

Innovative Instrumentation and Analysis
of the Temperature Measurement for
High Temperature Gasification

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ABSTRACT

The systematic tests of the gasifier simulator on the ultrasonic vibration application for cleaning method were completed in this reporting period. Within the systematic tests on the ultrasonic vibration application, the ambient temperature and high temperature status condition were tested separately. The sticky dirt on the thermocouple tip was simulated by the cement-covered layer on the thermocouple tip. At the ambient temperature status, four (4) factors were considered as the input factors affecting the response variable of peeling off rate. The input factors include the shape of the cement-covered layer (thickness and length), the ultrasonic vibration output power, and application time.

At the high temperature tests, four (4) different environments were considered as the experimental parameters including air flow supply, water and air supply environment, water/air/fine dust particle supply, and air/water/ammonia/fine dust particle supply environment. The factorial design method was used in the experiment design with twelve (12) data sets of readings.

Analysis of Variances (ANOVA) was applied to the results from systematic tests. The ANOVA results show that the thickness and length of the cement-covered layer have the significant impact on the peeling off rate of ultrasonic vibration application at the ambient temperature environment. For the high temperature tests, the different environments do not seem to have significant impact on the temperature changes. These results may indicate that the ultrasonic vibration is one of best cleaning methods for the thermocouple tip.

TABLE OF CONTENTS

	Page
TITLE PAGE	i
DISCLAIMER	ii
ABSTRACT	iii
TABLE OF CONTENTS	iv
LIST OF GRAPHICAL MATERIALS	v
LIST OF TABLES	v
1. INTRODUCTION	1
2. EXECUTIVE SUMMARY	3
3. EXPERIMENTAL	4
3.1. Facilities for Ultrasonic Vibration Application Experiments	4
3.2. Experimental Procedure	5
4. RESULTS AND DISCUSSION	6
4.1. Temperature Changes under Air Supply Environment	8
4.2. Temperature Changes under Air/Water Supply Environment	9
4.3. Temperature Changes under Air/Water/Ammonia Environment	10
4.4. Temperature Changes under the Environment of Air/Water/Ammonia/Fine Dust Supply	11
4.5. Analysis of Experimental Data and Results under Ambient Temperature Condition	13
4.6. Analysis of Experimental Data & Results under Hot Temperature Condition	14
5. CONCLUSIONS	16
6. RESEARCH CONTINUATION	16
REFERENCES	17
APPENDIX I	18
APPENDIX II	19

LIST OF GRAPHICAL MATERIALS

		Page
Figure 1	Pictorial View of Ultrasonic Vibration Facility	5
Figure 2	Pictorial View of Overall High Temperature Gasification Simulating System	7
Figure 3	Pictorial View of Thermocouple Simulation of Thin Cement Layer	7
Figure 4	Pictorial View of Thermocouple Simulation of Thick Cement Layer	8
Figure 5	Temperature Changes under the Air Supply Environment	9
Figure 6	Temperature Changes under Air and Water Supply Environment	10
Figure 7	Temperature Changes under the Environment of Air/Water/Ammonia Supply	11
Figure 8	Temperature Changes under the Environment of Air, Water, Ammonia and Fine Dust Particles Supply	12

LIST OF TABLES

Table 1	Temperature Changes under Air and Air/Water Environments	18
Table 2	Temperature Changes under the Environment of Different Factors Supply	19
Table 3	Cold Test of Peeling Effect of Ultrasonic Vibration	13
Table 4	ANOVA Table of Cold Test for Peeling Effect	14
Table 5	Hot Model Test Results of Ultrasonic Vibration Application	15
Table 6	ANOVA Table for Ultrasonic Vibration Application	15

1. INTRODUCTION

Gasification is a method for exploiting poor-quality coal and thin coal seams by burning the coal in place to produce combustible gas that can be collected and burned to generate power or processed into chemicals and fuels. A process called pyrolysis is used in combination with gasification to breakdown organic waste materials combining high heat and combustion. Pyrolysis, as the ‘front end’ process, is the thermal decomposition of organic material either in the absence of air or with a very small amount of air [1]. Pyrolysis generates three main products; char, oil (pyrolysis oil’) and gas. These products vary depending on the composition of the waste materials fed into the pyrolysis reactor and process conditions (e.g. amount of oxygen). Gasification is the process whereby most of the char, tar and volatile gas resulting from pyrolysis are converted into a steam and a combustible gas (syngas) by a reaction with steam, with or without air [2].

