SLAG CHARACTERIZATION AND REMOVAL USING PULSE DETONATION FOR COAL
GASIFICATION

QUARTERLY TECHNICAL REPORT
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The research activities performed in this quarter (reporting period: 07/01/97-09/30/97) are summarized as follows:

The research activities concentrated on

- Design, development, and fabrication of a 9 positions (3x3 matrix form) fixture
- Preparation of the test parameters
- Multi-cycle detonation wave slag removal test
- Partial analysis of the test results
- Interpretation and discussion of the test results

MULTI-CYCLE TESTING

Dr. Ziaul Huque, Dr. Daniel Mei, and Muhammad Ali (Graduate student) went to Aerodynamics Research Center , University of Texas at Arlington to perform the multi pulse testing for removing utility boiler slags.

The test chamber facility at the Aerospace Research Center for single shot detonation wave had been modified to run in a multi-cycle mode as a pulse detonation engine simulator. The test chamber, injection system, ignition system, and instrumentation were exactly same as before except few modification. A fuel injection system to inject repetitively was incorporated as well as an ignition system which could be used repetitively to ignite the combustible mixture. The injection portion of the facility has been replaced with one designed for repetitive use. The ignition system has also been upgraded for repetitive use. A control circuit was designed and built to sense the injection of fuel and oxidizer, provide a short time delay, fire the ignition source, recharge the ignition capacitor bank and provide a synchronized signal to the data acquisition system if required or desired. The injection system has been designed for hydrogen, propane, or methane as the fuel and oxygen or air as the oxidizer. Other oxidizers could be used if they are compatible with the valve materials and seals. The fuels and oxidizers are injected through a passage on the end plate which closes one end of the tube. The fuel and oxidizer is measured by setting the valve supply pressure according to regulator flow rate charts and

injected using rotary valves. The opposite end is open for the exhaust of the detonation wave and combustion product. The pneumatic gas control system used in the single shot experiments was also used in the multi-cycle test with minimal modifications. The fuel, oxidizer, and air lines were used as before. The remote control valves were retained as a measure of positive control over fuel and oxidizer flow through the rotary valves for safety reasons. In multi cycle experiments unlike single shot experiments no diaphragms were used in the open end. In addition to the 4 axial positions and triangular positions fixture, a 9 positions fixture (Figure 1) was also used to hold the slag sample at the exit of detonation tube.

TEST PARAMETERS

Input conditions

Several experiments were performed with multi-cycle detonation wave at the Aerospace Research center at University of Texas at Arlington. The effects of sample tube reflection, slag reverberation, axial distance, slags orientations, slag types, and wave frequencies are discussed below.

Input parameters for the experiments were as follows:

Wave pattern:	Weak detonation (multi-cycle)
Wave frequencies:	10-20 Hzs.
Types of slag:	MTI 96-54 (soft), MTI 96-55 (hard), MTI 96-56 (medium soft)
Types of fixture:	(i) axial configuration (ii) triangular configuration (iii) matrix configuration (3x3)
Slag orientation:	Around the steel tube.

Slag types

The same types of slag which were used for single shot detonation wave have been used for performing multi-cycle detonation wave test.

Three different types of Northern States Power Solid Slag Deposits which were used are as follows:

- MTI 96-54: air-heater inlet deposit which is softer than others.
- MTI 96-55: reheater deposit which is very tough like a rock.
- MTI 96-56: economizer deposit which is softer than MTI 96-55 but harder than 96-54.

Wave pattern

Weak detonation waves were generated using propane as the fuel . Wave frequency varied from 10 Hzs to 20 Hzs.

Sample location

Three different arrangements were used to study the effect of detonation wave on the position of the sample with respect to the exit of the detonation tube. In axial arrangement samples could be attached at four different locations, 2 in., 4 in., 6 in. and 8 in. from the detonation tube exit. In the second arrangement the samples are attached at the corners of a unilateral triangular arrangements at 1.3 in. apart from each other with the first tube at 2 in. from the exit of the detonation tube. In the third arrangement slag samples can be attached at nine positions in a 3x3 matrix form. The reference number of each positions in the fixtures could be read as I, II, III,.....IX starting from right to left closer to the exit of detonation tube. This arrangement has been used to see the effects of sample tubes wave reflection, reverberation, and tubes bank effect.

Slag orientation

The slag samples were attached around the steel tube.

RESULTS AND DISCUSSION

Effects of Tube Banks

The matrix configuration fixture has been used to investigate wave reflection among the sample tubes and reverberation effects within the slags. In the multi-cycle test runs the pressure build up inside the detonation wave chamber varied from 32-45 psi which was almost one-eighth of the pressure range developed in the single shot test runs. Test results indicated that the pressure is an important factor, in addition to the other factors such as waves reflection, thermal shock, and reverberation, in removing slags. During the first test a sizable portion of the soft slags were removed from the first two rows closets to the exit of the detonation tube. Considerable amount of slags were chipped off from positions I, II, IV, and V. The effect on the last row was not that significant. Figure 2 shows the picture of soft slags before and after the test run. After repeating the test run for 4 times, it was noticed that more slags chipped-off from positions I, II, V, and VIII. The position V looked almost clean. Sample positions II, IV, VI, VIII were exchanged with sample positions I, III, VII, and IX and the test was repeated. The same pattern of slag removal was observed as expected due to wave reflection.

Effects of slags type

In multi cycle test, slag types is also an important factor. Tests performed with hard slag showed more or less slags removal from all the positions. Figure 3 shows the picture of hard slags before and after the test run. Picture shows complete removal from positions I, II, IV, VI, and VIII and partial removal from positions I, III, VII, and IX. The pattern of slag removal from positions II, IV, VI and VIII , revealed the fact of wave reflection. The hard and medium soft slags chipped off more because of the waves reflection, reverberation and thermal shock developed inside slags. Another conclusion can be drawn

that the impact of big chunk of hard slag removed from front rows helped in removing slags from later positions due to their collisions.

CONCLUSIONS

From the test results using single and multi-cycle detonation wave in removing utility boiler slags, several conclusions can be made. These are as follows:

- Pressure impact has the vital role in removing the slags.
- Nine positions fixture is more effective for same pressure force and wave frequency level than axial and triangular positions fixture..
- Waves reflection and slag reverberation has also important role in removing slags.

Future Work:

- Complete analysis of the test results
- Interpretation of velocity and pressure diagrams
- Recommendation and conclusion

Figure 1: Schematic of 9 Positions Fixture Plate

Figure 2: Picture of soft slag before and after the test in tube banks.

Figure 3: Picture of hard slag before and after the test in tube banks.