FEASIBILITY OF USING ULTRASONIC TECHNIQUE TO MEASURE THE BLAST FURNACE LINING THICKNESS

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ABSTRACT

Blast furnace process has been the most effective way to produce iron for over 200 years. Throughout the years, large efforts have been put on finding ways to increase the productivity and extend the campaign length. The condition of the refractory lining of a blast furnace plays a very important role to determine its campaign length. Many methods have been employed to measure blast furnace lining thickness including radioisotopes, thermal measurement and core-drilling. Temperature measurement is among the most widely used method for on-line monitoring the profile of the blast furnace inner surface, which is based on numerically solving inverse problem using heat transfer models and readings from thermocouple. Optimization methods are applied to obtain the boundary of the domain iteratively, and hence the computation is very expensive and calculation cannot be very accurate. This paper presents the feasibility of using non-invasive ultrasonic technique in bi-static mode to measure the profile of the refractory liner of the hearth region of blast furnace.

KEYWORDS

lining thickness, blast furnace, non-invasive, ultrasonic

1. INTRODUCTION

Blast furnace (BF), a high-efficiency counter-current packed bed reactor is being successfully used in all integrated Iron & Steel plants of the world to produce pig iron. Throughout the years, large efforts have been put on finding ways to increase the productivity and extend the campaign length of the plants. The state of the hearth has by many been identified as the most important factor for a long campaign length. This lower region of the furnace is exposed to liquid iron and slag at high temperatures that could be in direct contact with the lining, causing erosion and corrosion of the lining material. The most aggressive environment is found in the region closest to the tap hole. It is exposed to thermal stresses and liquid iron and slag at high flow rates. An increased productivity results in higher load on the furnace, which potentially can shorten the campaign length. To strive to optimize both these goals, it is important to carefully control the state of the hearth. As the refractory lining of the hearth gradually worn out during operation, the lining thickness distribution is an important factor that limits the remaining life of the blast furnace and is taken as a major check point for evaluating repair quality. Many methods have been employed to measure blast furnace lining thickness, including radioisotopes, thermal measurement and core-drilling. Temperature measurement is among the most widely used method for on-line monitoring the profile of the blast furnace inner surface, which is based on numerically solving inverse problem using heat transfer models and readings from thermocouple [1-3]. Optimization methods are applied to obtain the boundary of the domain iteratively, and hence the computation is very expensive and calculation cannot be very accurate. Radioactive method uses radiation source that emits gamma ray into the wall and the wall thickness can be obtained as a function of scattering intensity [4,5]. Core-drilling is an invasive method to inspect the wall thickness of a particular position on the wall by taking sample of a very small portion. These methods can only give localized information with disadvantages such as radiation safety concerns as well as accuracy issues. Therefore an effort has been made to develop non-invasive technique based on low frequency ultrasonic to measure the blast furnace lining thickness. This paper presents the feasibility of application of ultrasonic technique in a bi-static mode to measure the lining thickness of blast furnace.

2. EXPERIMENTAL

2.1 Construction of mock-up facility

A mock-up facility as shown in Fig.1 has been set-up at National Metallurgical Laboratory to study and optimise the measurement parameters under cool and hot conditions. As the hearth lining is the most critical area of the blast furnace, a full scale model of 9^{o} sector of hearth zone of designated BF of Bokaro steel plant, SAIL was considered for the mock-up facility. The facility was built with identical constructional materials of the designated BF. The mock-up facility consists of a furnace capable of attaining temperature up to $1250^{o}C$ using LPG burners. The size of furnace (inside) is approximately 1000 mm wide, 1500 mm high and 3200 mm long. The testing side of the furnace wall was comprised of carbon blocks baked by carbon mass lining, stave cooler, refractory grouting material and the furnace shell.

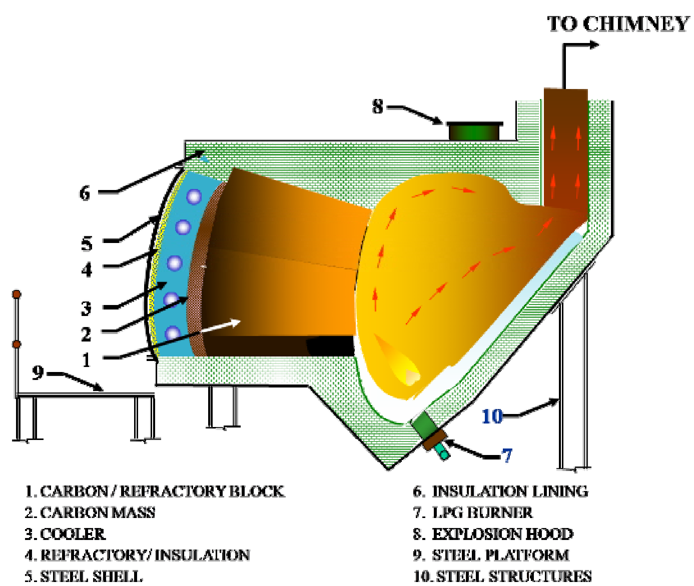

Fig.1: Schematic view of the Mock-up facility

2.2 Lining thickness measurement of mock-up facility

After the complete construction of the mock-up facility, lining thickness measurement was carried out at room temperature as well as at elevated temperature using low frequency ultrasonic technique (LFUT) in a bi-static mode. A schematic view of the multi-layered structure is shown in Fig.2.

