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Design, Development, Evaluation and Adoption of a Husk Fired Furnace for Forced Ventilated Paddy Dryers in Sri Lanka

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ABSTRACT: Drying of parboiled paddy in the wet and intermediate zones of Sri Lanka is a serious problem since rain prevails during most harvesting seasons. This operation which requires an extensive area could be replaced by introducing mechanical systems for the rice industry.

Therefore, a furnace was designed to overcome the constraints of drying related to conventional energy cost and to develop and provide groundwork for intermediate technology.

The capacity of the designed furnace is 50 kg of husk. It could be successfully adopted for any forced ventilated type batch dryers using an appropriate air duct. The husk consumption rate of the furnace is about 10 kg/h for drying of one tonne of paddy which is very low compared to the highly efficient rotary dryers used in other countries. Maximum rate of combustion is 0.0036 kg/s, which occurs at an air flow rate of 1.0158 m^3/s. The temperature inside the drying chamber could be maintained at 60 C by means of the thermoregulator mechanism of the furnace.

The advantages of the furnace are simplicity of design, low construction cost, ease of operation, low husk consumption rate and possibility to adopt to various kinds of force ventilated paddy dryers.

INTRODUCTION

The mechanical paddy dryers in use today are limited to some government farms and few privately owned rice mills due to lack of appropriate low cost furnaces. The heat requirement for this type of dryers is produced by a diesel burner. Heat exchangers are being used in these furnaces to prevent possible contamination of the grain from oil fumes. In addition to that, the drying system should always include a safety device which ensures that the fuel supply to the burner is shut off if the flame goes out or if the fan stops. These types of furnaces are more complicated and expensive.

A husk furnace has been designed for the fluidized bed dryer at the Rice Processing Research and Development Center in Anuradhapura. In this furnace air gets heated when sucked (blower) through cast iron tubes which are directly heated by burning husk in a combustion chamber. A mixture of husk and air is fed into the combustion chamber by another (husk) blower coupled to a 0.75 KW motor. This would indirectly effect the running cost of the dryer, in addition to expensive cast iron pipes. In order to prevent husk ash being exhausted with combusted gasses through the chimney, a trap is provided between chimney and combustion chamber. Hence the furnace is not so simple as it could be. A furnace has been developed for the rotary dryer require 50 kg of paddy husk to dry one tonne of paddy.

In order to overcome the excessive cost and complexity, the direct husk fired furnace was designed. Thus a system such as the direct fired husk furnace becomes the source of energy to heat the air for mechanical dryers, being a simpler and cheaper system. The paddy husk which is approximately 20% of the weight of paddy has a calorific value of 14,000 KJ per kg. A huge amount of paddy husk is produced annually. However a small percentage is used in rice mills as fuel mainly for parboiling and the rest is wasted by burning in the open fields or on the road sides. Thus the use of husk directly in the drying process for generating heat could prove to be a very attractive method in the future.

The heat input rate of the furnace is quite sufficient to maintain 60 C in the drying chamber for a two tonne capacity forced ventilated paddy dryer. Constant temperature of the drying chamber could be maintained by means of the thermoregulator of the furnace. This furnace could be adopted to any kind of forced ventilated dryer by use of different air ducts. The objectives of this study were to design and develop a low cost furnace which could be coupled to most of the existing dryers and to compare it with other existing furnaces.

MATERIALS AND METHODS

The design

Design criteria

Air could be heated either by conventional fuel usage, electricity or by non conventional sources like solar or waste product utilization. The two later methods are the most feasible for the dryers used in the country. Although the design of solar collectors for the heating process are possible, its heating rates are insufficient when it couple to thick bed dryers. Hence, the project was oriented towards developing a husk fired furnace.

Designing of husk fired furnace

The husk fired furnace is the heat generator of the dryer. The furnace is a modification of a larger version of husk fired cookers used at village level. The combustion rate of the furnace depend on the characteristics of husk compaction, total grate area, air passage area of the grates and the draught applied. The average combustion rate, approximated to be as 60 kg/m^2 h under draught, since it has been reported that a maximum rate of combustion as 69.79 kg/m^2 h for IR – 8 occurred at an air flow rate of 532 kg/m^2 h (Maheswari and Ojah 1976). The design procedure is given in Appendix 1.

According to the calculations made on the design, the required volume of the furnace was 0.018 m^3. Hence husk container was made from an used oil drum (170 l) for this purpose (Useful volume of the drum = 0.246 m^3) since it is cheap and is freely available in the market. The husk container connected to a conical receptacle attached and hot air duct leading to the plenum chamber through the blower. The husk container could be attached and detached from the conical receptacle when necessary by means of a supporting frame. The furnace design is given in Figure 1.