Due to the harsh reducing environment in gasifiers, temperature measurement in the gasifier is always a challenge. To ensure the safe, reliable and efficient operation of gasifiers, the temperature measurement in gasifier should be accurate. Unfortunately, most available temperature measurement technologies for gasifier are not robust enough to fulfill the requirement of the gasification process. Most current temperature measurement techniques use thermocouple as a base to measure the temperature in gasifiers [3]. The thermocouples are easily getting polluted and broken down in a very short time. The proposed project is to develop the innovative cleaning method to clean the thermocouple and extend its life in an accurate measuring the temperature in gasifiers.

One of the proposed cleaning methods is ultrasonic peeling, which utilizes the high energy generated by ultrasonic vibration. Ultrasonic vibration physically moves the

thermocouple horizontally or longitudinally under pressure. The energy created by the vibration should be sufficient to remove the condensate ash on the thermocouple tip. Some researchers have successfully applied the ultrasonic vibration to remove burrs from manufacturing process [4, 5]. In this research, burrs are defined as undesirable projections of material beyond the edge of a workpiece during machining. Burrs are created around the edge of workpiece due to plasticity during mechanical manufacturing process. Recently, because of miniaturization and increased precision of the machined parts, the size of burrs has been also reduced and deburring became even more difficult. Generally, burrs have been removed by method of physics and chemistry. There are a few publications in the area of applying ultrasonic to deburring [6-8]. When ultrasonic vibration propagates in the liquid medium, a large number of bubbles are formed. These bubbles generate an extremely strong force, which removes burrs [9]. The object of this study is to analyze the effects of ultrasonic vibration, medium and the type of abrasive in deburring process. From the above research, it is believed that peeling off the condensate ash shall require less energy than the burrs. Hence, we are confident that the ultrasonic vibration shall be a very successful solution to clean the thermocouple in gasifiers.

In our research, an ultrasonic welder was used to simulate the ultrasonic vibration to the thermocouple [10]. The vibration frequency was set to the range of 20 KHZ. The thermocouple probe was covered with cement-covered layers at the different thickness. These concrete layers were used to simulate the ash condensate in the gasifier. Different thickness was used to simulate the amount of ash condensate. The temperature changes were measured by the thermocouple of cement covered layers under the ultrasonic vibration applied environment.

2. EXECUTIVE SUMMARY

The systematic tests of the gasifier simulator on the ultrasonic vibration application for cleaning method were completed in this reporting period. The ambient temperature and the high temperature testing environments were arranged separately for the systematic tests on the ultrasonic vibration application. The sticky dirt environment on the thermocouple tip was simulated by the cement-covered layer on the thermocouple tip. Four (4) input factors were considered to affect the response variables of the peeling off rate at the ambient temperature environment. The input factors include the different shapes of the cement-covered layers (i.e. thickness and length), the ultrasonic vibration output power, and application time.

At the high temperature tests, four (4) different environments were considered as the experimental parameters: (i) air flow supply, (ii) water and air supply environment, (iii) water, air, and fine dust particle supply, and (iv) air, water, ammonia, and fine dust particle supply environment. The factorial design method was used for the experimental design along with twelve (12) data sets of readings.

Analysis of Variances (ANOVA) was applied to the results from systematic tests. The ANOVA results showed that the thickness and length of the cement-covered layer had the significant impact on the peeling off rate of ultrasonic vibration application at the ambient temperature environment. For the high temperature tests, the different environments do not seem to have significant impact on the temperature changes. These results may indicate that the ultrasonic vibration is one of the best cleaning methods for thermocouple tip cleaning in high temperature gasification.

3. EXPERIMENTAL

3.1 Facilities for Ultrasonic Vibration Application Experiments

The scheduled experiments on ultrasonic vibration application were conducted during this research period. The ultrasonic vibration system was manufactured in Sonobond Ultrasonics Company [11]. The pictorial view of the system is shown in Figure 1. The ultrasonic welder is composed of a hand held device and a generator. The hand held device consists of a handle, trigger switch, converter, horn and name plate on the handle. While the generator (model name – RL35) consists of a generator module handle, model designation, LED (light emitting diodes) bar, LED power, function key “US-TEST” (ultrasonic test), weld time, hold time, fastening screws, mains switch and status displays [11]:

- US ON (green)
- Valve (green)
- Error (red)

