APPLICATION AND DEVELOPMENT OF RICE HUSK FURNACE

Chung-Teh Sheng, Mins Huang

Department of Bio-Industrial Mechatronical Engineering,
National Chung Hsing University, Taichung, Taiwan
e-mail:ctsheng@dragon.nchu.edu.tw

ABSTRACT

The energy-rich substance to have high energy content as thermal mass can be used directly or converted into other energy forms to serve the needs of human beings, such as light, heat, and power, which acts as a carrier of energy resources. A biological thermal mass with fixed energy content is created by photosynthesis via solar radiation. The regular production of biological thermal mass is closely related to the outcome of agriculture practice. As rice is the staple food for many oriental nations, the accompanied product of rice as rice husk can be said to be a representative of biological thermal mass. Biological thermal mass usually can be used with different phases: gaseous (hydrogen and biogas), liquid (bio-diesel and bio-ethanol) and solid (ingot type solid derivative and directly burning).The directly burning of solid thermal mass is the most convenient application way and needs the application cost to be low. This biomass application way is considered to be one of future renewable energy application development focuses. The husk incineration furnace, related to application and the energy conversion technology, will be fully investigated in this research.

Keywords: Rice Husk, Furnace, Thermal Mass.

INTRODUCTION

"Energy saving and carbon reduction" has now become a global issue in past two decades. Taiwan's greenhouse gases emission is among the high growth rate countries in the world. Since about 99% of Taiwan energy needs is depended on foreign imports, the "energy saving and carbon reduction" issue is more important in Taiwan. With the socio-economic development, the domestic energy demand has increased dramatically. Therefore, the entire Taiwan socio-economic development is affected by international energy production and price. The use of fossil fuels also generates large quantities of greenhouse gases, such as CO_2. The serious greenhouse gases emission problem has jeopardized the world environmental and ecological balance. It is the main reason to cause the global climate change, which is seriously endangering the environment and man's survival. Countries around the world continue to make every effort to solve the oil crisis as energy issue and look for alternative energy with carbon reduction function. On the day of 2009, 12,6, Taiwan Legislative Yuan finally passed the renewable energy regulations, which codified the refers to renewable energy resources as solar energy, biomass energy, geothermal energy, ocean energy, wind power, non-pumped storage hydro power, domestic waste and general waste directly produced or treated, such as energy, or other approved by the central competent authority to be sustainable use of energy. To this moment, the bio-energy application and development in Taiwan is not only consistent with policy but also in line with the world trend.

Solar energy is absorbed through plant photosynthesis to be limited, but it has still become a major source of biomass or bio-thermal mass. In addition to solar energy absorption, the process of photosynthesis must also absorb CO_2, which has performed the fixed CO_2 function. In addition to CO_2 production and absorption, a complete CO_2 cycle is formed with the photosynthesis process, so the biomass is renewable and inexhaustible essentially. In reality, the earth is rich in solar energy, and the use of bio-thermal mass will not become a burden of the earth. The abundant biomass energy is still waiting for people to develop related applications. During the energy crisis, people often think of solar energy and are actively engaged in the development and utilization of solar energy. During the first oil crisis period from 1975 to 1980, which is also known as the energy crisis for the first time, countries around the world had been trying hard to find alternative sources of energy, in particular renewable and sustainable energy. At that stage the use of solar energy was a very hot topic, and this status was extended to 1980 until the oil price fell back. Other energies are unable to compete with the fossil oil as regards of the utilization convenience and economic advantage, thus the attempts of alternative energy development and utilization have been greatly reduced or ceased. But in the first energy crisis, agriculture was playing a very active role on both energy utilization and new energy development.

Because the bio-energy production and utilization has the functions with fixed carbon and zero net carbon output, some bio-energy related products have the advantages of fossil fuel substitute. Such as the heat generated with a rice husks furnace can be partially replaced the consumption of fossil fuel or heavy fuel for agricultural products drying. It has become the focus of alternative energy development. However, some constraints to restrict the widespread use of biomass must be taken into account, especially the lack of suitable equipment to perform the operations of collection, treatment, transportation, and storage of the agricultural by-product as biomass effectively and economically.

Rice husk is rich in cellulose, semi-cellulose and lignin. Rice husk does not have any production cost for a rice mill, because it seems to be a naturally occurring product in a rice milling process. If the rice husk should not be treated as a furnace fuel, it is a waste or trash for a rice mill. It will become a burden of the rice mill. In terms of calorific value of rice husk is about 3,000-3,542 kcal/kg (12,600-14,876.4kJ/kg) (Lee, 1998). The energy value is approximately one-fourth of kerosene or 1kg kerosene is about 2.4kg of rice husk. Because combustion temperature can reach 800-1000℃, rice husk is a good furnace combustion material. The application of rice husk furnace in a rice mill has the following advantages, such as low production and transportation costs, high calorific value and ease to use; therefore, it is a very good bio-energy resource.

