Non Destructive Evaluation and Qualification of high purity Alumina Cored bricks for Storage Heater system

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Abstract

High purity Alumina cored bricks having high heat storage capacity, compressive and rupture strength and thermal shock resistance are used as the heat storage medium in the heater systems of the Hypersonic Wind Tunnel (HWT), VSSC and have been developed indigenously. Cored bricks are designed for a maximum operating temperature of 1550 K and are preferred over the pebble bed heaters because of its minimum dust generation characteristics.

Considering the extreme conditions to which the bricks are subjected to during the operation, proper evaluation of its characteristics and qualification of the bricks is a must. The conventional evaluation and qualification schemes are based on the destructive tests such as measurement of Cold Crushing Strength, Modulus of Rupture, Abradabilty index, Density measurements etc. However such tests being destructive in nature, limited to sample level, hence individual property variation cannot be captured. X ray cannot be used since property evaluation is not feasible. Inspection cannot be done in-situ because of X-ray hazard and Cost of film is also high. Hence a special customized non-destructive testing and evaluation scheme based on Acoustic Ultra Sound (AUS) inspection was developed for the qualification of the alumina cored bricks. The technique being non destructive in nature can be employed for the qualification of each and every individual brick, a definite advantage over the conventional destructive qualification techniques

The scheme has been successfully implemented for the qualification of nearly 20,000 nos. of cored bricks for the storage heater of Hypersonic Wind Tunnel. The validity of the scheme has been established by comparing the measured velocities with the cold crushing strength of the samples from the pilot batches. The details of the qualification scheme devised and the results obtained are covered in this paper.

Introduction

Hypersonic Wind Tunnel (HWT) facility in Vikram Sarabhai Space Centre is one of the largest aerodynamic characterization facilities in the world. The facility consists of two heater systems - to heat the high pressure air to the required temperature to prevent

liquefaction of air, as the air expands through the wind tunnel nozzle. The heaters are storage heater systems where high purity Alumina cored bricks are used as the heat storage medium. High temperature flue gas generated from the combustion of LPG by the burner will heat the alumina cored bricks to the required temperature.

The cored bricks were tested using ultrasonic equipment AUS, which measures the velocity of ultrasonic wave passing through the brick in order to ascertain whether the sintering of bricks is done properly. The velocity at different locations on a given brick gives the indication of variation of properties across the same brick and the average velocity through different bricks gives the indication of variation of properties across the same batch of bricks.

Brief on Studies to implement the AUS equipment system

Technical studies to ascertain the validity and applicability of the technique are conducted on two sets of pilot batch bricks with identical sintering to ensure the repeatability of properties. Sample bricks are tested and evaluated for its properties such as Cold Crushing Strength, Modulus of Rupture, Abradabilty index, Density, etc after ultrasonic measurements. The ultrasonic velocity of wave through the brick at various locations of the brick directly indicates the properties like porosity percentage, density variations and sintering properties. By giving the thickness of the sample as an input to the instrument, it calculates the velocity of the wave through the sample and plots the velocity profile.

General description of the equipment

Velocity of propagation of the acoustic wave through a material and the extent of attenuation of the acoustic wave in the materials can be used for evaluating highly attenuating non metallic materials. The Sounds Mk 2 is a PC based system which facilitates measurement of velocity of propagation of the acoustic waves and the attenuation. The system consists of a PC, Signal generator, Power amplifier, Transducer, Signal conditioners, Receiver amplifiers, and data acquisition circuits. The software controls all the above hardware as well as provides Graphical User Interface to facilitate measurements. Wave velocity is directly measurable from the displayed transmitted wave and received wave, is the time transit of the wave through the material. From this, if the distance between the transducer is known, velocity can be calculated. Arrangement of the equipment is shown in fig1.

Fig 1: Evaluation of cored bricks for storage heaters.

