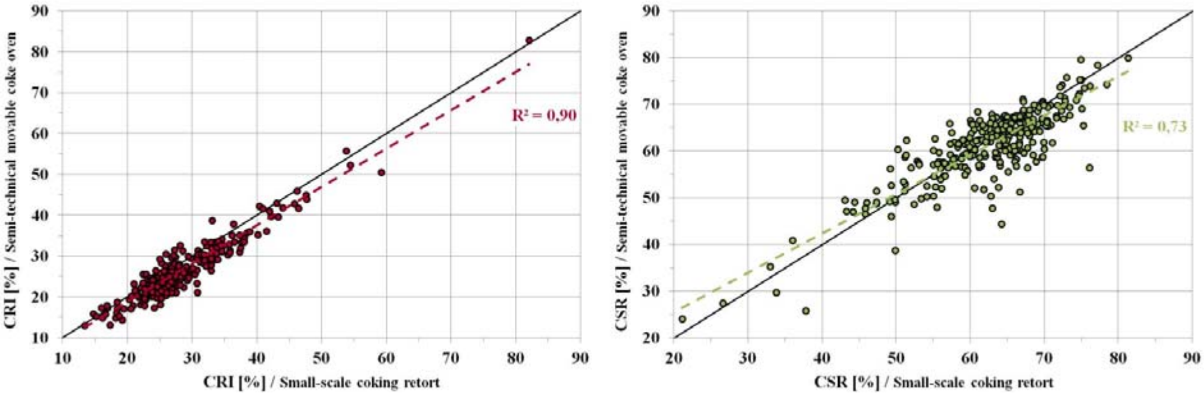

Figure 3. Comparisons of CRI and CSR values from pilot-scale and semi-industrial ovens.

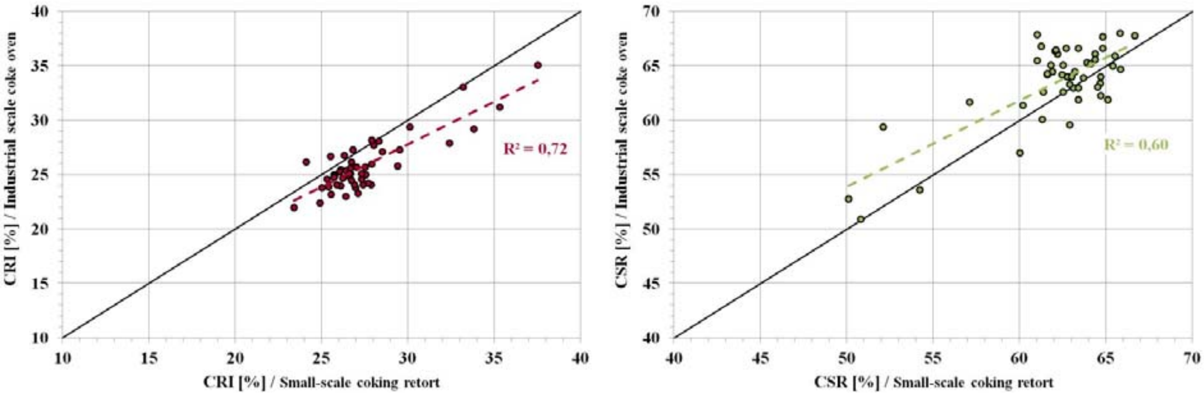

Figure 4. Comparisons of CRI and CSR values from pilot-scale and industrial scale ovens.

The comparison between the CRI and CSR values which generated in the pilot-scale coking test retort and the semi-industrial coke oven is satisfactory. A small difference is indicated between the CRI values and some more difference in the case of the CSR values due to the greater influence of operating conditions on the CSR value. The correlation between the pilot-scale coking test retort and the industrial coke oven is acceptable, but a greater difference can be recognized in the correlation between the pilot-scale coking test retort and the semi- industrial coke oven. The correlation indicates the influence of the huge scale-up from pilot-scale to industrial scale on the CRI value and in particular for the CSR value. The pilot scale coking test retort generates up to 4 points higher CRI values and up to 6 points lower CSR values as the industrial produced coke.

In the case of the mechanical strength investigation DMT used the obtained M_{30} and M_{10} values from the drum test of the produced coke from the pilot-scale coking test retort to estimate the M_{40} and M_{10} values that would be obtained in semi-industrial or industrial scale. Figure 5 shows the evaluated M_{40} and M_{10} values from the drum test of the of the produced coke from the pilot scale coking test retort and the M_{40} and M_{10} values from the coke which produced in the semi industrial coke oven. Figure 6 shows the evaluated M_{40} and M_{10} values from the drum test of the of the produced coke from the pilot-scale coking test retort and the M_{40} and M_{10} values from the coke which produced in the industrial scale ovens.