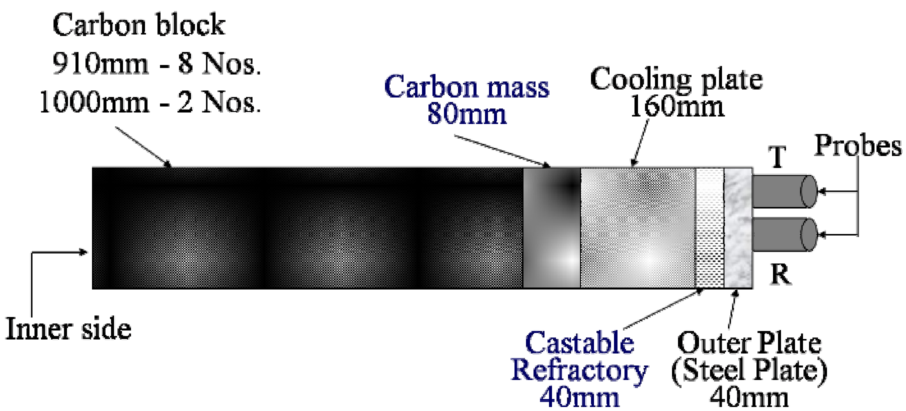

Fig.2: Schematic view of the multi-layered structure

Two longitudinal 50 kHz probes were used, one as a transmitter and the other as a receiver for the measurement. Receiver was placed close to the transmitter and the distance (x) between the transducers was noted. From the received ultrasonic signal as shown in Fig.3, the beam path (l) was measured.

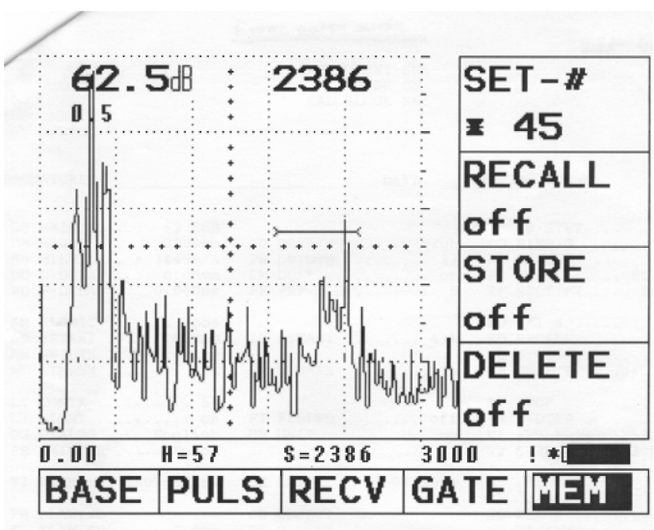

Fig.3: View of received signal

From beam path and the distance between two transducers, the thickness of the wall (d) was determined using the equation

$$d = \sqrt{l^2 - x^2}$$

3. RESULTS

LFUT was used in bi-static mode to measure the wall thickness of the mock-up facility at room temperature and also at elevated temperature and the results as obtained are listed in Tables 1 and 2 respectively.

Table 1: Results obtained from ultrasonic testing at room temperature

Carbon Blocks	Actual Thickness (mm)	Measured Thickness (mm)	% Error
T1	1230	1215	1.2
T2	1320	1118	15.3
T3	1230	1173	4.6
T4	1230	1222	0.7
T5	1230	1221	0.7
B1	1230	1202	2.3
B2	1230	1173	4.6
B3	1230	1250	1.6
B4	1230	1121	8.9
B5	1320	1227	7.0

T: Top layer blocks; B: Bottom layer blocks

Table 2: Results obtained from ultrasonic testing at 1140^{o}C

Carbon Blocks	Actual Thickness (mm)	Measured Thickness (mm)	% Error
T1	1230	1183	3.8
T2	1320	1167	11.6
T3	1230	1222	0.6
T4	1230	1280	4
T5	1230	1206	1.9
B1	1230	1142	3
B2	1230	1199	2.5
B3	1230	1197	2.7
B4	1230	1221	0.6
B5	1320	1350	2.2