In making one more familiar to the ultrasonic device, it is necessary to comprehend the actual size of the generator, this includes:

- Width = 130mm
- Length = 450mm
- Height = 300mm
- Weight = 7kg



Figure 1 Pictorial View of Ultrasonic Vibration Testing Facility

3.2 Experimental Procedure

The experiments are conducted by the following the procedure:

1. Prepare the covered specimen of thermocouple.
2. Set up the gasification environment parameters.
3. Turn on the cooling water to keep the outer wall of gasifier in lower temperature.
4. Install the clean thermocouple into the gasifier.
5. Switch on the heating coil and start the heating process.
6. Start recording the temperature data

7. Connect the thermocouple probe to the specimen once the temperature reaches the steady state and keep recording the temperature data.
8. Apply the ultrasonic vibration continuously once the new temperature reaches the steady state.
9. Observe closely and record the temperature changes during the ultrasonic vibration application.
10. Turn off the heating coil and start the shutting down procedure.

4. RESULTS AND DISCUSSION

Figure 2 shows the overall high temperature gasification simulating system with the ultrasonic vibration testing facility.

A series of experiments were conducted under various gasification environments including air only, air and water, air water and ammonia, and air, water/ammonia and fine dust. The different environments were arranged to find the different influences upon the temperature changes.

Two different specimen thermocouples were used in these experiments. The thermocouples were pre-covered by two different shapes of the cement-covered layers to simulate different sticky dirt on the thermocouple probe. As shown in Figures 3 and 4, the dimension for the thick layer is 16.7mm of outer diameter and 44.5mm in length. The dimension for the thin layer is 6.7 mm of outer diameter and 44.5mm in length.



Figure 2 Pictorial View of Overall High Temperature Gasification Simulating System



Figure 3 Pictorial View of Thermocouple Simulation of Thin Cement Layer
($D=6.7\text{mm}$, $L=44.5\text{mm}$)



Figure 4 Pictorial View of Thermocouple Simulation of Thick Cement Layer
(D=12.8mm, L=44.5mm)

4.1 Temperature Changes under Air Supply Environment

The data for temperature changes under air environment experiment is shown in Table 1 (in Appendix I). Temperature changes under the air injection condition are shown in Figure 5. The temperature inside the gasifier changed smoothly during the heating up process. Once the temperature reaches the steady state, the thermocouple was exchanged with the cement-covered one. As shown in Figure 5, the temperature was dropped sharply at that moment. At that point, the temperature was measured using the covered thermocouple. Once the measured temperature reached steady state, the ultrasonic vibration was applied. The temperature slightly decreased due to the cooling process applied to the ultrasonic vibration. Then the temperature increased steadily. This phenomenon means that the ultrasonic vibration could shake away the cement cover.

