Consiglio Nazionale delle Ricerche

Reprint

Lab and In-field Experimental Activities Using MITER 1600" for Real Time Measuring Unburned Content in the Ashes of Coal Fired Power Plants

Mauro Bramanti, Rizzieri Marco Celli, Guido Gagliardi, Mario Graziadio Luciano Sbrana and Aurelio Cipriano

In: Combustion Meeting '98
XXIst Event of the Italian section of the Combustion Institute

B2-01
may-1998

I.E.I.
ISTITUTO DI
ELABORAZIONE DELLA
INFORMAZIONE

Pisa

Lab and In-field Experimental Activities Using MITER 1600^R
for Real Time Measuring Unburned Content in the Ashes of Coal Fired Power Plants

M. Bramanti, R. M. Celli***, Gagliardi*, M. Graziadio**, L. Sbrana**, A. Cipriano,***

** Istituto di Elaborazione dell'Informazione (IEI), CNR, via S. Maria 46, Pisa, Italy*
*** ENEL Ricerca, Polo Termico, via A. Pisano 120, Pisa, Italy*
**** Dipartimento di Fisica, Università degli Studi di Pisa, P.za Torricelli 2, Pisa, Italy*

Introduction

Real time determination of the unburned carbon content in coal fly ashes is greatly important as it allows optimisation of the combustion process, control of the emissions and production of ashes with suitable quality for commercialisation. Conventional laboratory procedures (chemical analysis) have high precision, but the measurement time is too long to fulfil the above requirements; for this reason, ENEL Polo Termico and CNR-I.E.I has developed an instrument named MITER 1600^R for real time measuring unburned coal in fly ashes produced by fossil fuel power plants [1, 2]. The present work describes the most recent activities both on a Power Station and in lab for the determination of MITER reliability, accuracy and repeatability of measurements.

Basic principle of MITER 1600^R operation

A schematic diagram of the measuring system is shown in fig. 1. The microwave signal generator feeds the cell containing the ashes under test by a microwave signal (about 1600 MHz) through a directional coupler and a circulator: the directional coupler picks up a portion of direct signal V^+ while at port 3 of the circulator the reflected signal V^- from the cell is available.

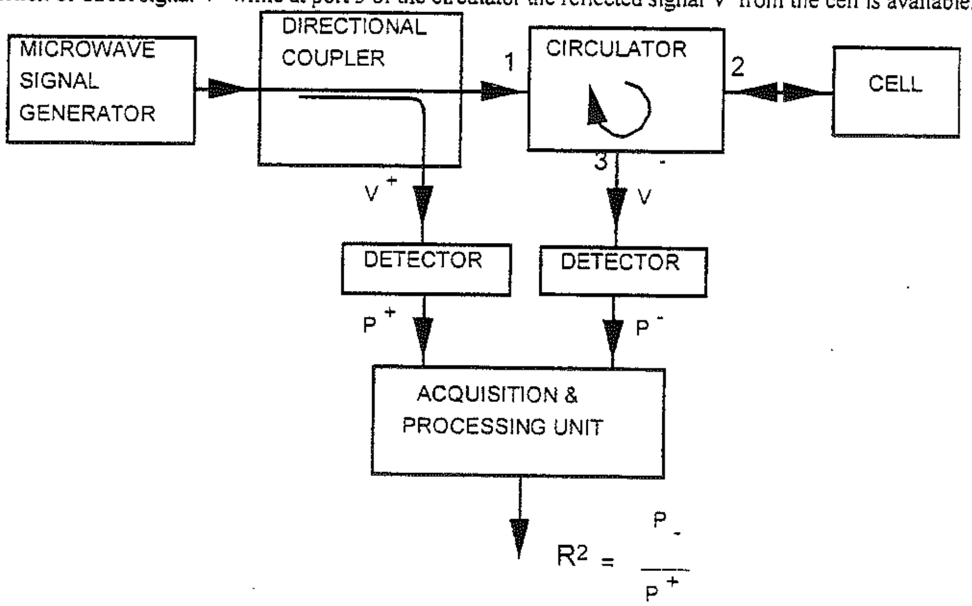

Fig. 1: schematic diagram of MITER

Using a matched pair of square law detectors, signals proportional to direct power P^- and reflected one P^- are obtained. The Acquisition & Processing Unit (APU) computes the power reflection coefficient $R^2 = P^+/P^-$, supplies all the required timing signals and suitably displays and stores the measured variables of interest.