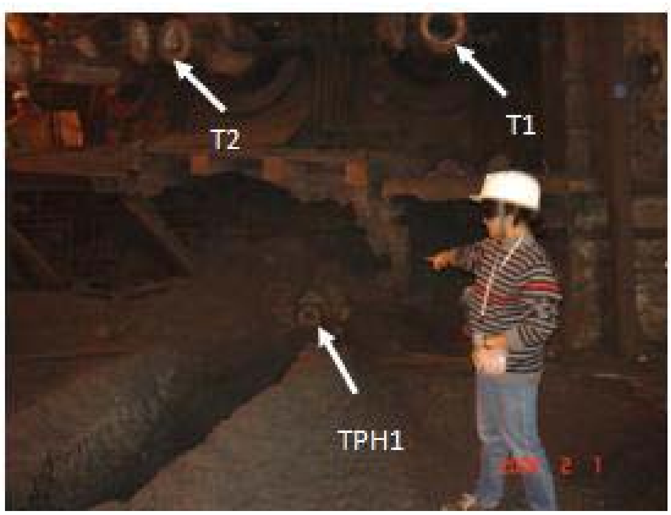

Fig.4: View of reference point at BF#5

3.1 Lining thickness measurement at BF#5 of Bhilai Steel Plant:

Refractory lining thickness measurements were carried out at BF#5 of Bhilai Steel Plant just after the tapping. Measurements were carried out at different positions mainly in the Tuyer layer (T). Considering the Tap Hole #1 (TPH1) (shown in Fig.4) as the reference point, measurements were made on all possible regions in between T7 & T8, T8 & T9, T11 & T12 and below T11. Fig.5 shows few of the signals correspond to the different measurement locations.

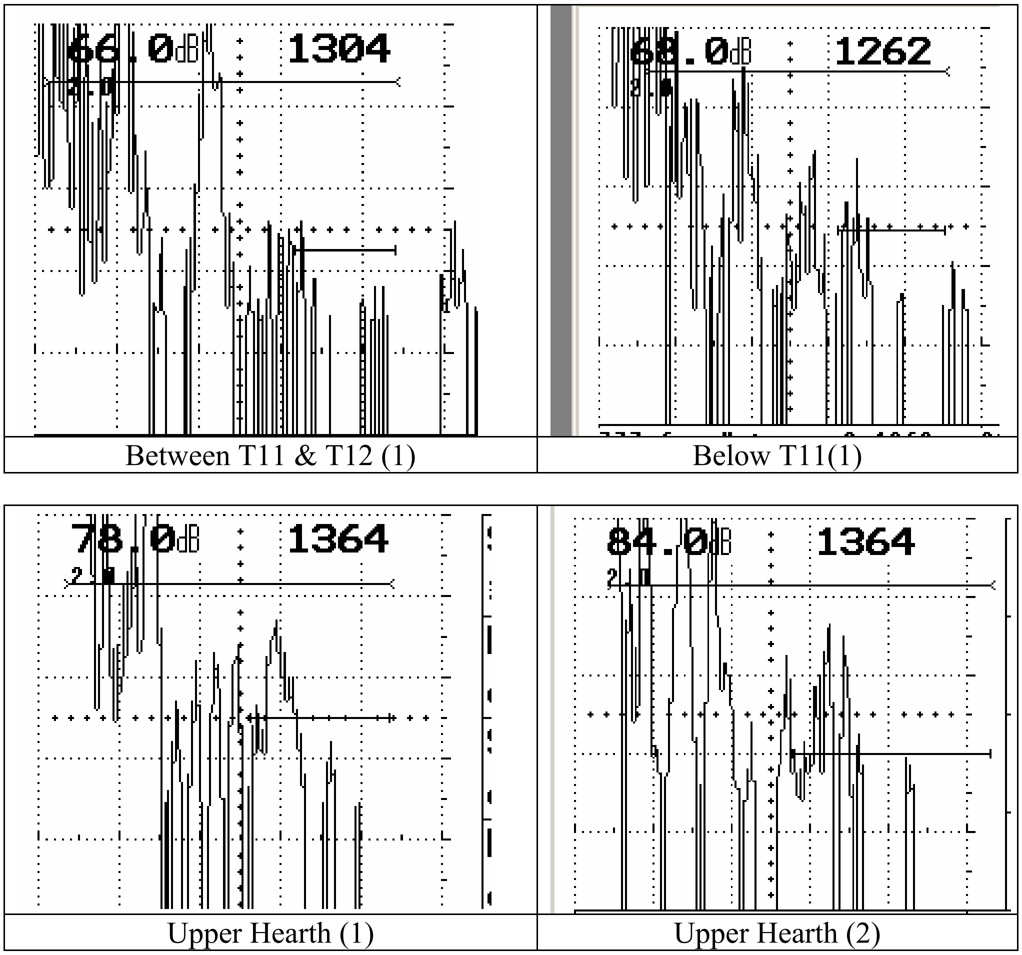

Fig.5: Ultrasonic signals as obtained at few measurement locations

Table 3: Measurements of lining thickness recorded at various locations

Location of Measurement	Thickness (mm)
Below T11 (1)	1262
Below T11 (2)	1249
Between T7 & T8(B1)	1299
Between T7 & T8(B2)	1299
Between T11 & T12	1304
Upper Hearth (1)	1364
Upper Hearth (2)	1364

Velocity of multilayer region was considered to be 4500m/s as calibrated in the mock-up facility and all the thickness measurements were made taking the same velocity. Table 3 below listed the measured thickness at different measured locations.

4. CONCLUDING REMARKS

From this work though it has been observed that low frequency ultrasonic technique in a bi-static mode can be used to monitor the liner profile of blast furnace in empty condition, still it is required to validate the results with thermocouple data for the establishment of the technique.

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