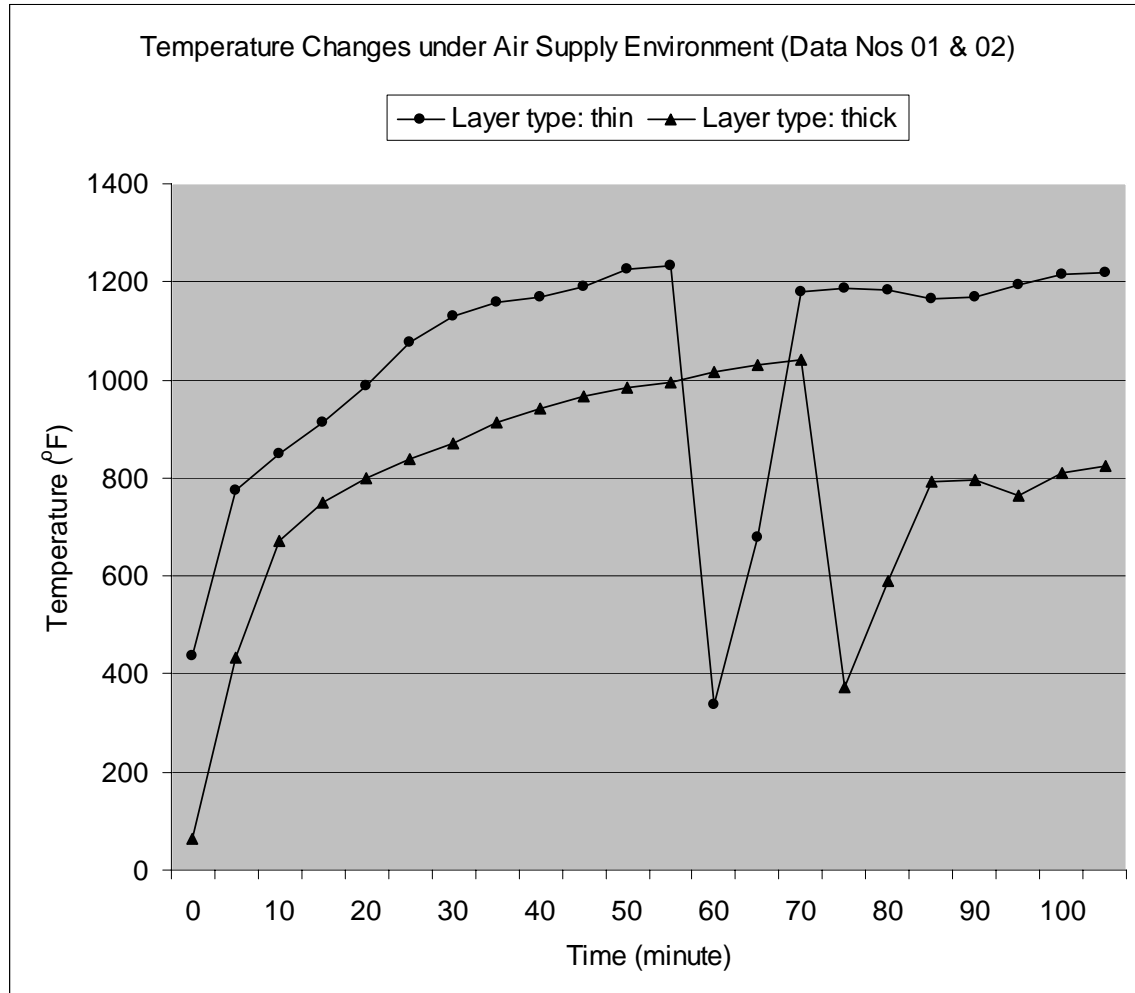


Figure 5 Temperature Changes under the Air Supply Environment

4.2 Temperature Changes under Air/Water Supply Environment

The temperature changes under air and water supply environment were tested and the data are shown in Table 1 (in Appendix I). Figure 6 shows the experimental results under the air and water environment. The thermocouple specimens were the same size as in the only air environment case. The experiments under this environment were repeated once for each thermocouple specimen of the cement-covered layer. The temperature changed smoothly at the heating up process. The thermocouple by the cement-covered

layer caused the steady state temperature gap. After application of ultrasonic vibration, the temperature slightly decreased and then reached the steady state.