The ash to be tested is sampled from the stack of the power plant and conveyed to the cell: during the loading operation the P^- signal is monitored: its value is assumed to be meaningful for the measure and supplied to APU only when a saturation value in the signal itself is reached. After the computation of R^2 a pneumatic system is activated for extracting the ash from the cell so that a successive measuring cycle can be start. The whole operation in its present form will be described in more detail in the next paragraph.

The cell, where the interaction between material and microwave radiation takes place, may have different forms without influence on the operation of the remaining measuring system. The present cell is obtained from a short length coaxial structure, fed by the microwave signal at one end and open at the other; this allows an easier loading and extraction of the ashes and requires a lower quantity of material before starting the measure. In the present configuration, a triple stub tuner has been

installed between the circulator and the cell in order to enhance the sensitivity of MITER's measurements.
The present configuration of MITER 1600^R has been already reported elsewhere [3, 4].

In-Field Applications of MITER on Coal-Fired Power Stations

Some prototypes of MITER were constructed in 1995-96 and, starting from 1996, were tested in different sites including Vado Ligure, Marghera and Longannet (U.K.) Power Stations.

The main object of the trials was the assessment of the reliability of the instrument in long term operation.

The most extensive demonstration was carried out at Vado Ligure. On this plant, one MITER was installed on July 1996 and operated till October 1997. In this period, 32000 measuring cycles were performed without operator assistance, corresponding to about 3000 hours of operation. The longest period of uninterrupted operation was about 950 hours.

On the whole, the automation of MITER was quite reliable notwithstanding the adverse ambient conditions (night-to-day thermal shocks, presence of vibrations, dust and humidity).

The measurement of unburned carbon content was very sensitive to boiler operating conditions, thus confirming previous results. This feature is not only appreciated by the P.S. operating personnel but is particularly important when the instrument has to be used to detect anomalous situations or potentially dangerous conditions.

The experimental trials clearly demonstrated that the sensitivity and the accuracy of MITER measurements is maximum when the tuner is set so that $V^{-}=0$ when the cell is manually filled with carbon-free ashes of the same type of the coal currently burned in the plant.

Together this operation, another factor critically important for accuracy is the use of the correct calibration curve, that is the curve corresponding to the coal in current use. The trials at Vado Ligure showed that there exist two equivalent approaches to obtain the curve.

One possibility is to fill the MITER cell manually with several ash samples having different carbon content and then read of the corresponding R^2 (the samples can be constructed in lab by mixing appropriate quantities of high-carbon ashes and carbon-free ashes).

The other approach consists in manually operating MITER with the boiler in different conditions (load, excess air), so that it is possible to collect several fly ash samples (to be analysed later for unburned carbon content) and read the corresponding R^2.

Further to these general results, the experimental activity at Vado Ligure pointed out the characteristics of MITER, which had a major negative impact on the instrument reliability.

The most frequent reason of failure was the insufficient heating of sampling and discharge ducts, especially during the winter season when temperatures were often below 0 °C. The trials indicated that the best solution is to connect the instrument's cyclone directly with the sampling probe or, in case that such ducts have to be maintained, to heat them electrically so that internal skin temperatures are always above 150 °C.

The second major problem of MITER was the erosion of some mechanical components due to the ash flow.

Erosion can be minimised by using long radius bends, avoiding restrictions in the pipes and maintaining flue gas and ash velocities below 20 m/s. Even with these precautions, the ash discharge ejector and the cut off valves between the sampling probe and the ducts are subject to strong erosion. In this case a possible solution is the use of erosion resistant inserts, e.g. made by alumina.

Accuracy and reproducibility tests in lab

After the in field trials, MITER was returned in lab in order to improve its sensitivity and dynamic range and to enable the instrument to measure lignite ashes. These trials were partly carried out using a network analyser HP850044A and a transmission/reflection test set, both connected to the MITER's tuner and cell, partly with the instrument, alone which was operated manually. In all cases the measurement cell was filled by hand with several ash samples of different origin.

At the beginning, a test procedure was defined in order to guarantee the best correspondence between the results obtained in lab and the MITER operation when installed in power stations.

In this frame, in order to avoid errors due to the air humidity present in the ashes, the samples were dried in a muffle furnace at 150°C for about 30 minutes before being loaded in the test cell. For the same reason, the m.w. cell was maintained at 150°C.

Two different techniques for ash loading were compared. One consists in vibrating the cell during the loading phase; the other is characterised by the manual compacting of ashes before the measurements. For comparison the same measurements were repeated without compacting the ashes or vibrating the cell. As shown by fig. 2, the ash compaction technique seems to guarantee the minimum spread of the experimental points. It is necessary to note that at present MITER is configured only for the vibration technique and, in case these results were confirmed, some mechanical modifications will be required.

