Development of a New System for Pyrolytic Gasification of Rice Husks

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Introduction

The present study has been carried out with the purpose of getting energy source for heating, cooling, and motive power required for drying and storage in cooperative grain-drying facilities from crop residues such as rice husks.

On the basis of research results[1,2] obtained in the "Green energy research program" (1979–1981) and "Biomass conversion research program" (1982) of MAFF*, a pilot plant for pyrolytic gasification of rice husks, which was scaled for 10 ha, was constructed in the "Project of practical implementation of energy-saving technology" (1982–1985) of MAFF. A large number of experiments were conducted repeatedly with the pilot plant, and finally in 1985 the guidline for designing the facilities for pyrolytic gasification of rice husks was established. The system thus developed is presented in this paper. We aim at the practical application of this system starting from 1986.

Methods

1) Trial production of husk-gas generators of pyrolytic type

(1) Type DHF791

To obtain basic information on husk-gasification, preliminary experiment was carried out by the Batch method, before starting the designing work. Then, on the basis of the results obtained from the preliminary experiment, a gas-generating furnace of an updraft type and moving layer form was designed and produced (Fig. 1). This furnace is able to generate husk-gas continuously by gasifying the husks fed into the furnace by using a part of combustion heat of the husks. It is simple in structure without roster, and a combustion residue, i.e. carbonized husks, is discharged by driving a plunger by the air-cylinder.

(2) Type DHF801 and DHF811

Starting from the type DHF791, the following improvements were made:

(i) To supply husk-gas to gas-receiving equipments at stabilized gas pressure, a gas-holder (capacity

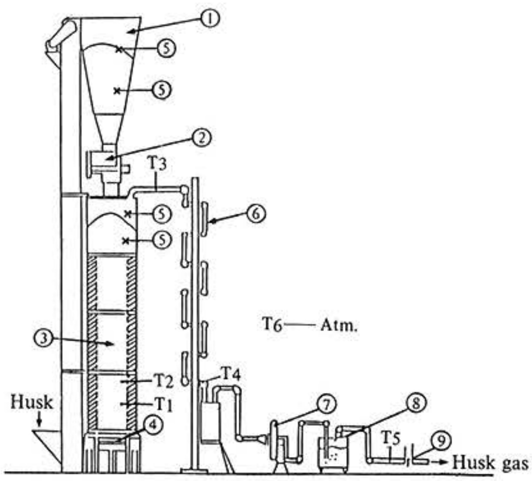

Fig. 1. Schematic figure of the pyrolytic gasification system for rice husks (DHF791 and 801 type)

① Hopper ② Rotary valve
③ Pyrolytic gasification furnace (Diameter: outer 700, inner 450, Height: 2700 mm)
④ Plunger ⑤ Leveller
⑥ Heat exchanger ⑦ Fan
⑧ Gas cleaner ⑨ Orifice
T1–T6: Temperature

* Ministry of Agriculture, Forestry and Fisheries.

30 m³, gas pressure 200 mmAq) was installed for temporary gas reserve.

(ii) For the safety measures of the gas-holder, a three-way valve, which is driven in response to oxygen concentration, was provided in order to avoid the entering of husk-gas with oxygen content higher than 5% into the gas-holder. A gas-volumeter was also used to detect the volume of gas in the gas-holder.

(iii) For the automation of the system by the use of a microcomputer, the computer-program was formulated by BASIC to make it possible to generate husk-gas continuously at the rate of keeping the gas volume in the gas-holder at 70% of the gas-holder capacity.