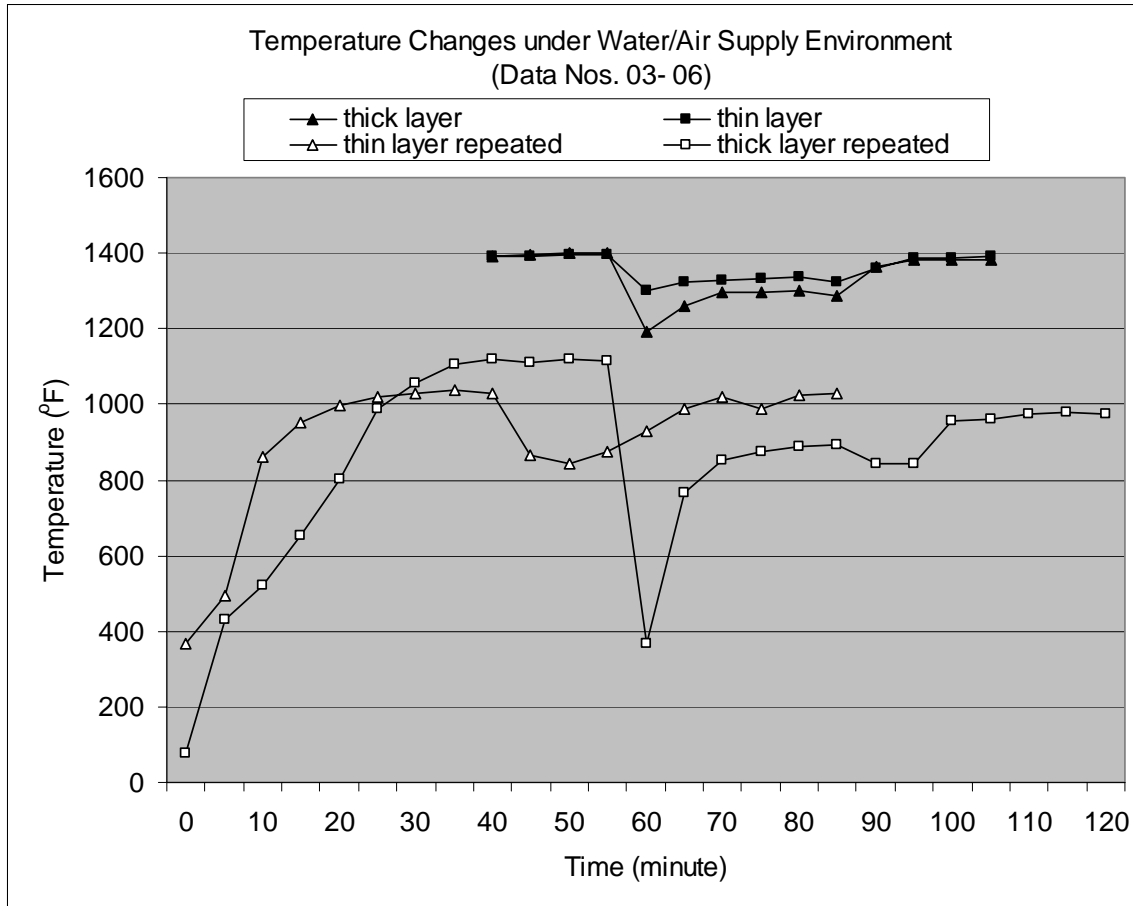


Figure 6 Temperature Changes under Air and Water Supply Environment

4.3 Temperature Change under Air/Water/Ammonia Environment

The experiments regarding to the air, water and ammonia environment were conducted to examine the temperature changes. The data of temperature change are shown in Table 2 (in Appendix II). The temperature changes are shown in Figure 7. The thin and thick cement-covered thermocouples were used in these experiments. The experiments were repeated two times for each environment. The temperature changes

followed the similar trend as previous cases. The temperature changes after the application of ultrasonic vibration decreased slightly and then reached the steady state.

