Report on the Combustion Experiment of Orimulsion Using Fuel Additives

I. Prepared by

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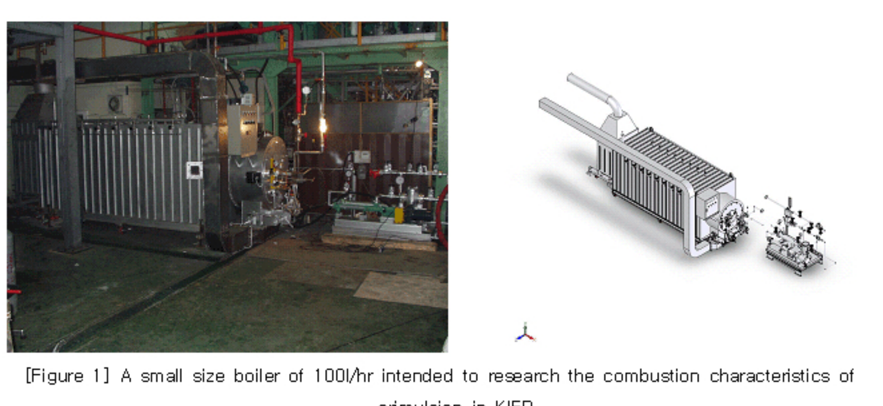
II. Purposes of the Experiment

- To evaluate the characteristics of orimulsion combustion through the additive made by Technobio Co.,Ltd by using a small boiler of 100l/hr, which was intended to research the combustion characteristics of orimulsion, a substitute of heavy oil and that installed in KEIR, as seen in [Figure 1]. The additives used for the experiment was POWER-Z, a product of Technobio Co.,Ltd, which is a special organic compound of which main ingredient is a liquid and penetrable fat acid material that is mixed of heat-stable microorganism enzyme(decomposition temp. 200℃) and special enzyme.



[Figure 1] A small size boiler of 100l/hr intended to research the combustion characteristics of orimulsion in KIER

- The experiment was to compare and review the composition of flue gas by excessive air amount for each fuel sample in order to analyze the effect of additives for orimulsion, orimulsion + additive and heavy oil. Especially, to see any changes in the characteristics of fuel due to the characteristics of orimulsion fuel, such as phase separation if mixed with a different material, the sustaining time of mixing orimulsion and additive was to be changed in order to know the changes as time goes on. The conditions of the experiment using the boiler of 100l/hr cap. Intended to research orimulsion and being executed for the combustion tests of orimulsion, orimulsion + additive and heavy oil are summarized in <Table 1>.

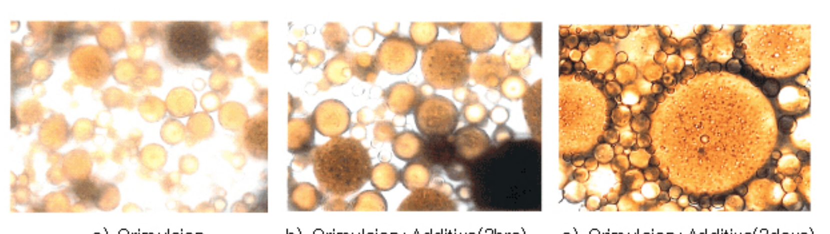
<Table 1> Experiment Condition to evaluate combustion characteristics(additive mixing ratio: based on orimulsion 0.1vol.%)

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Fuel	Orimulsion	Orimulsion + additive	Orimulsion + additive	Heavy oil	Heavy oil + Additive
Sustaining time of mixture	-	2days	2hrs	-	2days
Vol. supplied(kg/hr)	60	60	60	60	60
Supply temp.(℃)	40	40	40	90	90
Aerosol	Steam	Steam	Steam	Steam	Steam
Steam temp.(℃)	150	150	150	150	150

III. Experiment Results

1. Emulsion Status Observed by an Optic Microscope

[Figure 2] shows the emulsion status viewed by an optic microscope: a. Orimulsion, b. Orimulsion + Additive(sustaining time of mixture : 2hrs) and c. Orimulsion + Additive(sustaining time of mixture: 2days).



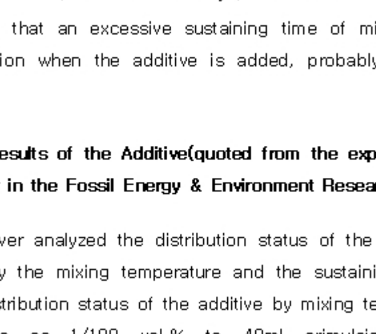
a) Orimulsion b) Orimulsion+Additive(2hrs) c) Orimulsion+Additive(2days)

[Figure 2] Emulsion status observed by an optic microscope

As seen in [Figure 2], the emulsion status of orimulsion looked almost uniform distribution of particles but if the sustaining time of mixing orimulsion + additive increased, it was found that coagulation of particles occurred, and in two days, the emulsion status was clearly changed. Therefore, it is considered that an excessive sustaining time of mixture causes changes in the emulsion status of orimulsion when the additive is added, probably having an influence on the combustion status.