(3) Type DHF821

As given in Fig. 2, the rotary valve, which was used to supply husks into the furnace of the model DHF791, was replaced by the double damper with higher air-proof effect, and the height of the furnace was reduced to 2/3 that of the model DHF791 for saving cost. In addition, gas-cleaner systems of a

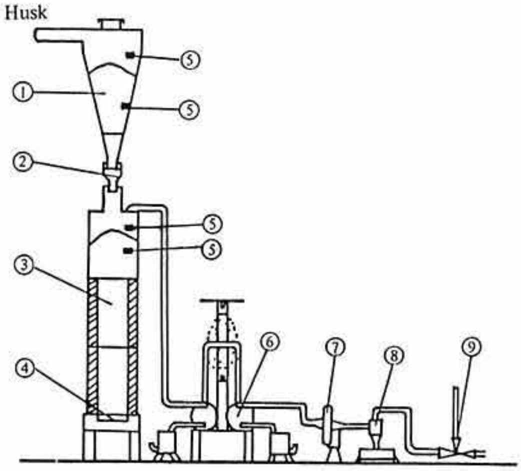

Fig. 2. Schematic figure of the pyrolytic gasification system for rice husks (DHF821 type)

① Hopper ② Double damper
③ Pyrolytic gasification furnace (Height: 1800 mm)
④ Plunger ⑤ Leveller
⑥ Gas cleaner ⑦ Fan
⑧ Cyclone ⑨ Three-way valve

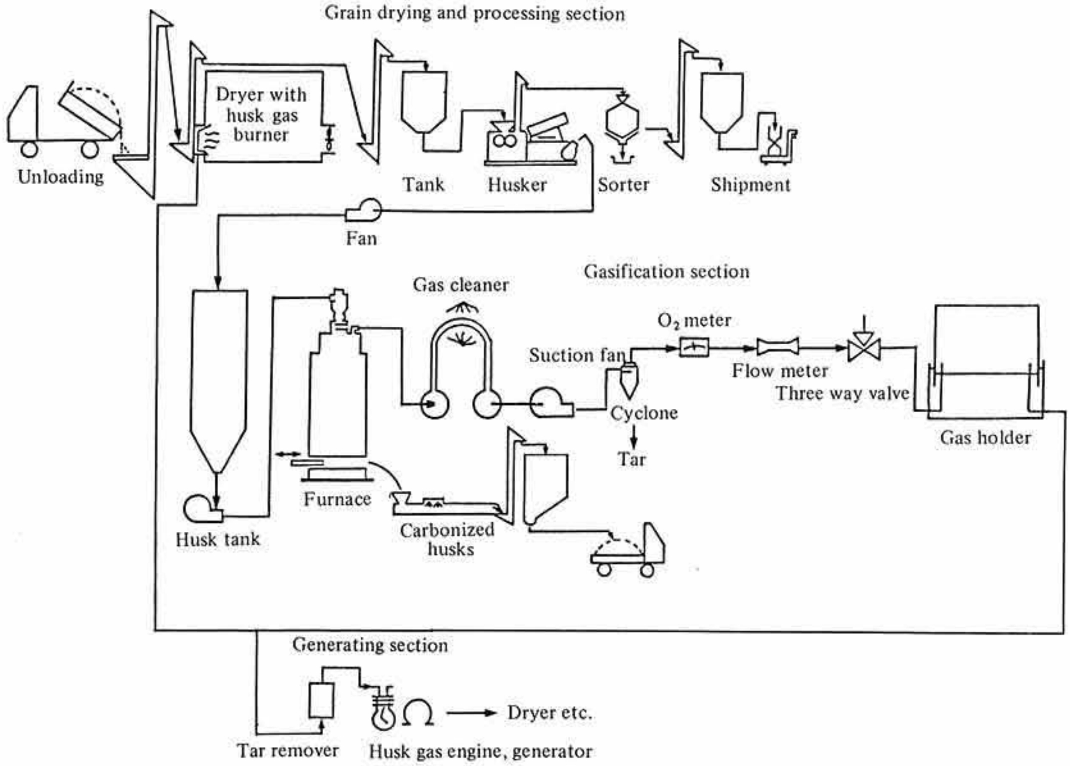

Fig. 3. Flow chart of the pyrolitic gasification system for rice husks

water-spray type from the outside of piping and cylone type were produced for trial. Moreover, to accelerate the control cycle and to optimalize the gas generation, the control program was changed to ASSEMBLER.

