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Selection of IGCC candidate coals by pilot-scale gasifier operation

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Abstract

Nine imported coal samples were tested to make the guidelines for IGCC (Integrated Gasification Combined Cycle) candidate coals — the guidelines that are applicable in future commercial IGCC plants in Korea. Entrained-bed slagging gasifier whose maximum capacity is 3 ton/day has been operated under pressure ranges of 10–29 bar. The factors considered were conversion efficiencies, moisture content, sulfur content, ash content, ash melting temperature, slag viscosity, slag characteristics, and coal reactivity. The best coal type for IGCC applications appears to be the one that contains low ash content with low-enough slag viscosity and high reactivity in coal. However, coal that exhibits high fluidity at the gasifier exit resulted in higher probability in plugging by fly-slag, so that the coal of ash fluid temperature lower than 1260 °C would require precaution for utilizing the feedstock in the entrained-bed gasifier. Conventional ash fusion measurement data might disagree with slag viscosity results in estimating the optimal operation temperature, and thus actual viscosity tests on slag would be necessary.

Keywords: Coal selection; Gasifier; IGCC; Slag viscosity; Fuel ratio; TGA

1. Introduction

IGCC (Integrated Gasification Combined Cycle) technology together with PFBC (Pressurized Fluidized Bed Combustion) is viewed as the most practical next-generation coal-utilizing power generation technology that can meet the ever-stringent environmental regulations of the mid-21st century. Korea imports 97.2% of energy resources from abroad and thus must use the abundant worldwide coal resources. Low-grade anthracite is the only resource Korea possesses, and most of the coal is imported from around the world, notably from Australia, China, United States, Indonesia, and Russia. For Korea, coal is an inevitable feedstock to cover at least 30% of the total electricity during the next 30–50 years. Unless there is a revolutionary discovery in energy conversion technologies, IGCC and PFBC will be the most suitable environmentally sound technologies for coal utilization in Korea. Considering the oscillating trend of oil price in the last decades, Korea is greatly in need of more fuel-diversified industries, and it needs to develop environmentally benign technologies in the power generation sector. Since coal is known to supply energy at the current rate at least for the next 200 years [1], clean coal technologies like IGCC appear to be an inevitable choice for utilizing coal for power and other purposes. In addition, recent interest in the hydrogen society prompts a wider application of gasification technologies including IGCC [2].

The essence of gasification technology is that dirty feeds containing a high level of sulfur and ash such as coal, petroleum residues, and even domestic wastes can be utilized as a clean energy source with an efficiency higher than the conventional methods. Fuel cells, synthetic fuels, ammonia production, and fertilizers are examples of final syngas applications.

The most eminent environmental advantage of gasification treatment lies in its inherent reaction features that produce negligible SOx and NOx during the oxygen-deficient reaction. New coal-based power plants that would be built from 2005 in Korea must meet the NOx level of 80 ppm. When this stricter environmental regulation goes into effect, the environmental advantages of Clean Coal Technology (CCT) would become even more eminent. The SOx and NOx problems from the conventional electricity generation by pulverized combustion can be effectively minimized through the IGCC technology. If

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the current concerns for the environment and energy get severer, technology shift from the combustion-based to gasification-based processes would be an inevitable trend in the long run.

IGCC technology is an environmentally benign power generation technology advanced by many developed countries with funding of several billions of dollars till now. Many countries like USA, Japan, Germany and Holland reached the demonstration stage of commercial-scale IGCC plants. However, many technological barriers still exist such as coal powder injection, erosion of refractory, plugging of heat exchangers by fly-slag, etc. More long-term operational experience is still required. Probably 5–10 years of time would be required to solve all the technological barriers and particularly for developing hot gas cleanup technology to improve the energy recovering efficiency. Emergence of high efficiency gas turbines utilizing hot gas of more than 1500 °C probably in the next 10 years would yield 50% plant efficiency [3] that is much higher than the conventional 36–38%. If IGCC system is connected to fuel cell technology, the efficiency can reach even 55–70%.

The most critical obstacles for commercialization of IGCC technology are capital cost and the risks involved with first-of-a-kind facilities [3]. Construction cost of a coal IGCC plant after 2010 would drop to less than US$1100/kW [3]. With higher efficiency and less generation of pollutants, it would be cheaper than the pulverized coal power plants installed with desulfurization and de-NOx facilities.