Today the application of bio-thermal mass can be classified into: solid state, liquid state and gaseous state. The solid state, as refuse derived fuel (RDF) and fixed solid fuel, is easy to transport and store, and can be used as fuel for boilers, cement kilns. Liquid state, as bio-diesel and bio-ethanol, can be used as the fuel for engine and fuel cell or direct combustion to generate heat and electricity, and so on (Sheng, 2006 and 2010). Gaseous state, as hydrogen and methane, can be used directly as gaseous fuel to cook or burn to generate heat. Biomass conversion and utilization patterns include thermo-chemical conversion, physical and chemical conversion, and biochemistry conversion. Although application of bio-thermal mass has so many different types, burning is still the most convenient way. The technological threshold of burning is very low and the related investment can be kept low. Therefore, the utilization of biomass to be the energy source can be applied in farm business. Utilization of agricultural waste by burning has the advantages, such as low technical difficulty, equipment acquisition easy and low cost. Burning can treat a great amount of agricultural waste in a short period. So if there is a major natural disaster to cause lots of animal death, the incineration method can quickly handle lots of animal carcasses easily.

Rice is the major staple food in Taiwan. Rice industry in Taiwan will produce about 1.5 million metric tons of paddy and 0.3 million metric tons of rice husk every year. If this tremendous amount of husk cannot be efficiently exploited, it not only is the waste of nature resource, but also has the serious negative effect on the environment. For dealing with rice husk, the new application or re-use technologies must be fully exploited. The invention of rice husk furnace is a successful achievement of rice husk application in Taiwan. Rice husk furnaces to generate the heat by burning husk have been used for various purposes in foreign countries for many years, such as Japan, Thailand, and etc.

Due to differences in production and storage situations in various areas or nations, the rice drying requirements from different nations are also varied. But the basic requirement for rice drying is remained to be the same to reduce the moisture content to safe level and keep the quality to be high. For the rice drying center to adopt the rice husk furnace is not only to save the energy cost in drying, but also to improve the product quality by adopting the indirect heating. The adoption of indirect heating can keep out the tar contamination problem. The rice drying center also has better and more precise control on ventilation and temperature of drying air. With using rice husk furnace to generate drying heat, the rice drying center achieves both to reduce the cost of drying and to enhance the quality of drying operation.

RICE HUSK FURNACE DEVELOPMENT

Rice husk combustion characteristics

The whole process of rice husk combustion can be divided into the following four thermal decomposition stages: moisture evaporation (an endothermic process), volatile substances release (an endothermic process), volatile substances burning (a heat generating process), and fixing carbon burning (a heat generating process) (Wong and Fon, 1993). The rice husk combustion can be treated as series continuous rapid oxidation reactions of rice husk and air at the appropriate temperature and pressure. In fact the burning process can be said to be four thermal decomposition stages occurring simultaneously. In addition to enough oxygen, to make an acceptable rice husk combustion needs proper burning temperature, sufficient time of burning, and proper disturbance of the combustion process. So the above four criteria can be used to evaluate the performance and effectiveness of a furnace, and result estimation of rice husk combustion reaction.

Four thermal decomposition stages in a rice husk combustion process can be further simplified into three phases: moisture evaporation, released volatiles burning, and fixed carbon burning. Three phases occur simultaneously in a combustion process, but the rates of three phases are different (Wong and Fon, 1993). As Figure 1 shows, the moisture vaporization to refer to the burning begins to ramp sections before rates change rapidly, or it may be called a warm-up period. If the furnace temperature is below 500℃, this area can be seen more clearly. As table 1 shows, the length of evaporation period at 500℃ is between 0~50 seconds. During this period, the moisture content of husk reduces significantly, and the total weight loss of husk is almost equivalent to the reduced amount of moisture. The occurrence of volatiles escaping and burning can cause the quantity of rice husk residue in steep decline, and the curve showed a final moderate decline in the combustion zone is responsible within this phase. At this phase, due to heat, vaporization and burning of the volatile materials of rice husk, the reduced residue weight is equivalent to released volatile matter content of rice husk. The fixed carbon burning period will immediately follow the volatile combustion period since the curve declines slowly until the level region. When the furnace inside temperature is higher than 700℃, the remaining material inside the furnace is the ash in the horizontal part on the curve. As Figure 1 shows, the lower operating temperature will have more residual material inside the furnace. If the residual amount is beyond the ash amount, it means the residue to contain the fixed carbon. In order to produce carbonized rice husk in a rice husk combustion process, the control of combustion temperature and residential time inside the furnace are key factors. The rice husk furnace must be controlled at 500℃ or below, then there is still a lot of unburned carbon (Sheng 2003). The ash is grey, and the unburned carbonized husk is dark in Figure 2. The burned husk in 700℃ above will have ash melting phenomenon, and the molten ash will melt to lump together, which will make the difficulty for final residue to discharge. The furnace controlled below 500℃ without sufficient oxygen aims at generating combustible gases as volatile substances and carbonized husk. The combustible volatile gas mixed with enough oxygen will proceed the second burning. At this stage, the furnace temperature is higher due to the volatile gas combustion. If the furnace has adopted two stages of combustion to produce carbonized husk, at the first stage the inside operating temperature is estimated below 500℃ for generating volatile gas, and above 700℃ for burning volatile gas (Sheng, 2003).