2) *Tests and trial production of equipments which utilize husk-gas*

(1) Possibility of power conversion

After the preliminary test was made with a gasoline engine by using the husk-gas generated from the model DHF801, starting and running tests of a gas engine (226 cc) were carried out by using the husk-gas generated from the model DHF811, and then the possibility of power conversion was examined by driving an electric generator.

(2) Trial production of a husk-gas burner (type HGB821)

A husk-gas burner produced for trial, which has combustion capacity equivalent to 3 *l*/h of petroleum, was attached to a circulating type dryer (holding capacity 2.0 t) available on the market, after the petroleum burner of the dryer had been removed, and the performance of the husk-gas burner was examined.

3) *Trial construction of a pilot plant for pyrolytic gasification of husks*

On the basis of the research results so far obtained, a pilot plant scaled for 10 ha was constructed. The flow chart of the pyrolytic gasification system is given in Fig. 3.

Experimental condition

An example of experimental plots designed for the performance test of the model DHF811 is given in Table 1.

1) *Items of measurement*

(1) Temperature

Temperature in the furnace was measured with a PR type thermocouple, and that of generated gas and air temperature with a CC type thermocouple.

(2) Amount of husks fed to the furnace

For the model DHF791 and 801, volume of husks to be supplied to the furnace was measured prior to each test, and is shown in the average.

(3) Amount of husk-gas generated

Orifice was used.

(4) Gas analysis of husk-gas

Gas chromatograph (Shimadzu GC-7AGPrTF type) was used.

(5) Oxygen concentration

A simple oxygen concentration meter of Orzat type was used for the model DHF801, while the O_2 analyzer of galvanic battery type was used for the model DHF811 and subsequent models.

(6) Amount of gas in a gas holder

A gas volumeter which determines the volume of gas by measuring the level of the gas bath in the gas holder was used.

(7) Tar content of husk-gas

Husk-gas was sampled at the flow rate of 600 cc/min. Tar contained in the sample gas was measured by collecting the tar with the use of cigarette filter available on the market.

(8) Volatile matter, fixed carbon, and ash

Measured according to JIS M8812-1976.

Results and discussion

The amount of production and utilization of rice husks in Japan is shown in Table 2. As a whole, among different usages, the utilization as manure ranks first. About the husks released from coopera-

Table 1. Test condition (DHF 811 type)

Amount of husk gas (*l*/sec)		7, 8.5, 9, 9.5	
Controlled temperature of plunger	1st layer (°C)**	1100-(1),*	1200-(2)*
	2nd layer (°C)	600-(1),	700-(2)
	3rd layer (°C)	400-(1),	500-(2)

* Figures in the parenthesis indicate times of plunger operation.

** Measuring point for each layer is shown by the distance from the bottom of the furnace.
1st layer: 450 mm
2nd layer: 800 mm
3rd layer: 1150 mm

Table 2. Utilization of rice husks

(Compiled from the MAFF statistics, %)

	Total							Husks released from cooperative grain-drying facilities						
	1983	1982	1981	1980	1979	1978	1975	1983	1982	1981	1980	1979	1978	1975
Production×1000 ton	2508	2381	2300	2248	2629	2338	3291	396	407	377	461	373	271	260
Mulch	8.2	5.8	5.8	7.8	4.0	3.4	3.8	5.2	7.2	6.1	4.7	3.0	3.0	2.3
Seedbed	2.1	2.8	2.4	2.7	2.6	2.5	1.7	2.7	4.9	2.8	3.1	3.3	1.6	3.3
Drainage	10.5	11.0	12.2	11.6	9.6	8.2	—	27.2	24.9	25.4	21.6	22.7	21.3	—
Litter	15.7	14.6	14.0	13.7	13.0	12.3	9.4	22.7	19.9	20.1	16.4	14.5	14.1	8.9
Manure	19.7	19.7	19.3	16.1	15.6	15.9	18.9	13.2	12.4	10.3	13.2	12.8	14.4	11.7
Processing	0.1	0.2	0.3	0.4	0.3	2.2	0.8	0.7	0.7	0.5	1.0	0.2	0.6	1.7
Fuel*	3.4	2.6	2.6	2.2	2.4	3.0	47.6 (Fuel*, Carbonized husk*, Burning*)	3.3	6.0	5.3	2.9	2.2	1.2	43.8 (Fuel*, Carbonized husk*, Burning*)
Carbonized husk*	5.6	5.2	6.1	6.1	6.1	33.0 (Carbonized husk*, Burning*)		8.1	6.8	7.4	7.0	7.3	23.8 (Carbonized husk*, Burning*)	
Abrogation: Burning*	26.2	28.0	26.6	27.4	31.0			7.9	8.6	8.7	19.8	14.0		
Abrogation: Others*	4.2	4.9	4.4	5.0	5.9	9.9	10.0	2.0	1.3	1.2	2.6	7.1	9.0	9.9
Others*	4.3	5.2	6.3	7.0	9.5	9.6	7.8	7.0	7.3	12.2	7.7	12.9	11.0	19.2
Total*	43.7	45.9	46.0	47.7	54.9	55.5	65.4	28.3	30.0	34.8	40.0	43.5	45.0	73.8