2. Distribution Experiment Results of the Additive(quoted from the experiment results by the Wastes Utilization Research Center in the Fossil Energy & Environment Research Dept. of KIER)

The research center has ever analyzed the distribution status of the additive when orimulsion and the additive were mixed by the mixing temperature and the sustaining time. The experiment was executed to analyze the distribution status of the additive by mixing temperature and sustaining time after adding the additive as 1/100 vol.% to 40ml orimulsion in a container with a temperature-controllable electric heating system and mixing them for half an hour as seen in [Figure 3].



Orimulsion + Additive, temperature-controllable container

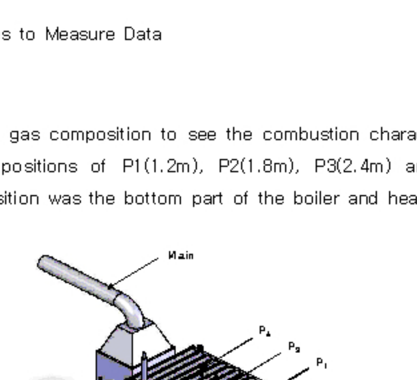
[Figure 3] A device for the distribution experiment of the additive

As a result of the experiment, in case the additive was mixed at an ambient temperature and sustained for 2 days, it was observed that layers were separated, showing the mixture status of orimulsion and the additive were not stable. However, when it was mixed at 50℃ and sustained in 30minutes, its distribution status showed very stable mixture status. Therefore, it was proven that maintaining proper mixture temperature and the sustaining time could have an influence on the emulsion status of orimulsion, as explained in [Figure 2].

3. Combustion Experiment Results

A. Configuration of Devices to Measure Data

The results of analyzing gas composition to see the combustion characteristics of orimulsion have been measured at the positions of P1(1.2m), P2(1.8m), P3(2.4m) and main(5.8m) as seen in [Figure 4]. The main position was the bottom part of the boiler and heat exchanger.



[Figure 4] Positions to analyze gas composition in order to see the characteristics of orimulsion

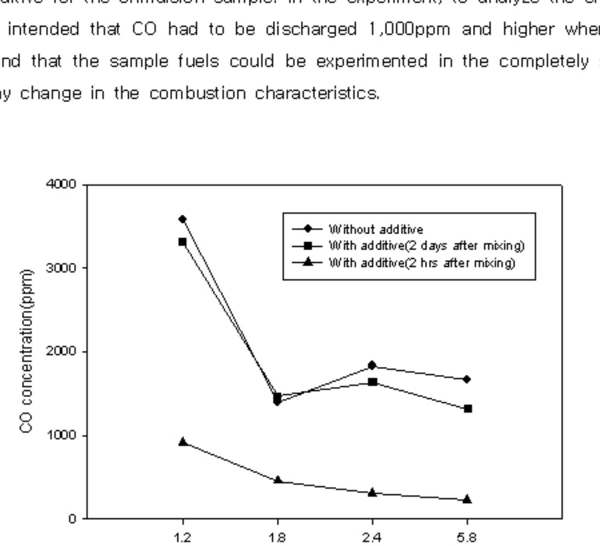
B. Gas Composition Analyzed

<Table 2> shows the results of (flue) gas composition in the experiments using the fuel samples and especially represents the results by analysis positions. In addition, in case of the gas composition, it was intended that excess O2 was set to 3% and the results were converted to compare the results

