Results of an Indo-Swiss programme for qualification and testing of 300 kW IISc-Dasag gasifier

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Results of an Indo-Swiss programme for qualification, testing of an 300 kW IISc-Dasag gasifier

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Abstract

The paper describes the performance and operational experience in India on a high efficiency, low tar, woody biomass gasifier developed at Indian Institute of Science, Bangalore. This development is also of interest to Switzerland, which has a substantial potential of biomass energy. The test scheme included measurements on tar and particulates and the effluents along with necessary measurements for the mass and energy balance. The results indicate a low tar level to meet the engine specifications and the effluents issuing out of the system could be treated using simpler techniques, as the levels are low.

Introduction

Test results on an open core gasifier system rated for 100 kWe are presented. These results are the outcome of collaborative testing between Indian Institute of Science, Bangalore, Dasag, Switzerland and ETH, Switzerland. The gasifier system developed at the Indian Institute of Science, was tested to determine the gas quality and consistency in its operation for a possible deployment of this technology on gasifiers in European countries.

The gasifier system consists of an open core reactor, a cooling and a filtering system along with a blower and a burner. The details of the configuration of the system are described in Mukunda et al (1994). The tests conducted were in the thermal mode, i. e., after cooling and cleaning the gas, the gases were flared. The main objectives of the tests were to determine the gas composition, and tar and particulate levels at the hot and cold ends at various loads. The gasifier was tested with wood chips (casurina) of 50-70 mm long and about 25 mm in lateral size and in a particular test with a mixture of 50 % of the above size along with small twigs of 1-10mm diameter and 25-75 mm long with 5% saw dust. The moisture content of the wood chips were in the range of 10-12%.

Instrumentation and measurement scheme

The system was instrumented to obtain data on the surface temperature of the reactor, gas temperature, and static pressure at various locations, along with gas flow rate using a venturimeter. All the data were logged onto a computer using suitable transducers. The gas composition was measured at the exit of the filter using a gas chromatograph and an online measuring system for CO_2 and O_2 using NDIR and electrochemical method respectively. The measurements were aimed at obtaining mass and energy balance during the various tests along with the amount of chemical pollutants in the cooling water and the various water seals. The tar and particulate in the gas was measured both at the hot and cold end of the gasifier. The first measurement would give the performance of the reactor i.e. how much tar is generated whereas the cold end measurement would give the quality of gas that the engine would be running on.

The apparatus for measuring tar and particulates was built based on the procedure identified by the Swiss group and the final set up was evolved by subsequent experimentation. Figure 1 shows the details of the apparatus. The apparatus was designed to run for 6 - 10 hours. It consist of a series of wash bottles - two of 3 liters and five of 2 liters capacity. The gas was bubbled first through the 3 liters bottle filled to one-third capacity (1000 ml) with water to remove dust and moisture and taken to another empty bottle to trap any droplets which is carried over. These two bottles were kept in an ice bath. The gas from the empty bottle was allowed to bubble through three bottles one-third filled with anisole (200 ml; used as the solvent for dissolving tar), and through an empty bottle to collect any carried over anisole droplets. At the exit of the empty bottle, thimble filters amounting to an area of 500 cm2 is provided in another three liter bottle, to trap any particulate matter escaping the wash bottles. The gas was pumped through the system by a vaccum pump, and was passed through a venturimeter for monitoring the flow rate and a flow integrator to obtain the total gas sampled before being led to a swirl burner. Extensive precautions (both pressure and vaccum test) were taken to ensure the sampling system is leak proof, as this is very critical to the accuracy of the measurements on the level of tar and particulates. Any leakage in the apparatus could be detected by examining the flame in the burners as the leakage of the air into the sampling system would transfer the diffusion flame in the burner to premixed mode.

The tests

The tests were planned at three loads namely, 33 %, 55 % and 100 % of the rated capacity and for duration of about 8 -10 hours. The gasifier is ignited at the air nozzles; the gas produced is flared in a burner. During this period the temperatures, pressures and mass flow rate of gas were recorded on computer. Flow rate is gradually increased to the desired value. It was ensured that the temperature profile in the reactor has become nearly steady before initiating the tar sampling. In order to ensure that the reactor is functioning normally and the tar and particulate measurements are meaningful.

The tar and particulate sampling bottles were leak tested before being introduced into the sampling train. Gas at a nominal flow 2 m^3 per hour was isokinetically drawn at the cold and the hot end through the sampling train to the burner, where it was burnt. At the end of 4-5 hours of sampling (approximately 8 - 10 m3 of gas), the tests were stopped. The samples were taken to an external agency (Cosmic Industrial Laboratories, Bangalore, India) for further analysis, as per the procedure identified by the Swiss team. The deposits on the thimble filters along the material need to move about the procedure the amount of particulate where as the soxhlet extraction and further evaporation of the solvent under vaccum provided the tar content. Table 1 shows the results of the different tests carried out during this period. It is clear from the table that the average particulate content at the hot end is about 600 + 100 mg/m^3 and 60 +15 mg/m^3 at the cold end. The tar levels are at 70 + 30 mg/ m^3 and 20 + 10 mg/m^3 at the hot and cold end. The results of 12-1-94 and 19-1-94 are in some error and these have been discussed in detail in the report.