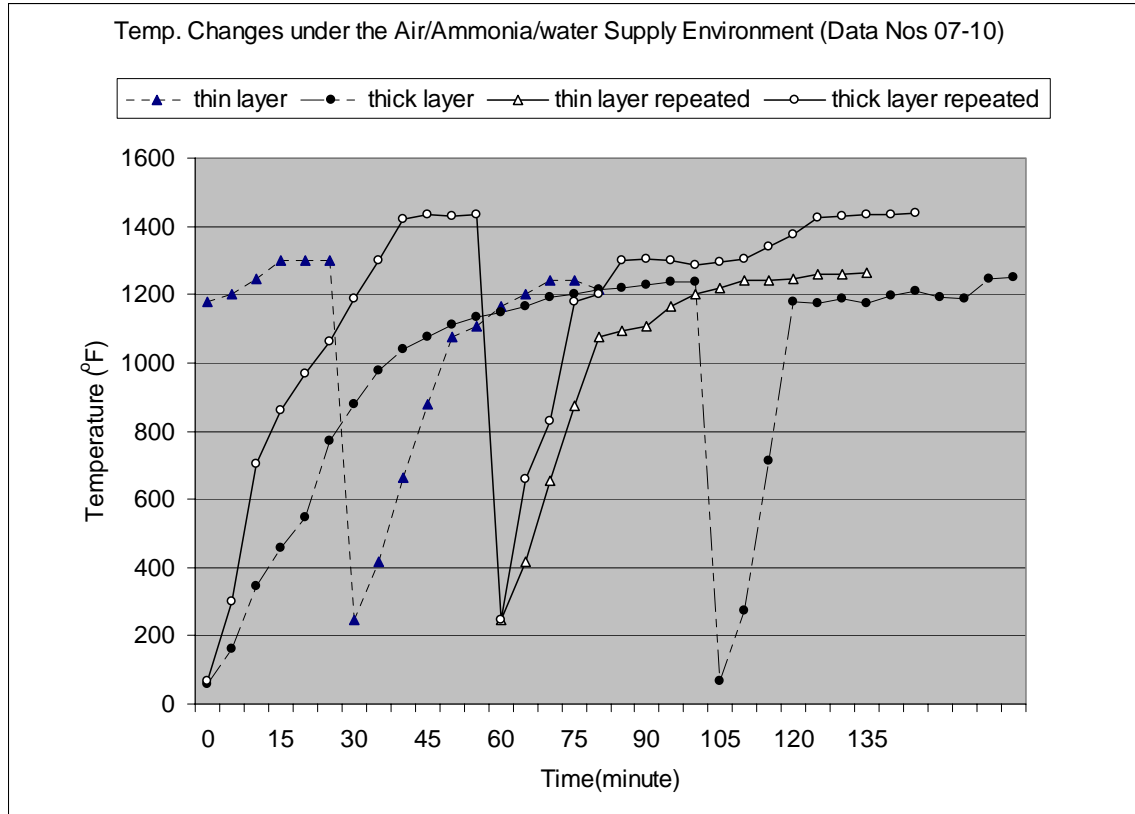


Figure 7 Temperature Changes under the Environment of Air/Water/Ammonia Supply

4.4 Temperature Changes under the Environment of Air/Water/Ammonia/Fine Dust Supply

The temperature changes under the all combined factors were conducted and the data are shown in Table 2 (in Appendix II). The amount of fine dust particles was 75 grams with the particles size of 0-250 μm . The fine dust particles were pre-injected into the gasifier. The temperature changes under this environment are shown in Figure 8. The temperature is not smoothly changed during the heating up process (time period from beginning to 140 minutes). It is believed that the dust particles were heated and the

unburned carbon caused the unstable temperature status. After the heating up process, the temperature changes were maintained as steady state. The ultrasonic vibration was then applied to the thermocouple probe. The temperature changes are similar in patterns with the other cases (in Section 4.1-4.3).