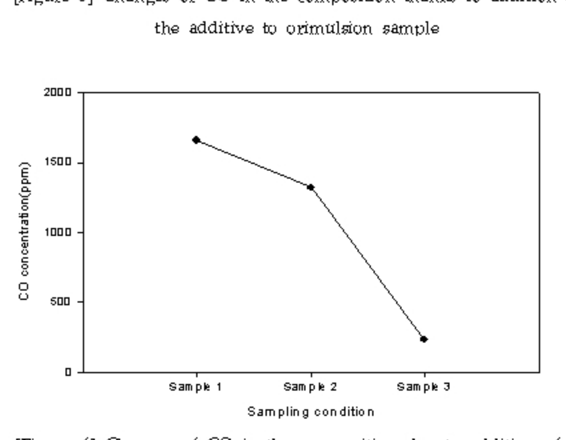
<Table 2> Analysis of gas composition

Sample No.	Experiment Conditions	Analysis	P_1(1.2m)	P_2(1.8m)	P_3(2.4m)	Main(5.8m)
1.	Fuel vol. : 60l/hr Aerosol : steam Fuel : Orimulsion	Excess O_2 (%)	3.0	3.0	3.0	3.0
		CO_2 (%)	13.7	14.9	15.0	15.0
		CO (ppm)	3,580	1,398	1,831	1,658
		NO (ppm)	272	227	227	240
2.	Fuel vol. : 60l/hr Aerosol : steam Fuel : Orimulsion + Additive (sustaining time: 2 days)	Excess O_2 (%)	3.0	3.0	3.0	3.0
		CO_2 (%)	13.9	14.8	15.0	14.8
		CO (ppm)	3,313	1,470	1,636	1,321
		NO (ppm)	269	228	222	237
3.	Fuel vol. : 60l/hr Aerosol : steam Fuel : Orimulsion+Additive (sustaining time: 2 hrs)	Excess O_2 (%)	3.0	3.0	3.0	3.0
		CO_2 (%)	15.0	14.9	14.9	14.8
		CO (ppm)	918	457	309	231
		NO (ppm)	274	224	233	248
4.	Fuel vol. : 60l/hr Aerosol : steam Fuel : Heavy oil	Excess O_2 (%)	3.0	3.0	3.0	3.0
		CO_2 (%)	14.0	13.1	12.6	13.0
		CO (ppm)	2,595	166	152	171
		NO (ppm)	267	261	258	243
5.	Fuel vol. : 60l/hr Aerosol : steam Fuel : heavy oil +additive (sustaining time : 2 days)	Excess O_2 (%)	3.0	3.0	3.0	3.0
		CO_2 (%)	11.9	12.9	12.7	13.0
		CO (ppm)	1,920	0	0	0
		NO (ppm)	239	237	235	231

Using the results in <Table 2>, changes in the composition of CO and NO are seen in [Figure 5] ~ [Figure 9]. [Figure 5] and [Figure 6] show the analysis of CO in order to represent the effect of using the additive for the orimulsion sample. In the experiment, to analyze the effect of using the additive, it was intended that CO had to be discharged 1,000ppm and higher when orimulsion was solely burned and that the sample fuels could be experimented in the completely same conditions, to figure out any change in the combustion characteristics.

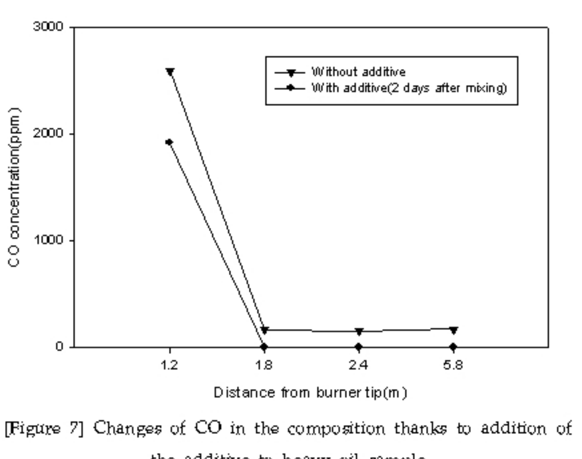


[Figure 5] Changes of CO in the composition thanks to addition of the additive to orimulsion sample



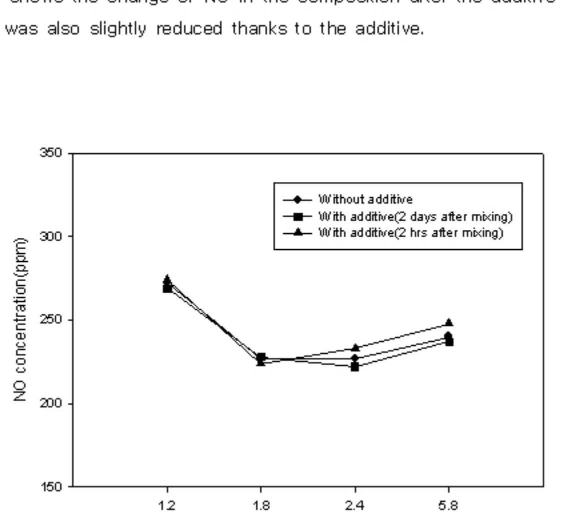
[Figure 6] Changes of CO in the composition due to addition of the additive to orimulsion sample analyzed at the main position(5.8m from a burner tip)