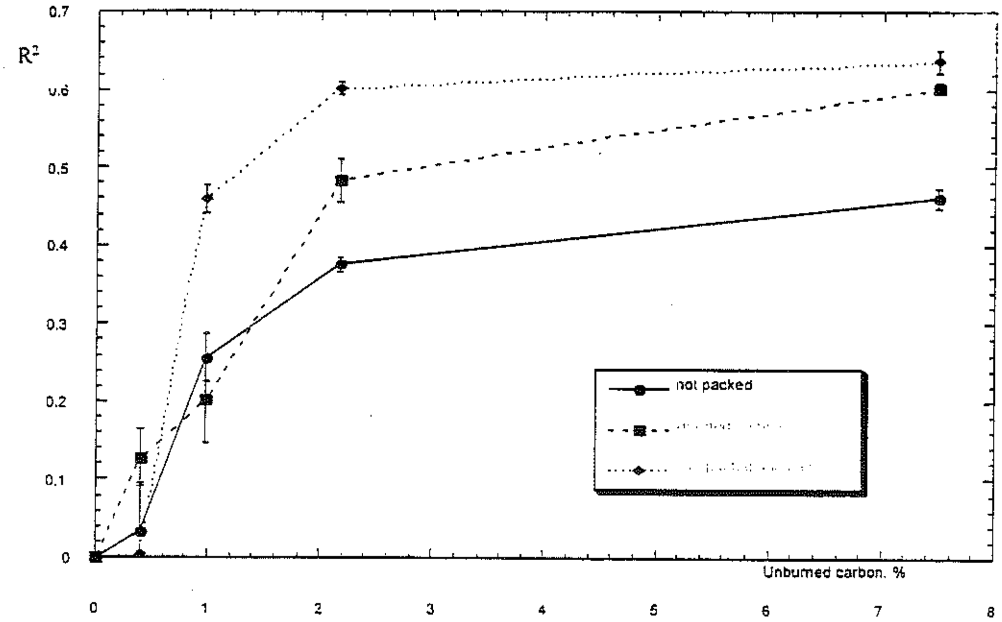

Fig 2. - Comparison between different ash loading techniques

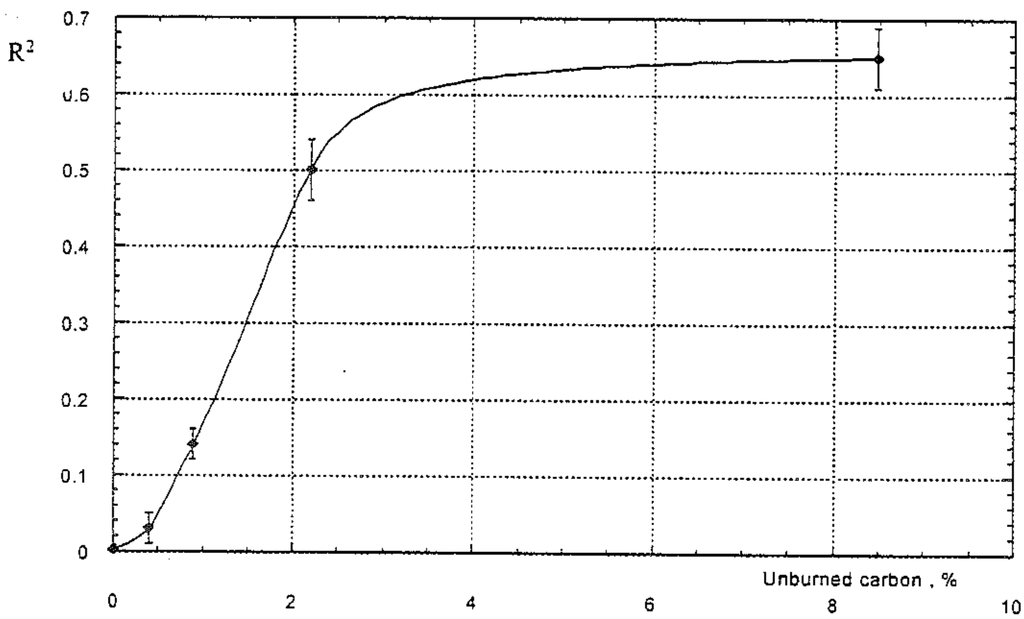

Fig. 3 – Typical calibration curve for coal fly ashes

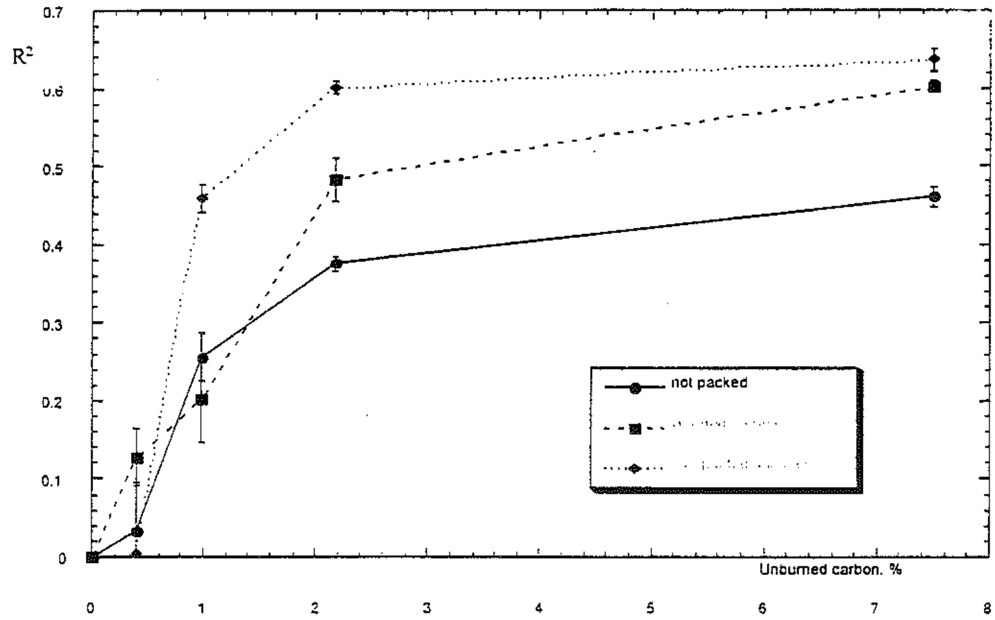

Fig 2. - Comparison between different ash loading techniques