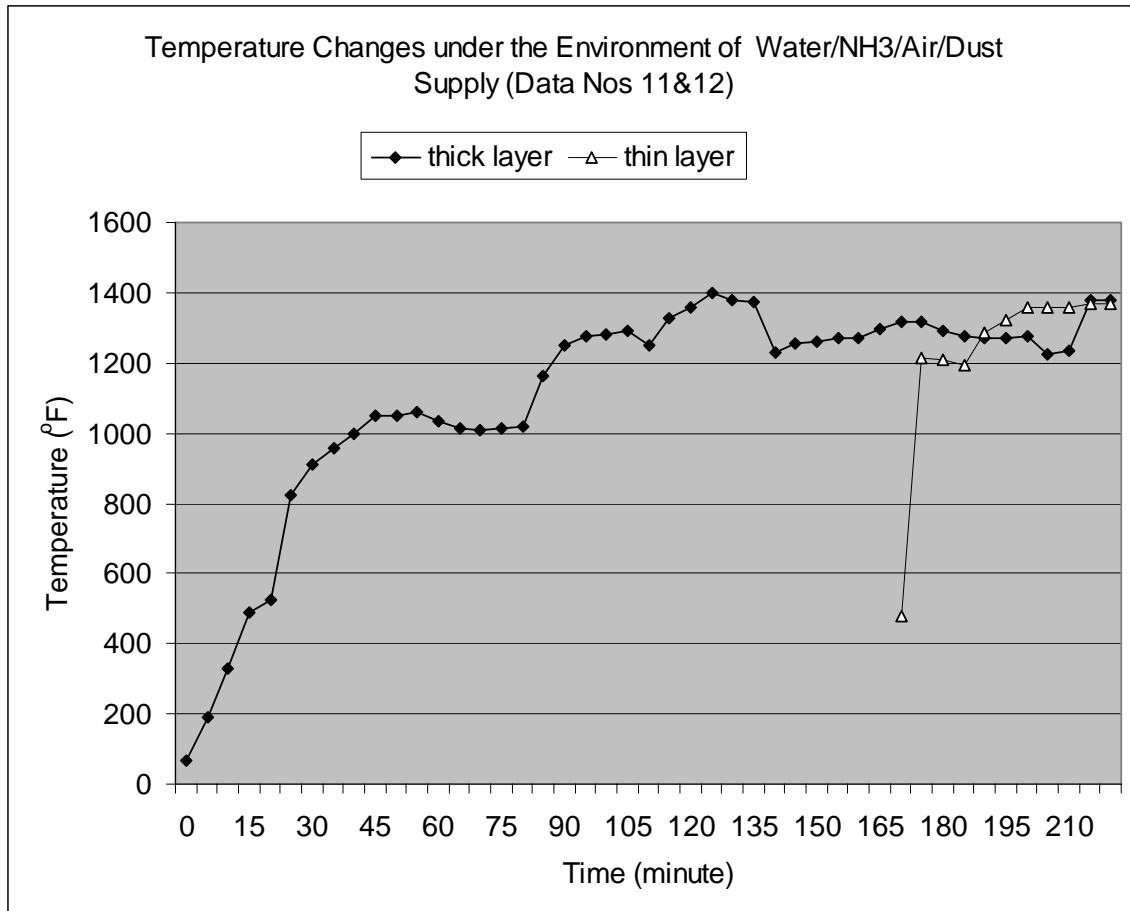


Figure 8 Temperature Changes under the Environment of Air, Water, Ammonia and Fine Dust Particles Supply

4.5 Analysis of Experimental Data and Results under Ambient Temperature Condition

The tests under ambient temperature condition were conducted to examine the ultrasonic vibration effect on peeling off the covered cements. The input factors affecting the peeling off for the cement-covered include the cover diameter, length, application time and ultrasonic vibrator output power. The series of experiments were conducted during this report period. The experiment results are shown in Table 3.

Table 3 Cold Test Results of the Peeling Effect by the Ultrasonic Vibration

Cover diameter(mm)	Length(mm)	Time (minutes)	Power (%)	Peeling rate (%)
12.8	44.5	3	5	97.4
12.8	44.5	5	10	97.6
6.7	45	1	5	83.9
6.7	45	5	5	85.5
6.7	45	3	5	77.9
6.7	45	5	5	84.1
8.8	35	5	5	25.5
8	36	5	10	38.8

Using statistical software, SPSS 12.0, the analysis of variance (ANOVA) of peeling effect is shown in Table 4. Table 4 includes columns of parameter, unstandardized coefficients, standardized coefficients, t (studentized t test), significant level. ANOVA is often used to uncover the main and interaction effects of categorical independent variables (called "factors") on an interval dependent variable [12-14]. Table 4 shows that the cover shape of diameter and length are significant for the peeling effect of the ultrasonic vibration application at the type-I error of 0.1. The length of the

covered-cement layer is more significant than the diameter. Other factors such as the application time and output power do not seem to have significant effects at the same type-I error.

Table 4 ANOVA Table of Cold Test for Peeling Effect

Parameter	Unstandardized Coefficients		Standardized Coefficients	t	Significant level
(Constant)	-211.955	20.869		-10.157	.002
Diameter	2.459	.666	.245	3.694	.034
Length	6.072	.419	.980	14.476	.001
Time	.118	1.235	.007	.096	.930
Power	.960	.850	.083	1.131	.340

4.6 Analysis of Experimental Data & Results under Hot Temperature Condition

In order to examine the effects of input factors on the temperature changes inside the gasifier, the analysis of variance (ANOVA) method was applied [15]. The input factors include different combinations of environments under air, water, ammonia, and dust, and the thickness of covered cements. The response variable was temperature. The detailed data for input factors and response variable are shown in Table 5.

Using statistical software SPSS 12.0, the analysis of variances of temperature is shown in Table 6. From the Table, the input factors do not show significant effects to the temperature changes inside the gasifier at the type-I error of 0.1.

Table 5 Hot Model Test Results of the Ultrasonic Vibration Application

Air (m3/sec)	Water (ml/sec)	Ammonia (ml/sec)	Thickness (mm)	Dust (gram)	Temp. (F)
0.0032	0	0	6.7	0	1218.5
0.0032	0	0	12.8	0	825.6
0.0032	0.0033	0	6.7	0	1387.3
0.0032	0.0033	0	12.8	0	1383
0.0032	0.0033	0	6.7	0	1026
0.0032	0.0033	0	12.8	0	977.77
0.0032	0.0033	0.003	6.7	0	1240.5
0.0032	0.0033	0.003	12.8	0	1248
0.0032	0.0033	0.003	6.7	0	946.5
0.0032	0.0033	0.003	12.8	0	1435.25
0.0032	0.0033	0.003	6.7	75	1362.8
0.0032	0.0033	0.003	12.8	75	1379.5