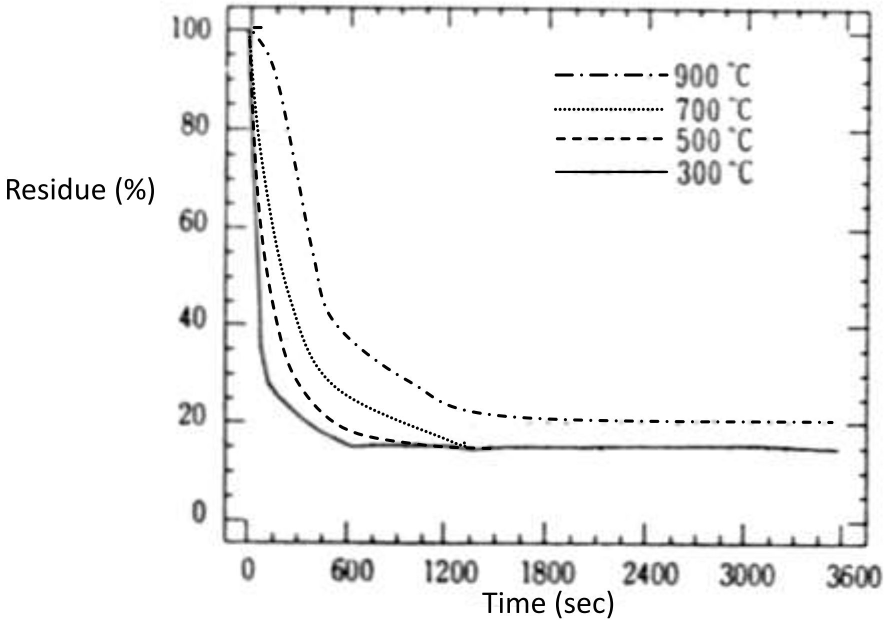

Fig. 1.The rice husk combustion curves with different temperature (moisture 12%) (Wong and Fon,1993).

Table 1. The three phase periods of rice husk combustion.

Temperature	Water evaporation	Volatile substance escapes burning period	Fixed carbon burning period
300 ℃	0 ~250 seconds	250 ~800 seconds	800 ~3000 seconds
500 ℃	0 ~50 seconds	50 ~400 seconds	400 ~2200 seconds
700 ℃	Less than 0~50 seconds	0 ~200 seconds	200 ~1800 seconds
900 ℃	Less than 0~50 seconds	0 ~150 seconds	150 ~1400 seconds

The internal temperature of the furnace has been determined by the amount of heat released from the combustion process, also influenced by the input rate of husk to be burned inside the furnace. Figure 3 shows the complete energy change flow chart during the ignition and combustion period for rice husk combustion. In Figure 3, the energy is generated by combusting volatile gas and fixed carbon. Figure 4 shows the energy change diagram in a furnace. In Figure 4, it clearly demonstrates three combustion phases. So the energy generating rate of a rice husk furnace can be controlled by the husk feeding rate.