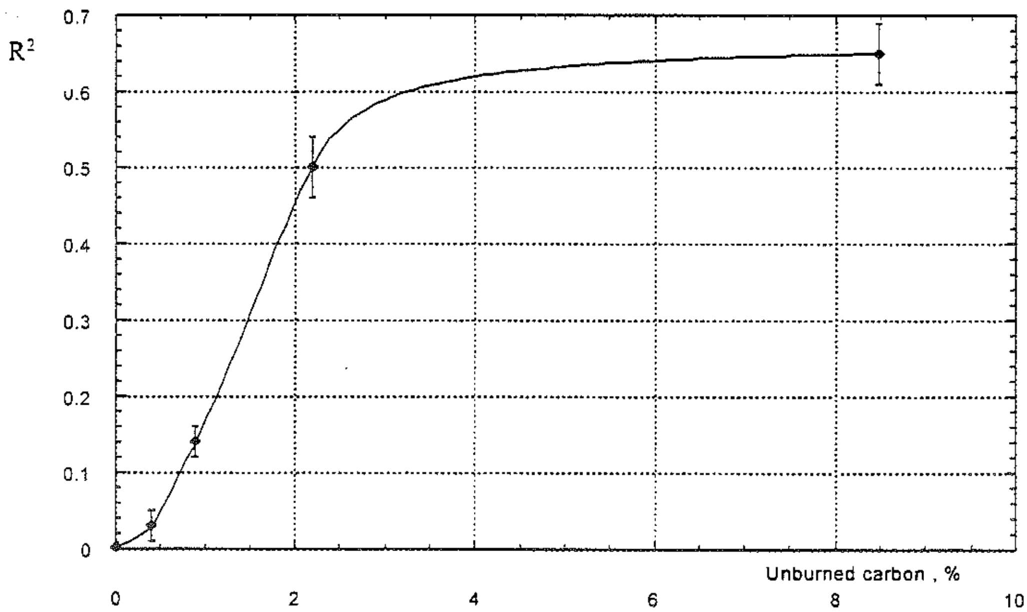

Fig. 3 – Typical calibration curve for coal fly ashes

Fig. 2 also shows that the compaction of ash samples corresponds to an increase of reflected m.w. power if the instrument is correctly calibrated.