Total*: Total of items asterisked, showing the amuont which can be used as an energy source in future.

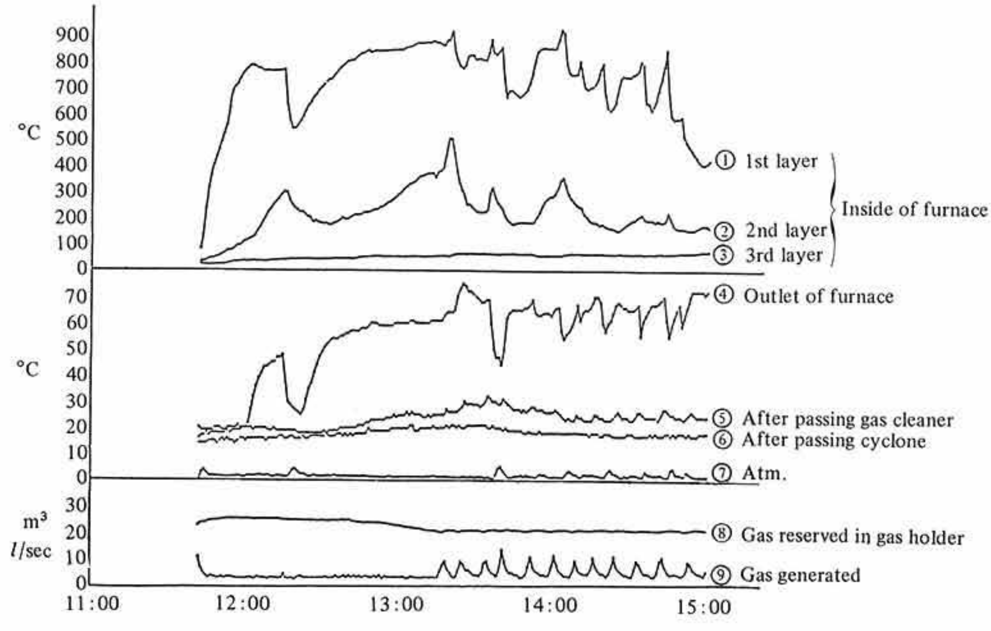

Fig. 4. Automatic operation of the system (DHF821 type)

tive grain-drying facilities, a larger portion of them is used as material for under-drainage and litter in barns than as manures. In both cases, the amount of husks discarded has been decreased in recent 10 years. However, the utilization of husks as heat-energy for grain-drying in cooperative grain-drying facilities is seldom.