Fig. 2. Carbonized rice husk produced by a husk furnace

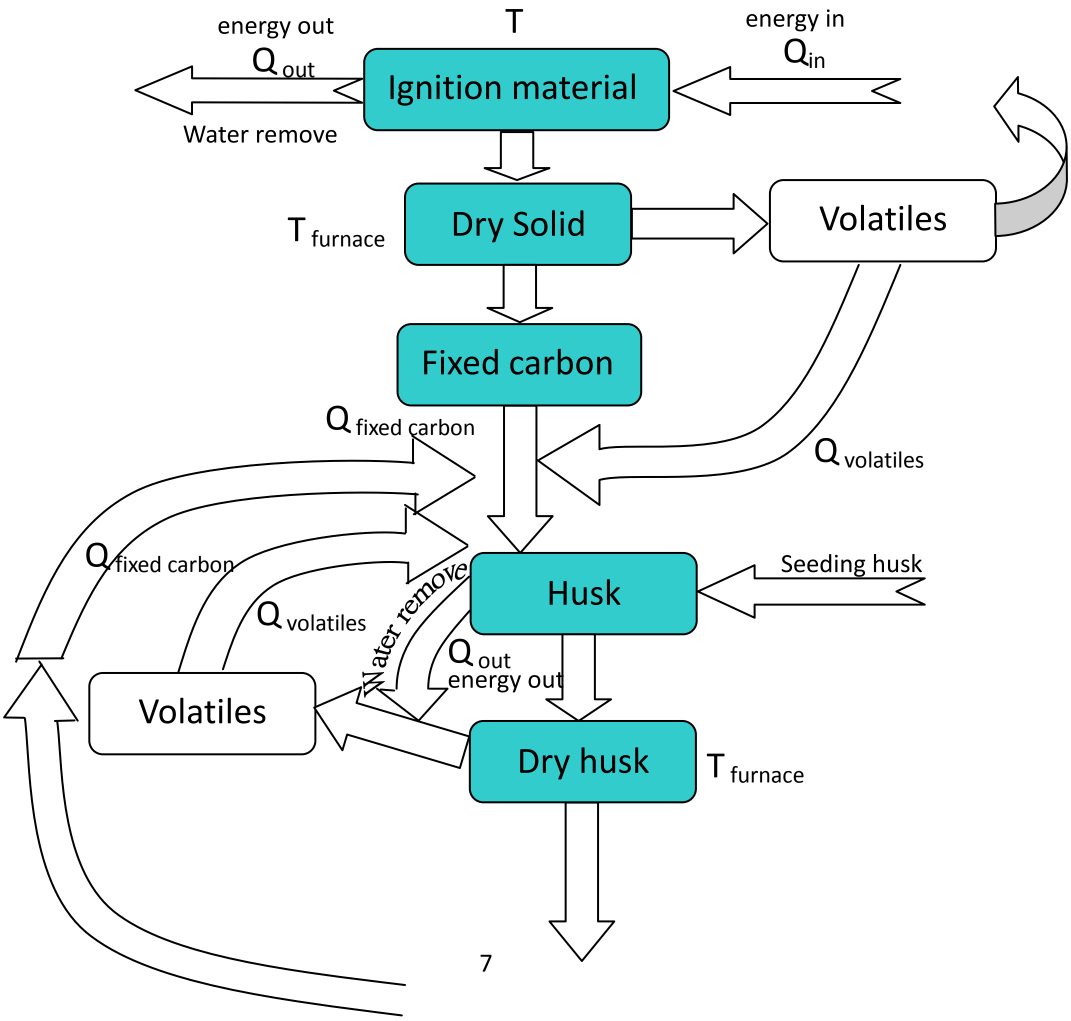

Fig. 3. Energy change flowchart in ignition and combustion processes.

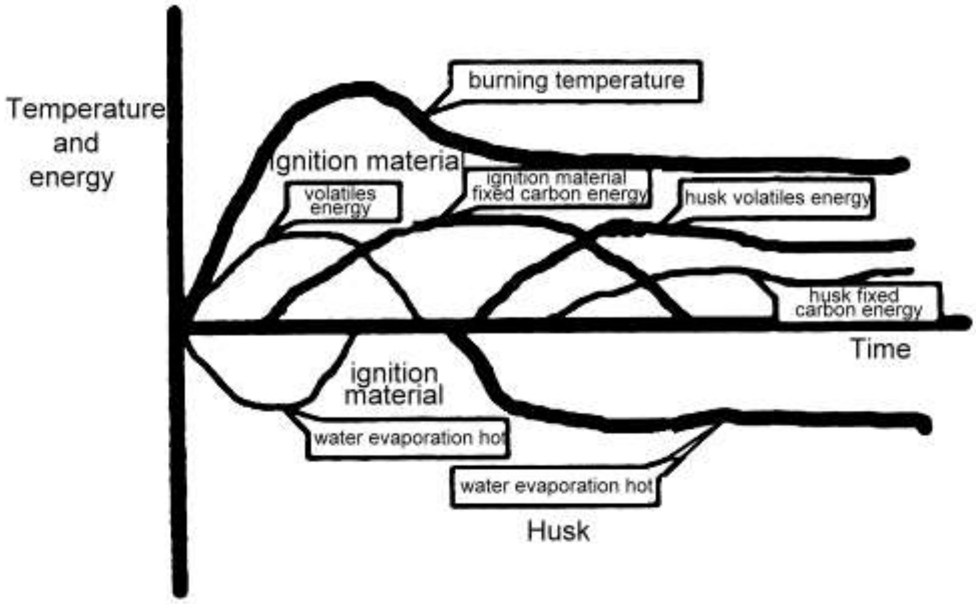

Fig.4. Energy change diagram in a furnace

Main operations for a rice husk combustion

The main operation elements of a rice husk furnace include feeding, combustion and discharging (Sheng, 2003 and 2009). The Details about the main operation elements are as follows:

1. Feeding: Feeding is to send the rice husk into the furnace in a controlled rate. The feeding system usually consists of a husk preparatory bin, a husk holding bin, and a blower (Figure 5). The preparatory husk bin has larger storage capacity to supply the husk to the holding bin. A blower connected to the bottom of the holding bin will send the husk into the combustion chamber (Figure 6). Due to the low calorific value and high residual amount after combustion of rice husk, the rice husk is not suitable for a fixed-hearth type furnace. The rice husk will be

sent into the middle position of the combustion chamber, and this design makes rice husk combustion reactions be carried out before the husk drops to the hearth.