The gas flow through the furnace would be carrying residue at the furnace outlet, if the velocity of the outlet gases (in conveying tube) is greater than 3.5 m/s. To avoid this, the internal diameter of the hot gases conveying tube was designed not to be less than 70 mm. In drying

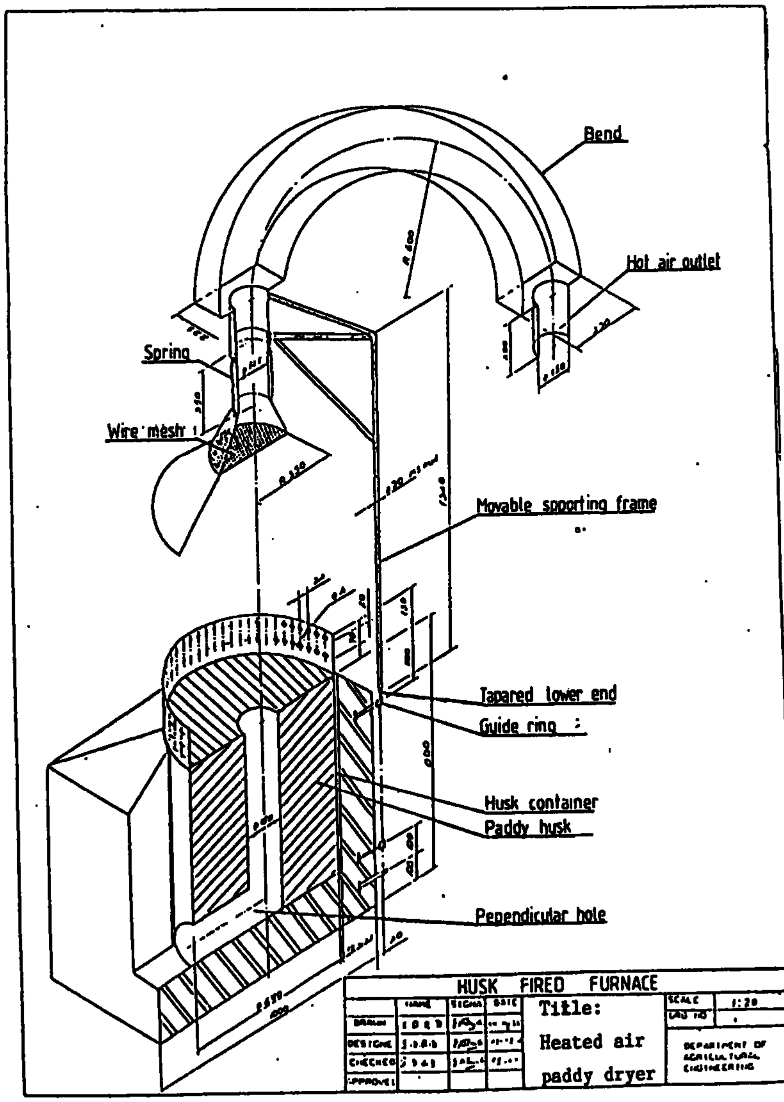

Fig.1. Design of the husk fired furnace.

seed paddy, a constant temperature of 43 C has to be maintained in the plenum chamber during drying. If parboiled paddy is to be dried the temperature should be maintained at 60 C. To maintain a steady temperature at the plenum chamber, a simple thermo – regulator was installed. By adjusting the air regulator mechanism of the thermoregulator, air flow could be controlled, and hence temperature of moving air. The cost of the furnace was less than Rs. 2000 (Appendix 2).

Construction of the furnace

A prototype furnace was constructed according to this design and installed at the Meewatura farm of the University of Peradeniya since it was felt that intensive testing at the University prior to field testing would give a better understanding of the problems. This definitely made it easier to find solutions. After modifications, the final models were installed in Kalutara and Kurunegala districts for field testing.

The furnace consists of a husk container, a supporting frame conical duct, and thermoregulator. A second hand oil drum (170 l) was used to make the container and 4 mm diameter holes at 2 cm spacing drilled in a circular cylinder, to enable the entry of excess air to facilitate complete combustion. A circular hole of 15 cm diameter was made in the bottom portion of the container. The paddy husk container was surrounded by 12 cm thick brick and clay wall to reduce heat losses. The outer wall of the drum was plastered with a thin layer of cement. The conical duct was made in a detachable manner could be attached or detached to the husk container by means of the supporting frame.