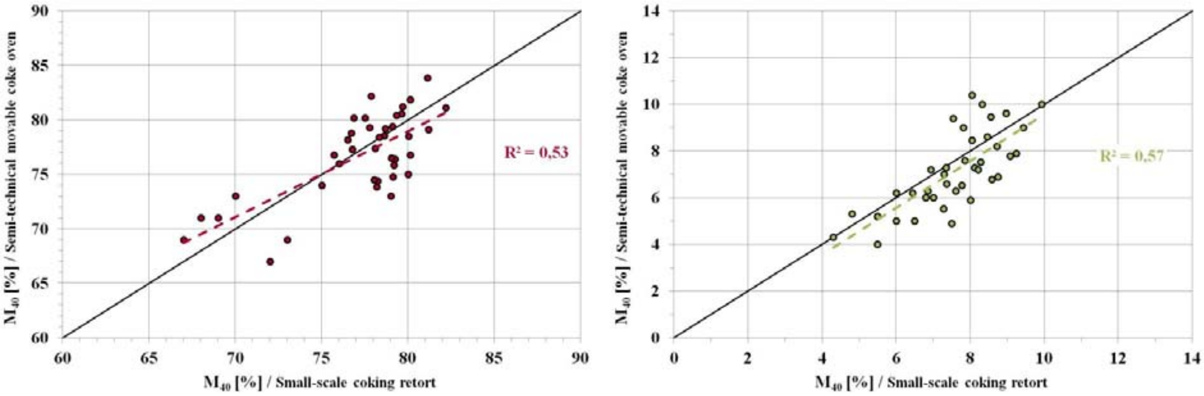

Figure 5. Comparisons of M_{40} and M_{10} values from pilot-scale and semi-industrial ovens.

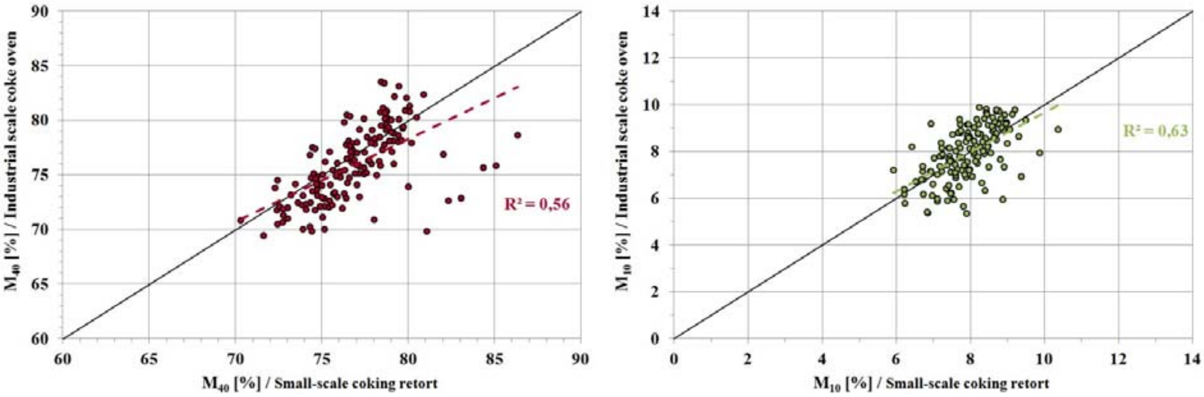

Figure 6. Comparisons of M_{40} and M_{10} values from pilot-scale and industrial scale ovens.

The comparisons display that drum test results from the produced coke in the pilot-scale coking test retort give a good overview of the possible mechanical strength of the coal or coal blend.

The consideration of the coke quality values of the produced coke in the pilot-scale coking test retort is one important part. However, to get information about coke oven safety is another main point. It’s well known that the measurement of internal gas pressure and wall pressure during the carbonization in the movable coke ovens helps optimize coal blends in relation to coke oven safety. This optimization and testing prevent the ovens from damage through swelling pressure.

The simple approach has failed when using obtained maximum internal gas pressures from the pilot-scale coking test as the expected maximum internal gas pressure in the semi- industrial coke oven. Also, the direct correlation of the obtained maximum internal gas pressure from the same coal or coal blend in the semi-industrial coke oven and the pilot-scale coking test retort is unsatisfactory. Figure 7 shows the direct correlation of the maximum internal gas pressure of the pilot-scale coking test retort and semi- industrial coke oven.