Fig. 5. The rice husk furnace with feeding facilities. (Suncue, 2014)

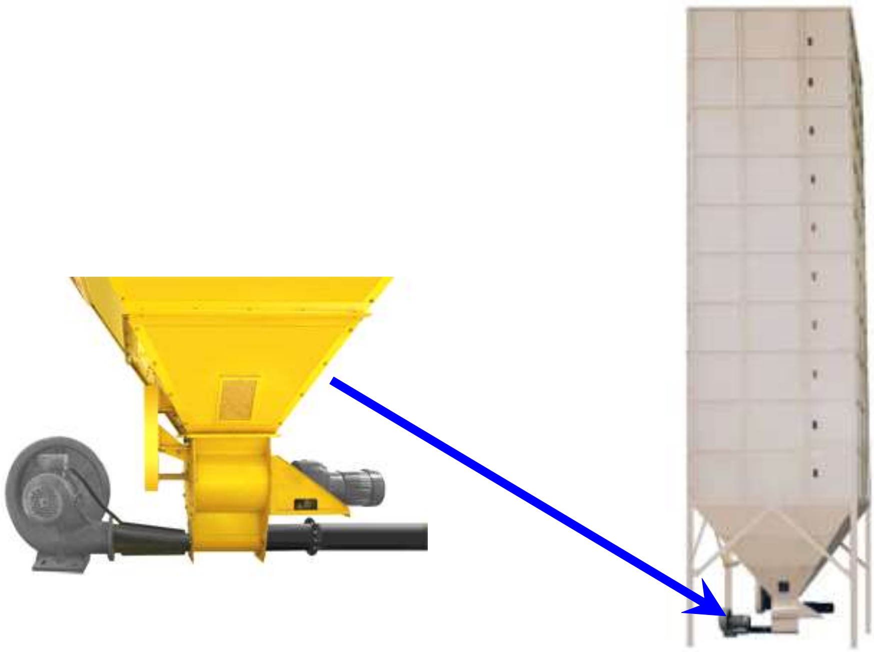

Fig.6. Husk feeder of a rice husk furnace. (Suncue, 20140)

1. 2. Combustion: The combustion occurs inside the furnace main body. The combustion process will bring out the stored energy inside the husk to become drying heat. The main furnace body can be categorized into direct burning (Sun, Figure 7) and indirect burning (Suncue, Figure 8). The difference between them

is to proceed only the combustion or both the carbonization and combustion. The carbonization will produce combustible volatile gases and carbonized husk. Suncue's furnace with a high round vertical combustion chamber can be divided into several sub-chambers, which will perform different functions. Three high-pressured air blowers do respectively blow the air into the combustion chamber from three different locations. Two of three air blowers and pipes only delivering air into the chamber are called air pipes. One air pipe sending the mixture of air and husk into the chamber is called the husk feeding pipe. The entire system can be roughly classified into two major subsystems as the combustion chamber and the heat exchanger, which is positioned next to the furnace.

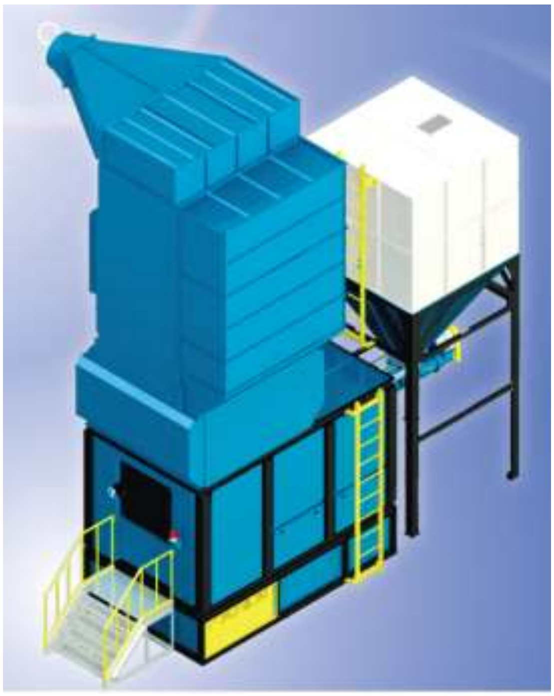

Fig. 7. Sun brand rice husk furnace. (Sun, 2014)