Table 1. Particulates and Tar in mg/m^3

Date	Load %	Particulate and Tar Mg/ m^3			Particulate mg/ m^3			Tar mg/ m^3		
		Hot End	Cold End	Hot End	Cold End	Hot End	Cold End			
28-12-93	39	751	-	706	-	45	-			
1-1-94	111	-	66	-	54	-	12			
6-1-94	98	717	-	676	-	41	-			
12-1-94	33	729	185	584	66	145	119			
14-1-94	55	663	102	562	87	101	15			
16-1-94	55	899	78	774	47	125	31			
19-1-94	100	796	191	722	45	74	146			
11-2-94	33	562	63	501	52	61	11			
17-2-94	100	686	76	642	66	44	10			

These data are at lab conditions; to get results for standard conditions multiply mg/m^3 by 1.19

The gas composition was measured using a gas chromatograph at the cold end after the filter. The continuos on line oxygen monitor recorded a value of less than 0.1 % through out the run, indicating that there was no leakage of air into the system beyond the reactor. The CO_2 monitor recorded an average 12 + 2 % during the run. The average gas compositions during the tests are given in table 2.

Table 2. AVERAGE GAS COMPOSITION AND CALORIFIC VALUE (LCV)

Date	CO	H_2	CH_4	Comb	CO_2	N_2	H_2O	Total	m	Q MJ/Kg
12-01-94	17 ± 0.5	20 ± 0.5	1.5 ± 0.1	0.25	14.5 ± 0.5	48 ± 0.5	3.0	104.2	25.7	4.34
14-01-94	17.2 ± 0.5	18.3 ± 0.5	1.2 ± 0.2	0.25	12 ± 0.3	46 ± 0.5	3.0	97.95	24	4.38
16-01-94	19 ± 1.5	18 ± 0.1	1.4 ± 0.2	0.25	12.6 ± 0.2	47 ± 0.5	3.0	98.25	25.1	4.43
19-01-94	19.5 ± 1.0	18.5 ± 0.2	1.4 ± 0.2	0.25	12.5 ± 1	48 ± 0.5	3.0	102.5	25.5	4.48
11-02-94	15 ± 0.2	18.7 ± 0.2	1.25 ± 0.1	0.25	13.3 ± 0.3	46.7 ± 0.2	3.0	98.0	24.3	4.23
17-02-94	17 ± 2.0	18.5 ± 0.2	1.1 ± 0.1	0.25	12 ± 0.5	46.5 ± 0.5	3.0	98.3	24.4	4.48

The mass and energy balance

The carbon balance data for the four tests are presented in table 3. As can be noticed the error in the carbon balance is small and hence the mass balance is well satisfied.

The energy balance is carried out using data available on the fuel input (wood chips) into the reactor, gas calorific value using gas composition and the heat loss at various locations in the gasifier system (based on temperature measurements). At full load, the cold gas efficiency is about 79 %. The other values relating to the losses are indicated in table 4.

Table 3 Balance of C

Date	SI	YI	SO	YO	diff. %
12.1.94	.452	.157	.435	.151	3.93
14.1.94	.452	.156	.431	.149	4.64
16.1.94	.452	.155	.453	.155	-.21
19.1.94	.452	.159	.436	.153	3.59
11.2.94	.452	.156	.437	.148	3.46

SI = Mass of the element /in the input unit mass of wood; YI = Mass fraction of the element in the input
SO = Mass of the element/in the output unit mass of wood; YO = Mass fraction of the element in the output

Table 4

Energy Form	12/1/94; 18g/s 33% load (kW)	14/1/94; 30g/s 55% load (kW)	16/1/94; 30g/s 55% wm load (kW)	19/1/94; 54g/s 100% load (kW)
Energy into wood, kW	+ 110	+ 175.9	+ 173.7	+ 319.2
Energy lost in recirculating duct, kW	- 0.654	- 0.76	- 0.76	- 0.88
Energy from twin shell to ambient, kW	- 0.4	- 0.50	- 0.52	- 0.68
Sensible heat + latent heat, kW	- 6.49 - 6.25	- 14.2 - 10.74	- 13.8 - 9.5	- 26 - 15
Energy from reactor walls into ambient, kW	- 1.82	- 2.04	- 2.04	- 2.14
Energy in char, left in the reactor & cyclone water seals, kW	- 0.43	- 1.43	- 3.00	- 7.40

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Energy in tar & dust, kW	- 0.29	- 0.293	- 0.56	- 0.76
Energy in reactor walls, kW	-0.80	-	-	-
Energy in gas, kW	- 85.1	- 139.3	- 139.5	- 250.2
Total -ve, kW	-102.2	- 169.2	- 169.8	-303.1
(+ve) + (-ve), kW	+ 7.76 (7%)	+ 6.7 (3.8%)	+ 4 (2.3%)	+ 16.14 (5%)
Cold gas efficiency, %	77.3%	79.2%	80.3%	+78.4%

The effluents

The overall effluents generated per kg of moisture free wood are listed in table 5.

Table 5. Effluents per kg moisture free wood

Item	P+T	BOD	COD	Phenol	DOC	NH_3/NH_4
g/kg mf wood	1.45	0.14	1.9	0.077	2.32	1.72

The Cosmic Industrial Laboratories carried out the analysis on the cooling water and the water below the seals. These results are consistent with that analyzed by the Swiss team (samples carried from Bangalore). The levels of BOD and COD are in the range which could be treated easily before discharging into the drain. The particulate matter consisting of fine carbon and ash can be removed by filtration. The low level of BOD is argued to be due to the effective thermochemical processing of the gas in the reactor. The contribution of COD is from particulate matter sine the COD on ultra fine filtration 2 micron filter, is much lower than before filtration. Thus the removal of particulate matter will reduce the COD. The other elements would call for specific treatment.

Remarks

The tests conducted at Indian Institute of Science, Bangalore, on the 100 kW gasifier systems at varying load conditions has indicated that the tar and particulate levels are independent of the load. An average tar and particulate of 20 +10 and 60 + 20 mg/m^3 is noticed at the cold end. Future plans are to install one system in Switzerland and carry out few tests under Swiss conditions before large scale commercialization.