Operation implementation and evaluation

The furnace was evaluated for optimum design after attaching to a 2 tonne capacity batch dryer. The moisture content of parboiled paddy and harvested paddy was 32% and 20% respectively. Air flow rate, pressure, moisture, temperature and reduction of husk were recorded every half an hour until the moisture content of paddy reached 14%. This procedure was followed with different depths (0.05 to 0.3 m) of paddy in the dryer.

RESULTS AND DISCUSSION

Performance of the furnace

Efficiency of combustion

Energy in the form of heat is generated in this system by means of complete combustion. The combustion efficiencies were comparatively greater at the beginning of each test and then rapidly decreased within the first hour due to excess air (Figure 2). During the first phase of combustion pyrolysis takes place and the pyrolysis gases burn giving high efficiency of combustion. At the beginning, most of the inner layers of husk were pyrolysed leaving char. The rate of combustion of char is much lower than that in the pyrolysis phase due to the reactions of chemisorption by dissociation of CO_2 to CO. The produced CO was perhaps not totally oxidized to CO_2 due to relatively low concentration of CO to O_2 reducing the probability of spontaneous combustion. The second reason for the reduced efficiency may be due to high flow rates and structures causing rapid cooling in the gas phase while producing soot. Unburn tars and volatiles are mainly responsible for the production of soot. The average value of combustion efficiencies were low compared to the combustion of diesel and petrol engines.

Combustion efficiencies and the temperatures of the combustion zone

Temperatures of the combustion zone increased with the increasing rate of combustion within the first hour and subsequently the rate of increase lowered for the rest of the duration of the trial. Temperature, as well as efficiency of the furnace were reduced because of excess air which eventually lead to some degree of incomplete combustion.

Energy balance of the furnace

Heat energy generated by even with incomplete combustion of husk (Qh_{ic}) was considerable, amounting to 32.33 KW and 27.61 KW for 0.1 m and 0.2 m depths respectively (Table 1). The energy loss (Q_1) by metal components varied from 4.15 to 6.58 KW and was minimized by bricks and clay walls. The average furnace efficiencies were comparatively high for 0.05 and 0.30 m depth trials.

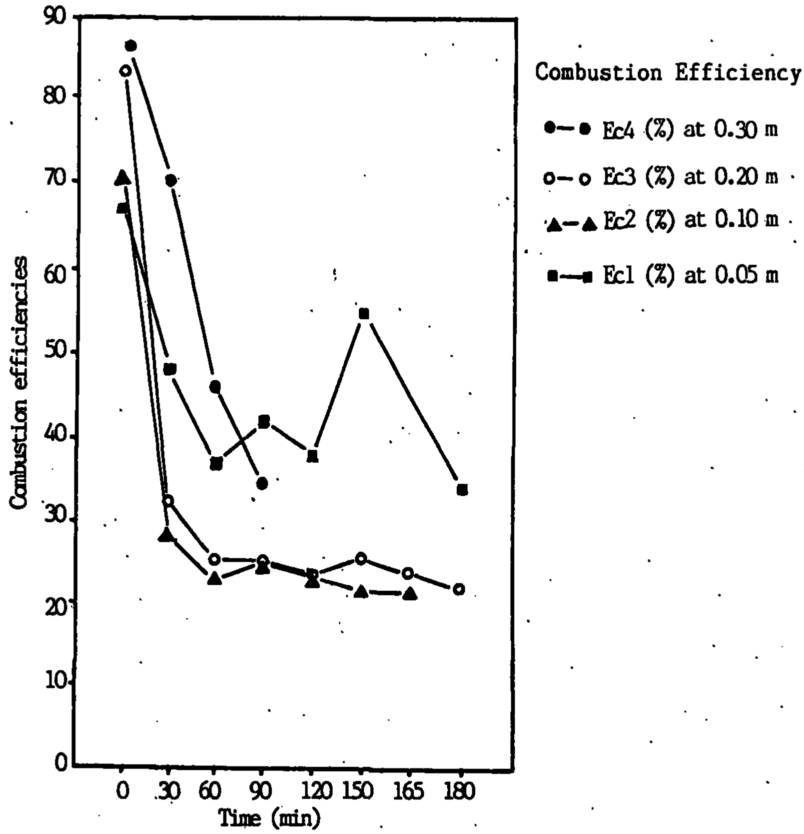

Fig. 2. Changes of combustion efficiencies with time.