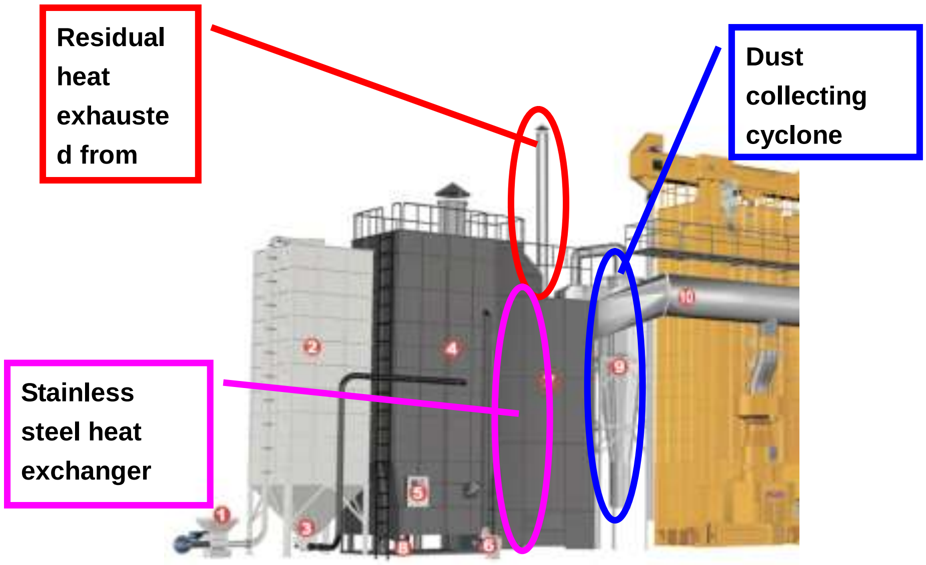

Fig. 8. Suncue brand rice husk furnace.(Suncue, 2014)

3. Discharging: As Figure 9 shows, the blower sends the air into the furnace from three locations. The air is used to assist the combustion and to help the discharging device to expel the ash or carbonized husk. The air will disturb and blow the ash up to avoid clogging the discharging orifice. The ash discharging device is located on the bottom of the furnace. The discharged ash will be further delivered by a screw conveyor to the ash tank or container.

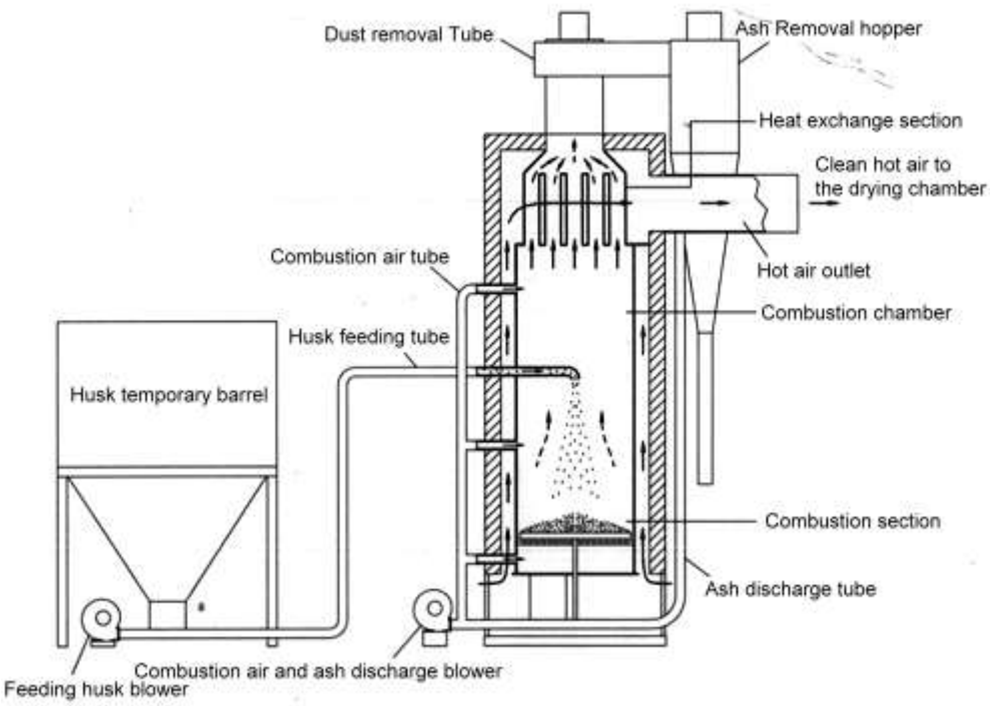

Fig. 9. A schematic diagram of rice husk furnace. (Suncue, 2014)

Rice husk furnace applications

Right now the rice husk furnace has been widely used in rice drying centers and rice mills with rice drying facilities in Taiwan. The main advantage for these businesses was the rice husk to be their major production waste as side product in a polished rice processing process before. Now they can convert the produced waste to become valuable energy resource. In other words, they produce their own drying fuel and don't need to worry about the problem of rice husk treatment any more. The rice husk is used to replace the drying fuel in many Taiwan rice drying centers, which can save tremendous costs of drying fuel and rice husk disposal.

The technologies of rice husk furnace used for drying wet paddy emphasize two key points. One is how to generate enough heat smoothly, and the other is how to deliver the heat into the dryer or drying facilities properly. In the past, the exhausted air from a husk furnace without a heat exchanger has been directly used in a drying process. The furnace structure for this application is simple, but it also causes some serious problems. The exhausted air contains high amount of tar, which will contaminate the rice and corrode ventilation pipeline and the rest of units, whatever will contact the exhausted air. The exhausted air is also full of combusted dust, which will not only pollute the environment but also affect the efficiency of a drying process and devalue the product. So currently most rice husk furnace manufactures employ the heat exchanger to improve the situation. The role of heat exchanger is to convey the heat from exhausted air to clean fresh air. Figure 10 shows one of the heat exchangers used in Taiwan.