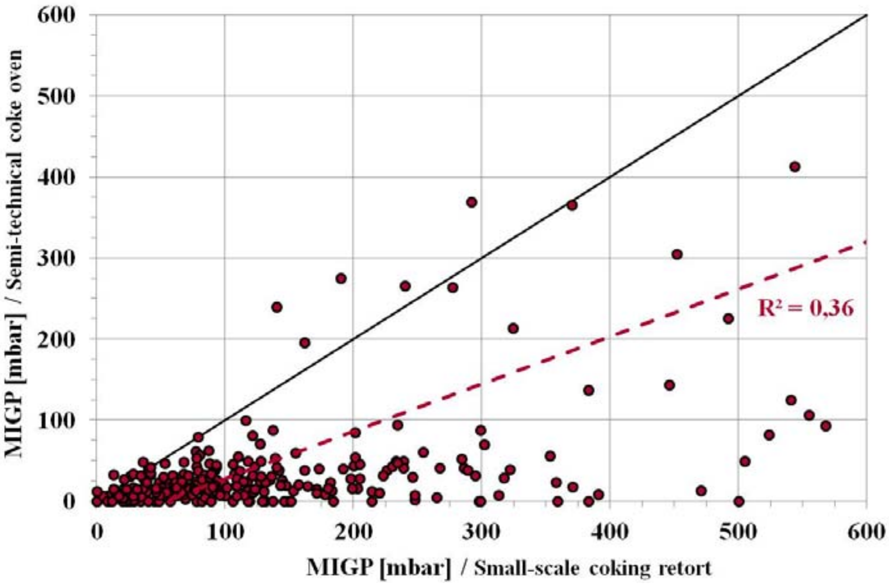

Figure 7. Correlation between maximum internal gas pressure of pilot-scale and semi-industrial ovens.

The maximum internal gas pressures indicate a clearly higher pressure in the pilot-scale coking test retort than in the semi-industrial coke oven. The pilot-scale coking test retort generates in particular higher pressures then the maximum internal gas pressure in the semi-industrial coke oven is lower than 100 mbar. Consequently a direct correlation between both values is not recognizable.
The comparison of the pilot-scale and the semi- industrial / industrial scale coke ovens indicates a sufficient correlation between the obtained CRI and CSR values. A good correlation is indicated by the mechanical strength values. The obtained maximum internal gas pressure from the pilot scale coking test retort can´t be use for the estimation of the maximum internal gas pressure that would be generated in the semi- industrial coke oven or industrial coke oven.
However, the above mentioned problem of insufficient correlation between pilot-scale coking test retort and semi- industrial / industrial scale coke oven has to be resolved. DMT takes another approach for the interpretation of the obtained pressure curve during carbonization in the pilot-scale coking test retort to overcome this problem.
Figure 8 gives an overview of the difference between the pressure diagrams that were obtained in the semi-industrial or industrial coke oven and the pilot-scale coking test retort with the same coal blend.

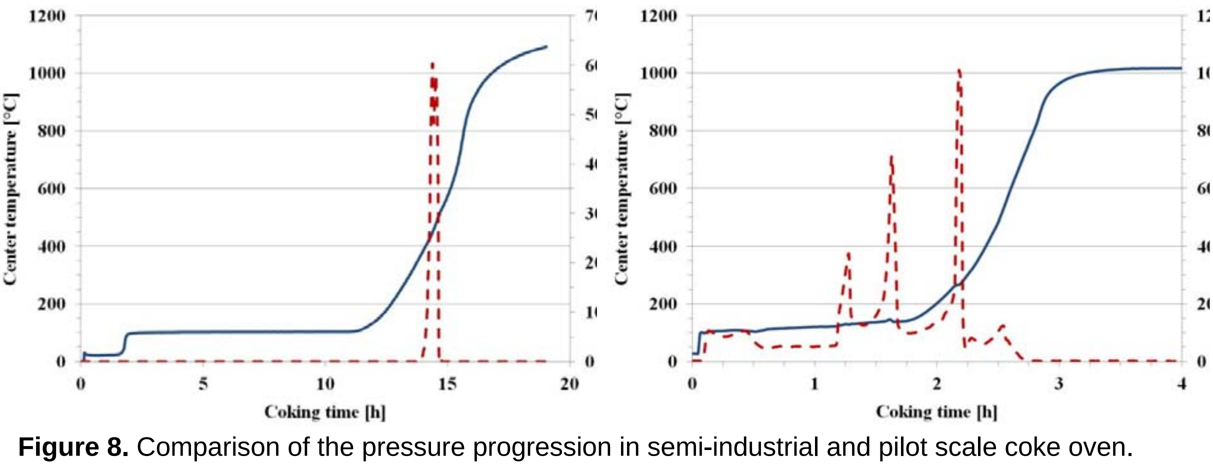

Figure 8. Comparison of the pressure progression in semi-industrial and pilot scale coke oven.