Development of methodologies, scanning schemes and analysis

Inspection of sample bricks from the pilot batch is carried out using the AUS (Acoustic Ultrasound System) system, various scanning methods are tried, and measuring scheme were evolved, developed, verified and implemented for final products.Inaddition to the measurement of sound velocity, signal strength of received waves are compared with a standard signal from a defect free brick sample which is used as a reference brick. The signal strength gives insight into the properties of the bricks.Referance/good signal and defect signal are shown in fig.2 and 3 respectively.

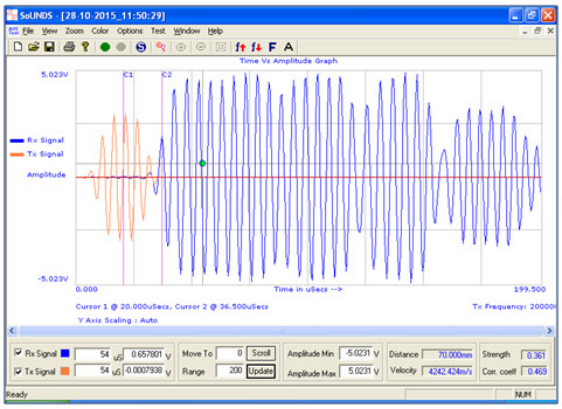

Fig 2: Reference brick signal

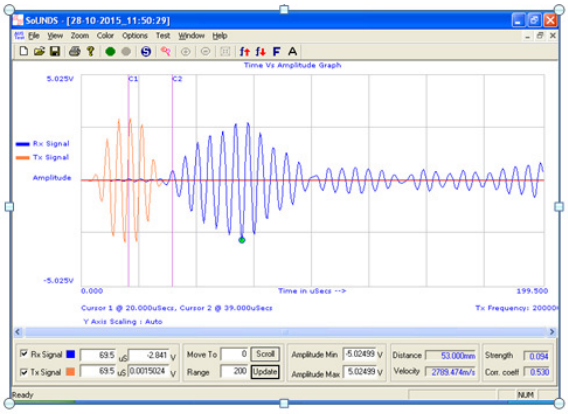

Fig 3: Defect brick signal

Some of the equipment setting parameters finalized after the sample measurements for consistent and precise measurements is as given in table 1.

Transmitter		Receiver	
Frequency mode	Single	Frequency mode	Single
Frequency	200KHz	Frequency	300KHz
Trigger mode	Auto	Measurement Mode	Normal
Level in dB	4	Gain in dB	25
No.of cycle	4	Duration	300 seconds
Sampling Distance	60mm	Sampling Frequency	2MHz

Table 1: Equipment setting parameters

Results

Studies were carried out on alumina brick specimens sintered through alternate cycles with different sintering time. A good correlation was observed between sintering time and ultrasound velocity in the material as shown in Fig 4.Since the properties of the bricks depends on the sintering time ,ultrasound velocity in the material could be used as an indirect measure of sintering. With the scheme finalized through trials, extensive ultrasound velocity mapping was carried out on all of bricks at field level. Histogram of velocities was near mean as shown in Fig 5 indicating uniformity in material and hence uniform sintering. The methodology has been employed for insitu characterization and qualification of about 20,000 bricks at shop floor for the heater system of Hypersonic Wind Tunnel.