Fig. 10. The heat exchanger. (Suncue, 2014)

The air must be properly adjusted to meet the drying requirements of each dryer, and the air adjustments mainly emphasize on the temperature and flow rate. The exhausted air will be expelled into the atmosphere after the dust collecting system.

This application focuses on the way how to collect the heat from the furnace and transfer to the dry air. The dry air will be tempered to a proper temperature and a uniform dry air velocity distribution within the dryer. The dry air temperature fluctuation should not be too large in order to maintain rice quality.

1. The hot air distribution system:

The system includes the following main functions:

(1) Control and management of dry air: The developed system can control and manage the flow rate and temperature of dry air based on the drying load and operating environment. But the actual operating load is never beyond the system maximum working capacity. No matter what dry load, all running dryers will have sufficient compliance of dry air.

(2) Energy and economic efficiency: The control and operation of the system must achieve the minimum cost requirement. The control of imported outside air temperature is important. The appropriate energy recovery system can be used to heat the imported fresh air before entering the heat exchanger, which can significantly improve the energy efficiency of the system.

(3) Operating environment considerations: The whole system will be operated in a hot and humid environment. Therefore, the designed hardware and software must be able to withstand the environment of high humidity and high temperature for a long time. The system must also be convenient for operator to use.

The air conveying system in a rice drying center is more complex than the general ventilation system. The system must not only deal with the requirements from different operating capacities of dryers, but also be required to maintain the stability of the drying temperature and air flow rate for various drying conditions.

2. Appropriate ventilation rate and drying temperature:

Proper ventilation and drying temperature are very important for rice drying systems equipped with furnace. The need of fresh air will actually be adjusted with the actual operating load changes of the system. Although the whole system will adjust its operating conditions accompanying with its working load, but the operation conditions for an individual dryer remains the same. The big challenge of the whole ventilation system design is to meet the demands of various working load, but it won’t cause any extra unnecessary energy consumption.

The air conveying system design is very important for a rice drying center with a furnace. Especially, the system must fully control the air flows for furnace and dryers. But some air conveying system for saving establishment cost has no control valves in the pipeline to adjust the air flow rate for an individual dryer. The system uses the air conduct size adjustment to change regional ventilation, but this air control strategy was applied only to fixed amount of ventilation. Drying center needs different drying operation conditions for different drying working loads. Each dryer is equipped with a fan, and the fan will determine the dryer air flow rate. Figures 11 12 are the layout figures of current rice drying center with rice husk furnace in Taiwan.

The air conveying and distributing system controls and maintains the furnace and dryer to have enough air at the right time. The difference between a drying ventilation system and a regular ventilation system is the air to be pulled out by a dryer fan and the air is blown out by a ventilation blower. The dryer fan will suck the air from the main hot air pipe, and it will generate a sucking pressure. Therefore, the drying air distribution is mainly controlled by the dryer fan. The dry air is conditioned within a drying air conditioner (Figure 13). The fan is equipped with the conditioner. The role of conditioner is to mix and adjust the heated air and fresh air to become appropriate drying air, and then the air is sent to the dryer for drying.

Application and development of rice husk furnace

1. Diversifying drying applications for other agricultural products

The drying treatment is a necessary process for many agricultural products, as corn, peanut, mushroom, tea, fruits, vegetables, and etc. The most important thing for successfully executing a drying process is to have enough heat, and the rice husk furnace can play the role to be a good heat supplier or heat source. As long as the heat from rice husk furnace satisfies the requirements for drying specific agricultural product, the drying system can handle and distribute the drying air