The left diagram reproduces the typical internal gas pressure and center plan temperature progression in the semi- industrial or industrial coke oven during the carbonization. The pressure reaches a maximum at a center charge temperature of 450 – 500°C. This corresponds to the closing of the plastic layers in the central plane of the oven. The interrupted red line on the right side of figure 8 indicates a confused progression of internal gas pressure of the pilot-scale coking test retort. A theoretical approach about the behavior of the plastic layer during the carbonization can clarify this progression. Figure 9 illustrates the shrinkage of the plastic layer in the main section in companying with temperature and pressure values.

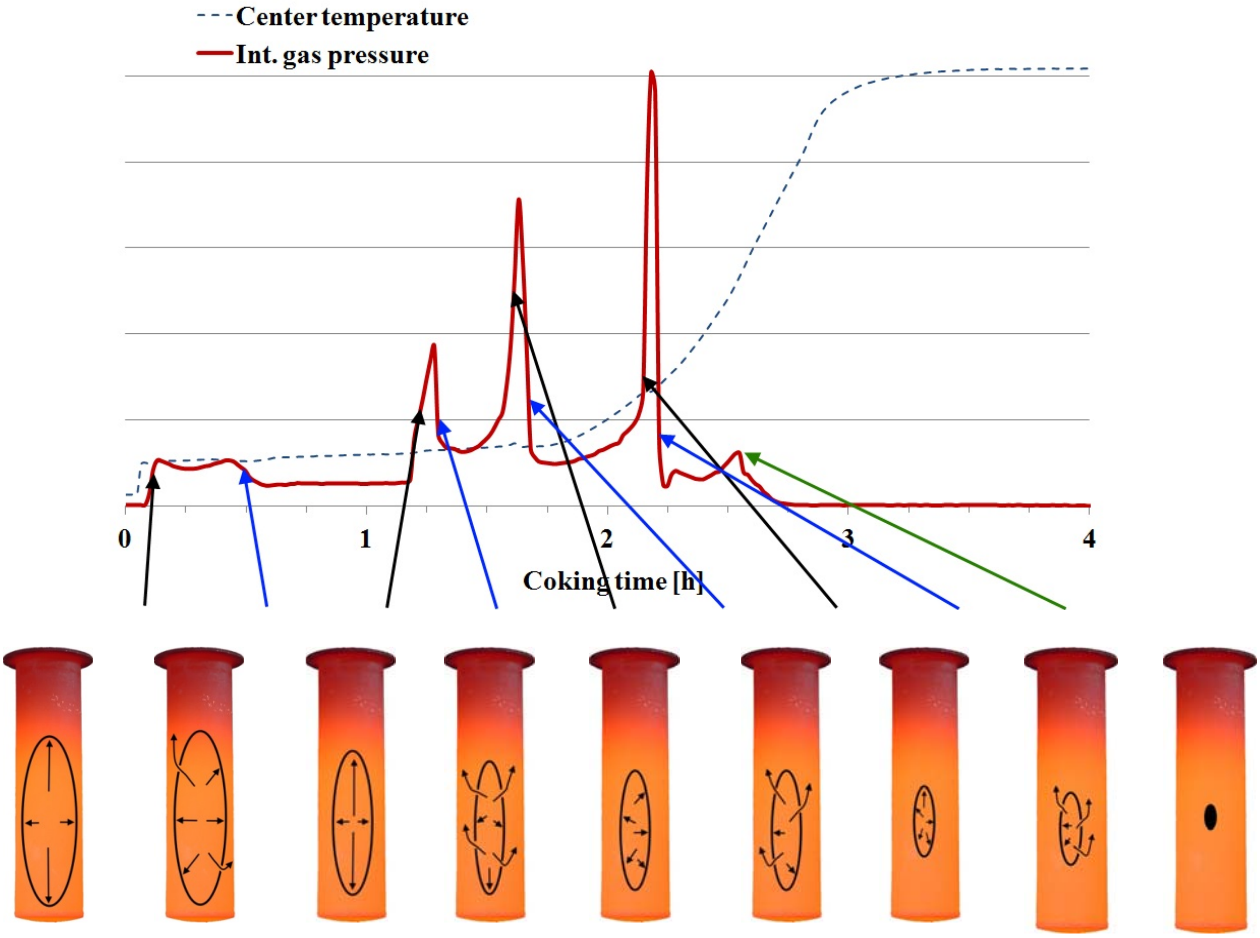

Figure 9. Shrinkage of the plastic layer during carbonization.