Fig. 4 shows the performance of the model DHF821 in automatic operation. It can be estimated that the optimum condition of the gasification furnace is about 30 kg/hr of a burning rate of rice husks with 30 m^3/hr of husk-gas generation. Roughly speaking, 1 m^3 of gas is obtained from 1 kg of rice husks. The result of gas-analysis indicated N_2

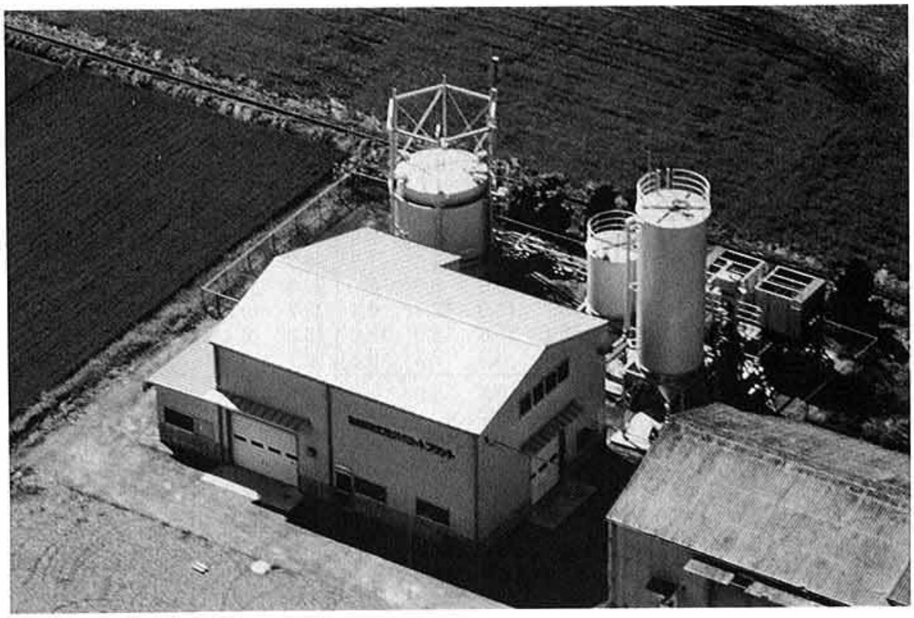

Plate 1. The pilot plant of the pyrolytic gasification system for rice husks (scaled for 10 ha)

50%, CO_2 10%, O_2 3%, CO 20%, H_2 10%, CH_4 2%, and others (C_2H_6, C_2H_4). The average of net calorie was estimated at 1,000 kcal/m^3, and gasification efficiency ca. 30%. The husk-gas is slightly lighter than air, with excess air ratio of 0.95, and it has strong odor. These characteristics are regarded as advantage for safe handling.

It was made clear that the automatic control program developed by the authors can be practically used. Within the range of the experiment, change of the height of the furnace from 6 times to 4 times of the inner diameter of the furnace caused no change in gas composition, showing the possibility of cost reduction. Tar content in the husk-gas was ca. 5 g/m^3 at the outlet of the furnace, and was ca. 80 mg/m^3 after cleaning the gas. This content gave no trouble to the operation of husk-gas burners and engines.

The rice husks used for the experiment contained volatile matter, fixed carbon, and ash at 61, 19, and 20%, respectively, and the residue after burning showed about 5, 36, and 59%, respectively. It indicates a possibility of re-use of the residue as fuel.

In September of 1984, a pilot plant for pyrolytic gasification of rice husks (Plate 1) was constructed, and practical operation aiming at grain-drying of rice, wheat and barley has been conducted to establish the practical designing guideline. As a result, no abnormality was recognized in quality of grains after drying. In addition, motive power conversion can be made. Thus, it can be concluded that this system is of high practicability.

Summary

1) Practicability of an automatic system for pyrolytic gasification of rice husks, composed of gas generation and its control, gas cleaning, and temporary gas reserve, and the possibility of utilization of the husk-gas were distinctly recognized.

2) The husk-gas has strong odor. It was generated at the rate of 1 m^3 per 1 kg of rice husks. It's composition was CO 20%, H_2 10%, CH_4 2%, C_2H_4, C_2H_6, etc. 5%, O_2 3%, CO_2 10% and N_2 50%. Excess air ratio=0.95, and net calorie=1,000 kcal/m^3.

3) Repeated practical operation tests conducted with a pilot plant of the automatic pyrolytic gasification system for rice husks demonstrated that this new system is highly practicable.

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