According to the long-term power plant construction schedule of the Korean Government published in 2002, the 300 MW-size CCT plants are supposed to start operating from 2009, 2013, and 2014 in Korea. After revision on the construction schedule, a decision has reached in 2006 to build a 300 MW-size coal IGCC plant by 2011, and to operate as a demonstration plant for ensuing two years. With the limited domestic energy reserve and the ever-increasing environmental regulations on pollutants and CO_2, the gasification-based process is most likely to be one of the best options when using coal for power generation.

Advantages and disadvantages of the entrained-bed gasifier are well noted [4]. Most prominent advantages are the ability to utilize nearly any type of coals with high throughputs per reactor volume and the simpler mechanical design with nearly 100% carbon conversion. Disadvantages are related mainly to the high temperature requirement for the gasification. Among others, possible troubles in slag handling and removal are the most significant issue in addition to the high oxygen consumption and refractory that needs to withstand severe conditions.

For the pilot plant in the study, we chose the dry-feeding entrained-bed type of reactor using pure oxygen as oxidant. This paper illustrates the results of gasifying nine imported coals at the pilot gasification facility that has a maximum 3 ton/day (t/d) capacity under high-pressure conditions of maximum 30 bar, with a specific goal of presenting the coal selection guide for IGCC applications in Korea.

2. Experimental

2.1. Coal samples

Nine imported coals that are utilized at the local power plants and a local cement company were gasified. Coals were chosen to represent the coals from different countries and coal ranks. Since the anthracite rank is unsuitable for the

Table 1
Coal properties tested in the 3 ton/day gasification system

Property\coal		Indonesia			Australia		USA		China	Russia
		Baiduri	Adaro	Kideco	Curragh	Drayton	Usibelli	Cyprus	Datong	Denisovsky
Proximate analysis (as-received, wt.%)	Moisture	26.28	25.27	7.63	7.13	2.06	9.14	13.85	4.60	8.79
	Volatile matter	32.78	34.28	45.44	19.98	34.93	44.11	36.37	32.64	20.08
	Ash	3.92	3.08	1.55	16.13	10.76	9.87	3.41	7.72	12.08
	Fixed carbon	37.02	37.37	45.38	56.76	49.25	36.88	46.37	55.04	59.05
Ultimate analysis (mf, wt.%)	C	70.77	68.08	63.04	72.96	70.61	54.40	71.45	67.08	74.15
	H	5.56	5.40	5.11	3.45	4.94	4.55	5.35	4.31	4.68
	N	1.49	0.40	0.24	1.69	0.34	0.64	1.71	0.66	0.72
	S	1.37	0.12	0.52	0.90	0.90	0.17	0.29	0.60	0.34
	O	15.47	21.88	29.41	3.63	12.22	29.38	17.24	19.26	6.87
	Ash	5.32	4.12	1.68	17.37	10.99	10.86	3.96	8.09	13.24
Ash fusion temperature (reduction, °C)	I.T.	1150	1250	1265	1175	1260	1162	1155	1241	–
	S.T.	–	–	1295	–	1580	1184	1165	1259	–
	H.T.	1250	1290	1326	1300	1590	1224	1193	1285	–
	F.T.	1280	1340	1408	1380	>1600	1257	1289	1343	1400
Inorganic analysis (wt.%)	SiO_2	27.93	39.18	37.93	44.22	63.30	42.73	59.80	56.80	54.59
	Al_2O_3	15.69	18.78	15.15	19.09	17.80	18.93	16.22	22.58	26.37
	TiO_2	0.69	0.85	0.73	0.80	1.09	0.74	0.89	1.10	0.99
	Fe_2O_3	9.48	16.57	21.47	8.74	4.96	6.00	6.91	3.59	8.29
	CaO	17.32	11.25	12.02	20.52	2.43	21.01	8.01	5.32	4.39
	MgO	5.67	2.59	2.57	2.58	0.72	3.13	2.07	1.33	1.89
	Na_2O	3.62	0.80	0.19	N.D.	0.21	0.93	10.6	1.39	0.44
	K_2O	0.99	1.42	0.98	1.12	0.21	1.27	1.06	0.87	1.69
	P_2O_5	0.84	2.42	0.10	1.66	0.33	0.33	0.34	0.27	1.16
	MnO	0.08	0.28	0.20	–	0.05	–	–	–	0.12
Gross heating value (mf, kcal/kg)		6367	6748	5670	7008	6556	5304	6824	6607	7139