In contrast to the semi- industrial and industrial scale coke ovens the plastic layer in the pilot-scale coking test retort quickly generates a closed envelope which is similar to an ellipsoid. The ellipsoid compresses the enclosed water vapors which are forced against the plastic layer. The first pressure peak in figure 9 shows the counteracting of the plastic layer. The plastic layer resists the water pressure for some minutes before get first fissures and the vapors escape in the semi-coke. After the recombination of the plastic layer the new generated vapor and cracked gases compress again the plastic layer. In the meantime the volume of the ellipsoid declines. The pressure peaks increase faster and reach higher values. The high pressure generates fissures in the plastic layer and the pressure immediately drops down. The plastic layer recombines and the pressure rises again. This act takes so long as the centre temperature rise up to 350 – 500°C and the ellipsoid shrink to a small ball that generates the last pressure peak.

This behavior during the carbonization can be interpreted as the resistance of the plastic layer against the pass of the evolved gases. Nomura et al. shows in their investigation the correlation between highest pressure force to go through the plastic layer and the measured maximum internal gas pressure in a semi- industrial movable coke oven.(1) The new interpretation of the pressure progression during the carbonization in the pilot-scale coking test retort and a test program of 50 tests in the pilot-scale and industrial scale oven allow DMT to generate a prediction model. The prediction model allows with the extracted pressure data to estimate the maximum internal gas pressure in the industrial coke oven. Figure 10 displays the calculated maximum internal gas pressure and the measured values at the industrial coke oven.

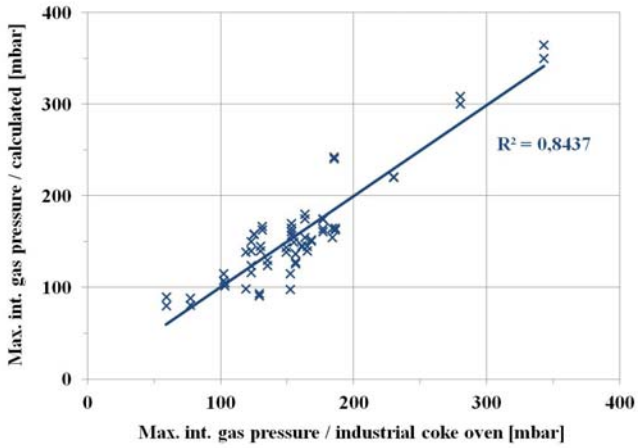

Figure 10. Comparison of measured and calculated max. int. gas pressure.

The accuracy of the model is in the range of ± 30 mbar. The comparison between the showed simple correlation of the maximum internal gas pressures (see figure 7) and the new approach indicates a clearly enhancement. The results of the new approach gives the pilot-scale coking test retort the possibility to be a fast and cost effective test method to consolidate the measured internal gas pressure in the industrial coke oven and to increase the reliability of the coke oven operator for the optimization of the coal blend in terms of coke oven safety.

4 CONCLUSIONS

DMT collect coke qualities and carbonization behavior data from coal and coal blend carbonization tests, which done parallel in the pilot-scale coking test retort and semi-industrial coke oven as well as in industrial coking plants, since 15 years. The pilot-scale coking test retort was dedicated for the fast and economical test for the determination of the CRI and CSR of coking coals. The evaluation of this bulk of coal and coke data shows also a high transferability of other important values from the retort test to the semi-industrial / industrial coke ovens. DMT is now able to estimate from the retort test the indices MICUM M_{40} / M_{10}, IRSID I_{40} / I_{10} and internal gas pressure and wall load which would be obtained in the semi-industrial coke oven.

REFERENCES

1 Nomura et al., “The mechanism of coking pressure generation I: Effect of high volatile matter coking coal, semi-anthracite and coke breeze on coking pressure and plastic coal layer permeability”, *Fuel*, Vol. 89, No. 7, 2010, pp. 1549-1556.