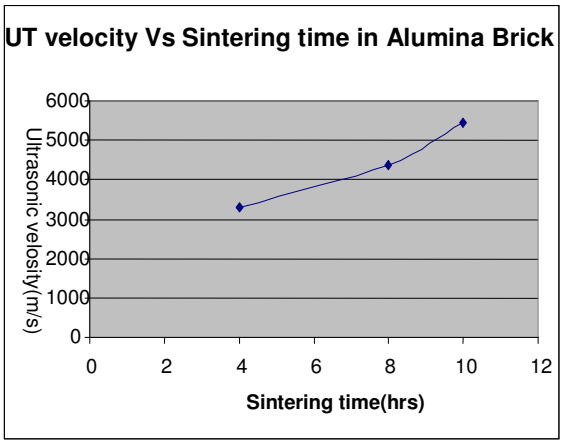

Fig 5: Sintering time vs velocity for alumina brick specimen

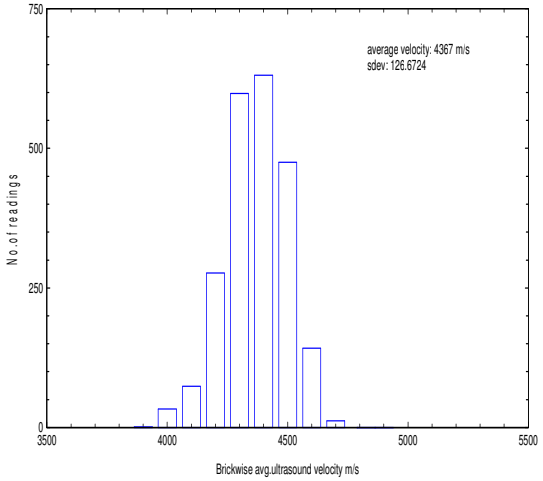

Fig 6: Histogram of ultrasound velocities.

Average ultrasound velocity of the sample bricks with bulk density, cold crushing strength, and apparent porosity are shown in the table 2.From this, a good correlation derived between

ultrasound velocity and other properties which establishes the acceptance criteria. This has been successfully implemented for the evaluation and qualification of 20000 nos. of cored bricks.

Ultrasound Velocity in m/s	Bulk Density in gm/cc	Cold Crushing Strength in MPa	Apparent Porosity in %
4531	3.33	112.3	13.29
4312	3.22	87.8	15.93
4437	3.25	102.3	15.44
4465	3.28	104.85	15.75
4354	3.24	85.8	15.34

Table 2: Sample values of bricks.

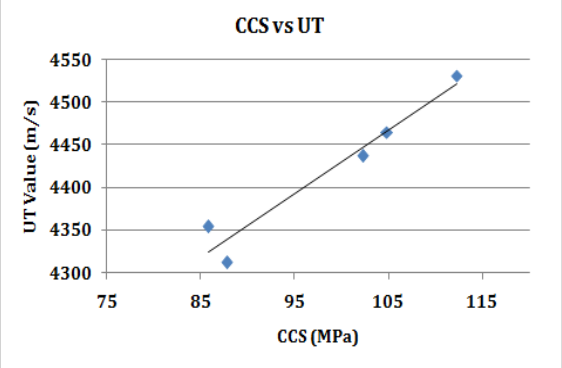

Fig 7: CCS Vs Ultrasound velocity

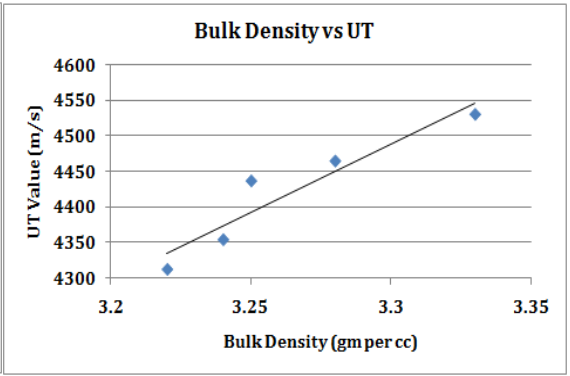

Fig 8: Bulk Density Vs Ultrasound velocity

Conclusion

Ultrasonic evaluation of cored bricks has been carried out using a customized scheme with NDE system named AUS system. Methodology was developed, standardized at specimen level and has been successfully implemented. The method is cost-effective and it is feasible for all the ceramic products. The direct correlation of the cored brick properties with measured ultrasound velocity gives confidence to accept the bulk volume of cored for end use. Studies are in progress for extending the application to more areas where conventional methods like radiography can be slowly replaced thus saving time, effort and money.

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