As a result of the experiments, as seen in [Figure 5], it was shown that CO measured at the bottom of the heat exchanger was 1,658ppm in case orimulsion was solely burned but CO was 231ppm when the mixture of orimulsion and the additive was burned, showing that the combustion was significantly improved. It was also found in the outlet that the measurement of excess O2 was only 0.8% in case of the only orimulsion was burned but it was 1.0%, which is 0.2% higher than the above measurement, in case the additive was added and burned. Such a result had been reported by a research(Kim Dong-chan, "Development of the technology to reduce micro dust by developing high efficient combustion catalyst and dispersing agent additive", 2005) to evaluate the effect of the additive to the combustion of heavy oil executed by the research center stating that excess O2 is reduced about 1% with the additive. The increase of excess O2 was significantly different with the experiment results and it must be why since the experiment was intended to produce CO about 1,000ppm under the incomplete combustion, the air supplied was to be consumed for the complete combustion. Therefore, it is determined that if normal combustion is maintained, excess O2 will be increased. In case mixing was sustained for 2 days, the results of combustion experiment were almost similar to these with the only orimulsion. Therefore, it is expected that, as explained in [Figure 2], if the sustaining time is extended, the combustion may be unstable due to emulsion status of orimulsion. In the meantime, since the volume of the additive used for the experiment was only 0.1vol%, the results were similar to the combustion with the only orimulsion even though the sustaining time would be extended. As seen in [Figure 6] showing the CO concentration of each sample measured at the bottom of heat exchanger, it was shown that the combustion of orimulsion + the additive that was sustained for 2 hours after mixing was improved than that with the only orimulsion. In addition, it is expected that the improvement of combustion will contribute to the improvement of boiler efficiency because when the additive is added, excess O2 can be significantly reduced to maintain the optimal combustion, from which heat loss is reduced, dust is, in turn, diminished and the heat exchange efficient is improved at the heat exchanging part. [Figure 7] shows the effect when the additive was added to the heavy oil(S: 0.1%) pre-heated to 90℃. In case of heavy oil, CO concentration was reduced when the additive was input, so the combustion was also improved as the experiment with orimulsion. However, since heavy oil is not a fuel in emulsion status unlike orimulsion, the combustion was not significantly influenced by sustaining time even though the time was maintained for a long while.

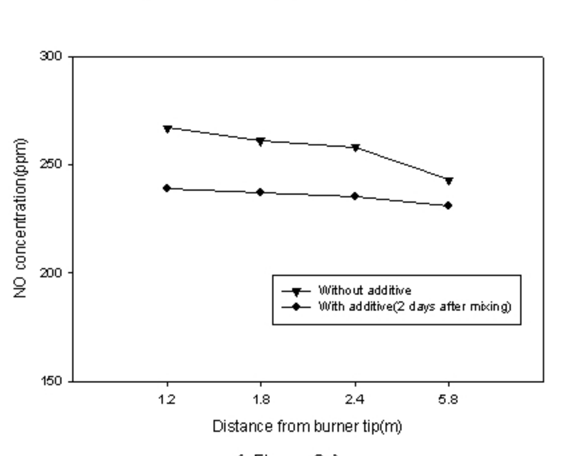


[Figure 7] Changes of CO in the composition thanks to addition of the additive to heavy oil sample

[Figure 8] shows the changes of NO in the composition when the additive was added to orimulsion. As seen in the figure, although orimulsion was added, NO was not changed at all in the analysis. Therefore, it is expected that thermal NOx will be reduced because improved combustion reduces the required air volume as long as the additive is added and sustained for appropriate time. [Figure 9] shows the change of NO in the composition after the additive was added to heavy oil and that NO was also slightly reduced thanks to the additive.



[Figure 8] Changes of NO in the composition thanks to addition of the additive to orimulsion sample



(Figure 9)

IV. Discussion

In order to evaluate the performance of the additive developed for combustion facilitation by Technobio Co,.Ltd, the combustion of orimulsion was experimented by using a small boiler of 100l/hr cap. that was intended to research the characteristics of orimulsion, a substitute of heavy oil in KIER. The experiment results were presented with the analysis results for (flue) gas composition due to addition of the additive and the emulsion status of samples observed by an optic microscope, from which it could be concluded as follows.

1. To see any changes in emulsion status of the mixture of emulsion and the additive, the emulsion status by sustaining time was analyzed with an optic microscope. As a result, if the sustaining time was long at ambient temperature, it was found that the emulsion status was changed owing to the coagulation of particles, probably having an influence on the combustion status of orimulsion.

2. As a result of the combustion experiment with orimulsion + the additive of which sustaining time was appropriately maintained, it was shown that the combustion status could be significantly improved from the change of CO in the composition, comparing to the experiment with orimulsion solely. It is expected in the experiment that the reduction of CO in the composition from the improved combustion will contribute to the improvement of boiler efficiency and the reduction of NO. In case of heavy oil, since it is not a fuel in emulsion status, it does not have any influence on the combustion even though its sustaining time is maintained longer. In addition, it was showed that the combustion was improved with the additive.

3. The change in NO, which was discharged when orimulsion + the additive were burned, was slight but it was found that it was little bit reduced in case of heavy oil + the additive.

4. From the above results, it could be concluded that adding the additive to orimulsion increases the efficiency of boiler and at the same time, the sustaining time of mixture should be considered appropriately.