It is worthwhile to underline that compaction strictly depends on ash typology: soft ash samples always collapse when pressed and, in order to fill completely the cell, the operation must be repeated several times. This is not necessary when the ashes are hard and almost incompressible.

The cell vibration is not completely equivalent to compaction. Two facts can be responsible of this behaviour: the segregation of ash particles with different density as a consequence of different carbon content, which is enhanced by vibration, and the non uniform sensitivity of MITER to the geometrical distribution of unburned materials in the cell.

Using fly ashes from different power plants, the corresponding calibration curves were obtained using the compaction technique. Also with this new approach, it was confirmed the necessity of the correct setting of the tuner in order to obtain the maximum sensitivity.

As a typical example, fig. 3 shows the calibration curve obtained compacting some samples of hard American ashes. It is possible to notice that accuracy is better than 0.33% in the range of unburned carbon less than 2.5%.

A special investigation was carried out with lignite ashes, which showed behaviour completely different from coal ashes. In this particular case, the benefit of compaction compared to vibration is not clear. Lignite ashes are quite elastic and relax after any compression. Moreover, the response of MITER is quite different with carbon and with partially burned fractions of lignite. These facts are the possible explanation of the significant difference between the calibration curve of lignite ashes and a typical curve of coal fly ashes (fig. 4).

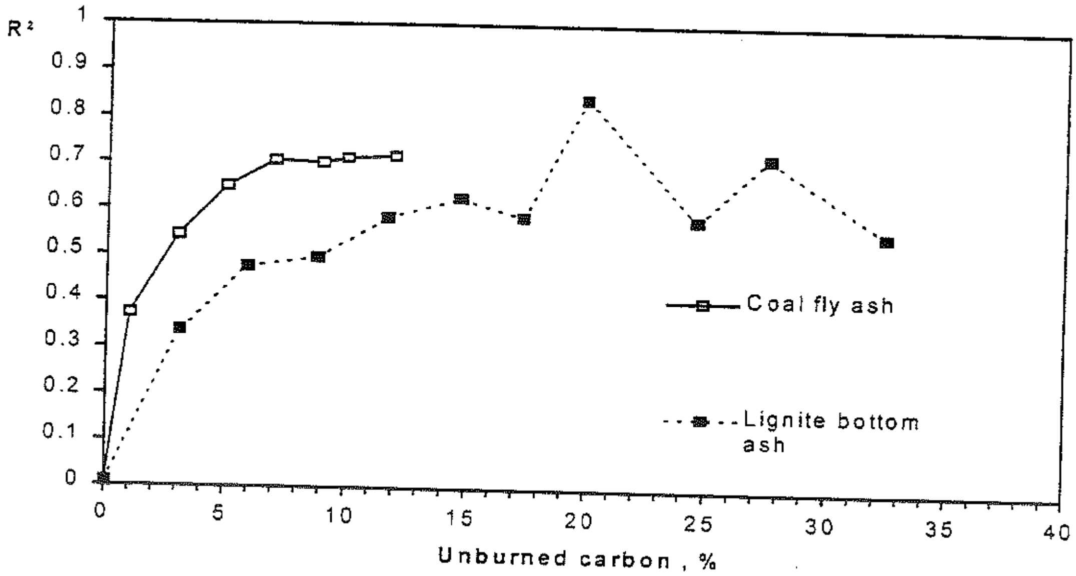

Fig. 4 – Calibration curves of bottom lignite ash and coal fly ash

Acknowledgements

The present work has been supported by the European Community in the frame of the Training and Mobility of Researchers Programme n° ERBFMGE-CT95-0039

References

1. M. Bramanti, G. De Michele, G. Saccenti " Proposta di una Nuova Tecnica per la Misura del Tasso di Carbone Incombusto Presente nelle Ceneri " 87th Meeting of AEI, October 1986.
2. M. Bramanti, G. De Michele " A microwave Method to Measure Unburnt Coal Content in Ashes " IEEE Trans. on Instrumentation and Measurement, vol. 39, n°5, 1990.
3. M. Bramanti, E. Bozzi., M. Graziadio, L. Sbrana "MITER 1600R: a Workstation for Real Time Measuring Unburned Content in the Ashes of Coal Fired Power Plants" Proc. CROCUS '94, paper II-18, Salsomaggiore Terme, 1994.
4. M. Bramanti, G. De Michele, M. Graziadio, Bozzi E. "Dalla tecnica delle microonde una classe di strumenti per la diagnostica della combustione: il MITER 1600R e la sua evoluzione" Proc. 97° Annual Meet. A.E.I., Baveno, 1997.