Table 1. Energy balance of the furnace

d (m)	Qh_c (KW)	Qh_{ic} (KW)	Q_i (KW)	Q_l (KW)	E_c (%)
0.05	27.31	10.93	12.2	4.15	59.97
0.10	50.36	32.33	13.3	4.73	35.80
0.20	49.91	27.61	16.2	6.10	44.68
0.30	32.84	9.36	16.9	6.58	71.48

Notation

d Depth of grain bed (m)
Qh_c Heat energy generated by complete combustion of husk (KW)
Qh_{ic} Heat energy generated by incomplete combustion of husk (KW)
Q_i Heat energy input to the drying chamber (KW)
Q_l Heat energy loss (KW)
E_c Combustion efficiency (%)

Energy supply and conveying efficiency

The energy generated by the husk (from actual quantity of combustible) was further lost while conveying heated air through the blower and hot air conveyer. The energy conveying efficiency was the indicator to show useful energy for the drying purpose. The energy conveying efficiencies varied from 26.51 to 51.46% corresponding to the varying depths of the paddy bed. Subsequently the rate of increase lowered for the rest of the duration of the trial. Temperature, as well as efficiency of the furnace were reduced because of excess air which eventually lead to some degree of incomplete combustion.

Comparison of the furnace with other efficient furnaces

The rate of husk consumption by Rotary dryer was 50 kg to dry one tonne of paddy, which is low in terms of energy as compared to other systems such as fluidized bed and continuous dryers. The husk consumption rate of the designed furnace is about 30 kg/tonne of paddy which is low compared to the furnaces used in other dryers.

Quality of dried paddy

Total milling recovery and head rice yield have been increased by 2.09 and 4.68% respectively as compared to sun dried paddy, when furnace was attached to the batch dryer (Dharmasiri, 1989). However, this increment is almost same as for other furnaces.

Adaptability

The air flow rate is the determining factor of the heat input rate of different dryers. Hence this furnace is not advisable to be coupled directly for any forced ventilated paddy dryer, if the air flow rate of the dryer exceeds 3 m^3/s. For high capacity dryers like the LSU, two or more furnaces of the same kind could be coupled to achieve the heat requirement of the envisaged dryer. If the air flow rate of the dryer is known, the heat requirement can easily be determined by the simple calculation as described in the procedure given in the Appendix 1. However, all air outlets should be connected to the blower inlet. Increase of the number of furnaces would not effect the temperature control system of the furnace.

CONCLUSIONS

The combustion efficiencies found, were low in comparison to fossil fuels and the efficiency varied with time. At the beginning, the efficiency was higher and its decrease was due to excess air. Also the average efficiency was found to vary with the depth of paddy in the dryer. The insulation used for the furnace was adequate to prevent excessive losses. However, the conveying efficiency was low due to inadequate insulation. The husk consumption rate is low which makes the system more attractive in comparison to other furnaces. The running cost of the dryer (1986) was 10 cents/kg of parboiled paddy. One of the major advantages of the furnace is that it could be coupled to any of forced ventilated paddy dryer. Although, the system could be installed for post harvest drying both at farms and mills, it is advantages if further work could be undertaken to improve the air regulation system *i.e.* thermoregulator.

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REFERENCES

Acasio, U.A. (1972). Some Factors Affecting the Efficient Burning of Rice Hull for Grain Drying Purposes, Master Thesis, University of Philippines.

Acasio, U.A., Andales, S.C. and Valdez, M.R. (1973). Factors Affecting the Efficient Burning of Rice Hull for Grain Drying. Philippines Agriculture paper, 324.

Akyurt, M. and Sekuk, M.K. (1973). A Solar Dryer Supplemented with Auxiliary Heating Systems for Continuous Operation. Solar Energy, 14(3): 313–320.

Beagle, E.C. (1974). Basic and Applied Research Needs for Optimizing Utilization of Rice Husk. Proceedings, Rice by-product Utilization, International conference, Valencia.

Beagle, E.C. (1978). Rice Husk Conversion to Energy. FAO.

Cundiff, J.S. and Dodd, J.W. (1979). Energy Model for Forced Air Tobacco Curing. Trans. ASAE, 24(1): 211-215.

Dharmasiri, I.D.R. (1989). Design Development and Dissemination of a Suitable Paddy Dryer for Sri Lanka, M.Phil Thesis, Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka.