Table 6 ANOVA Table for the Ultrasonic Vibration Application

Parameter	Unstandardized Coefficients		Standardized Coefficients	t	Significance level
(Constant)	1004.06	258.965		3.877	.006
Air	/	/	/	/	/
Water	51959.85	58456.84	.323	.889	.404
Ammonia	8015.000	52502.79	.061	.153	.883
Thickness	1.845	21.083	.028	.088	.933
Dust	2.048	2.572	.289	.796	.452

5. CONCLUSIONS

The major accomplishments in this semi-annual period are listed below:

1. The ultrasonic vibration application and series tests for the significant input factors upon the temperature readings are being successfully conducted during this reporting period.
2. ANOVA analysis is an efficient statistical method to analyze the experimental results and temperature measurements data under the ultrasonic vibration applied environment.
3. The test results under the ambient temperature environment show that the shape of the simulated cement layer on the thermocouple tip affected the peeling off rate for the ultrasonic vibration application. The thickness and length of the layer have significant effects on the peeling off rate.
4. The simulated environments under the different input factors seem to have no significant effects on the temperature changes. These results may indicate that the ultrasonic vibration could be one of the best cleaning methods for thermocouple tip in the high temperature gasification environment.

6. RESEARCH CONTINUATION

The ongoing research is on the schedule. The continuation of the research will include temperature measurement with the coating thermocouple and comparison analysis. The final report and poster presentation will be delivered as the project requirements to the sponsor for review.

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APPENDIX I

Table 1 Temperature Changes under Air and Air/Water Environments

Data Nos	No01	No02	No03	No04	No05	No06
Environment	Air only			Air and Water		
Time (min)	6.7mm	12.8m m	12.8m m	6.7mm	12.8m m	6.7mm
0	435.6	63.9			75	365.1
5	775	434.3			432.5	492.3
10	847.6	672			521.3	861.4
15	912	750			654.2	950.3
20	986.4	800			801.5	996.7
25	1078	837			986.3	1021
30	1130	869			1056	1031
35	1160	914			1107	1036
40	1170	940			1118	1030
45	1189	965	1392	1390	1109	865.7
50	1225	984	1395	1393	1120	843.5
55	1232	995	1399	1395	1115	875.3
60	339	1016	1192	1300	367.7	930.6
65	680	1029	1260	1323	765.3	986.7
70	1180	1041	1297	1326	851.1	1021
75	1188	373	1298	1334	875.1	1025
80	1185	589.3	1301	1338	889.3	1024
85	1165	792.3	1286	1322	895.1	1028
90	1168	795.2	1364	1358	843.5	
95	1195	765	1382	1385	841.6	
100	1217	809	1384	1387	955.3	
105	1220	825.6	1383	1390	959.6	
110					975.6	
115					981	
120					976.7	

APPENDIX II

Table 2 Temperature Changes under the Environment of Different Factors Supply

Data Nos	No07	No08	No09	No10	No11	No12
Environment	Air/Water/Ammonia				Air/Water/Ammonia/dust	
Time (min)	6.7mm	12.8mm	12.8mm	6.7mm	12.8mm	6.7mm
0	1178	57.4	69		67	
5	1201	161.4	300.7		190.5	
10	1246	346.7	705.6		327.5	
15	1301	456.7	861.6		487.9	
20	1300	544.7	968.8		524.9	
25	1301	771.3	1060		824.8	
30	248.2	877.7	1189		911.9	
35	415.2	977.2	1299		959	
40	665.2	1038	1419		998.4	
45	878.4	1075	1432		1048	
50	1075	1112	1431		1050	
55	1107	1132	1436		1059	
60	1164	1146	248.7	248.2	1032	
65	1200	1166	658.9	415.2	1011	
70	1240	1190	830.7	655.3	1009	
75	1241	1200	1178	875.4	1011	
80	1215	1213	1200	1075	1018	
85		1221	1300	1093	1161	
90		1229	1305	1107	1250	
95		1235	1299	1164	1275	
100		1238	1285	1200	1282	
105		69	1293	1220	1291	
110		274	1305	1240	1249	
115		713	1342	1241	1327	
120		1177	1378	1245	1356	
125		1176	1423	1260	1399	
130		1188	1430	1261	1377	
135		1173	1435	1265	1373	
140		1195	1436		1232	
145		1208	1440		1257	
150		1190			1260	
155		1189			1269	
160		1246			1272	

165		1250			1296	
170					1316	476
175					1315	1212
180					1291	1208
185					1274	1196
190					1273	1284
200					1270	1322
205					1276	1359
210					1222	1358
215					1235	1360
220					1381	1369
225					1378	1368