Joen, Y.W. Halos, L.S. and Bockhop, C.W. (1982). Furnace and Vortex Wind Machine. A Non-conventional Approach to Drying and Storing Technology. Paper Presented for the PSAE, Manila, Philippines.

Maheshwari, R.C. and Ojha, T.P. (1974). Fuel Characteristics of Rice Husk. Proceedings, Rice by-products Utilization. International Conference, Valencia.

Maheshwari, R.C. and Ojha, T.P. (1976). RPEC Husk Fired Furnace. RPEC Report no:2 (2).

Manalo, A.S. (1973). Rice Hulls or Kerosine for Paddy Drying. Proceedings, 4th Crop Sci. Soc. Phil. Sci. MTG., 474.

Ramalingam, J., Rama Rao, V., and Velupillai L. (1979). Adoption of a Dried Husk Fired Furnace and LSU Drier for Drying of Parboiled Paddy. RPRDC, Technical Note no: 8/79.

Singh, T.P., Maheshwari, R.C. (1980). Efficient Use of Agricultural Wastes for Energy Production. AMA, 11(4): 34-37.

Yong W.J., Leonides, H.S. and Clarence, W. (1983). Evaluation of Multipurpose Dryer Using Non Conventional Energy Sources.

APPENDIX 1

Assuming the following data, the design was undertaken as follows:

Quantity of paddy to dried	= 2000kg
Initial moisture content	= 20%
Final moisture content	= 14%
Temperature of ambient air	= 30 C
Height of the paddy bed	= 0.6 m
Expected temperature of the hot air at the combustion zone	= 200 C
Husk content of paddy	= 20%
Calorific value of husk	= 3220 kCal/kg
	= 5800 BTU/lb

Design

Expected air flow rate for batch dryer (Dharmasiri, 1989) = 1.173 m^3/s

The amount of water to be removed from the 2000kg of paddy when the moisture is brought down 20% to 14% ($W_2 - W_1$) where;

$$W_2(100 - M_2) = W_1(100 - M_1)$$

$$= \frac{W1(100 - M1)}{(100 - M_2)}$$

$$= \frac{2000(100-14)}{(100-20)}$$

Therefore $W_2 - W_1$ = 150 kg of water

The amount of heat required to remove one kg of water at 30 C = 600 kCal/kg

The total heat required to remove 150 kg of moisture = 150 x 600

= 90,000 kCal

APPENDIX 1, contd –

The weight of husk required to produce 90,000 kCal	$= \frac{90,000}{3,200}$ kg
	= 27.95 kg
Assuming the efficiency of the furnace is 60% (Since the efficiency of the most furnaces is above 60%), the husk required would be	$= \frac{27.95 \times 100}{60}$
	= 46.58 kg
Expected drying time for batch dryer	= 8.455 h
Therefore husk burning rate	= 46.58/8.455 kg/h
	= 5.51 kg/h
Projected area of grate	$= \frac{5.51 \text{ kg/h}}{60 \text{ kg/m}^2 \text{ h}}$
(Assuming combustion rate as 60 kg/m^2 h)	
	= 0.092 m^2
	= 0.02 m^2
Maximum volume of furnace	$= \frac{5.51 \times 3220}{500,000}$
(Assuming that the heat release rate is not exceed 598,000 kCal (35,000 Btu/cu.ft) of furnace volume under draught) (Ramalingam *et al.*, 1979)	= 0.036 m^3
Assuming the compaction ratio of the husk is 2:1 maximum volume should be	= 0.036/2 m^3
	= 0.018 m^3

APPENDIX 2

Cost estimate of the design (based on rates in 1986)

Item No.	Description	Unit	Qty	Rate	Amount (Rs)
i)	Empty oil drum for the container	–	1.0	125.00	125.00
ii)	Round iron (o=1") for the supporting frame	m	2.5	17.50	43.75
iii)	Flat iron (1/4"x1/2") for strengthening the heated air conveyer	m	3.0	13.50	40.50
iv)	Galvanized sheets (gauge) for the movable hot air duct and the conveyer	m^2	5.0	123.50	617.50
v)	Springs	–	2.0	5.00	10.00
vi)	Heat resistance asbestos	m	1.0	420.00	420.00
vii)	Window hooks	–	2.0	2.00	4.00
viii)	4 1/2" thick brick work in clay	m^3	0.25	400.00	100.00
ix)	5/8" external plastering in cement	m^2	4.5	15.00	67.50
	Welding and tinkering	days	1.0	150.00	150.00
					1578.25
	Adjusted amount (increased by 10%)				157.83
			TOTAL		1736.08