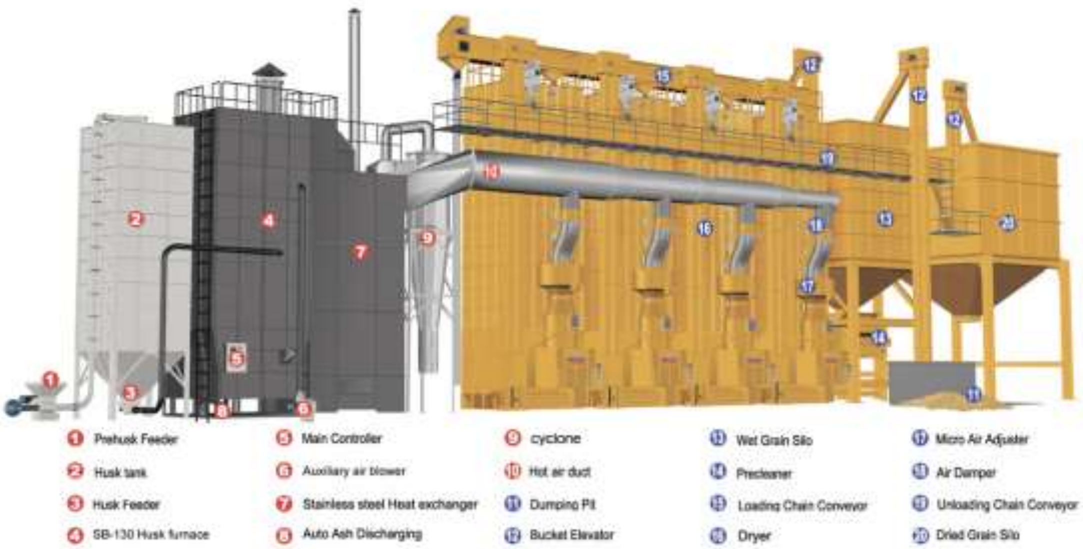

Fig. 11. A layout of a rice drying system with furnace (Suncue, 2014)

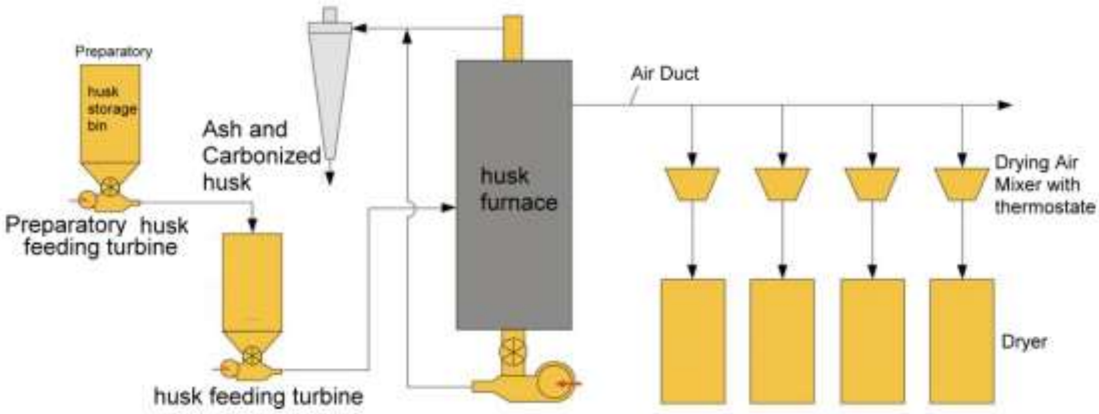

Fig. 12. System configuration diagram. (Suncue, 2014)

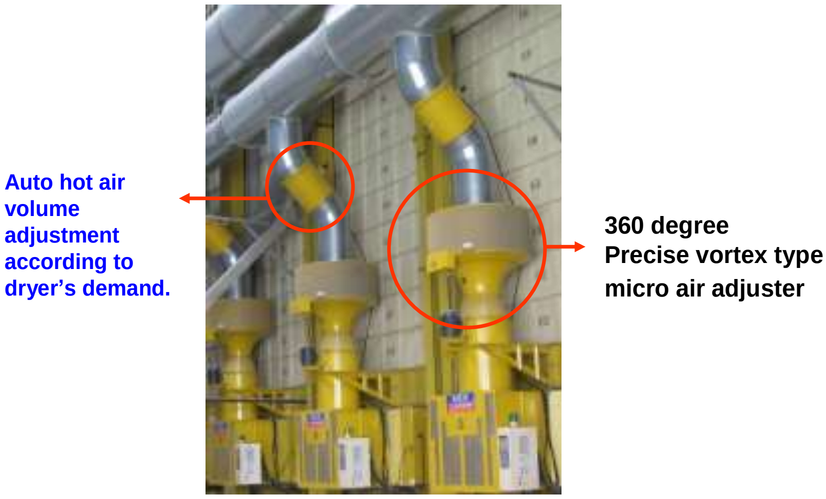

Fig. 13. Dry air conditioner. (Suncue, 2014)

to meet drying requests. In other words, both air flow rate and temperature satisfy the drying criterions. The rice husk furnace can be applied to dry other agricultural products, such as fruit, longan, garlic, sesame seeds, peanuts, and etc. Figure 14 is the slot block type drying bin with a rice husk furnace to dry peanut. A space bag has been designed to become a space drying bag. The top layer and bottom layer of a drying bag have been knitted with mesh, through which drying air can flow to do the drying work. Using the drying bag to dry peanuts, it does not only have the drying effect, but also reduce the work load to transport the peanut in and out of drying bin.

Fig. 14. Peanut drying within slot block drying bin.

2. Heat source for other applications

The generated heat of rice husk furnace can be converted into the different format, which can be used as a heat sources for many different applications. Of course, it can be used to dry many agricultural products. If the heat is used in a boiler, it will be used to produce the steam or superheated steam. The superheated steam can be applied to plant quarantine work due to its tremendous amount heat by condensation. The steam can be used to many processing processes and sanitary treatments. The steam can also be used to generate the electric power called the cogeneration. The generated electric power usually can satisfy the drying center electricity need.

3. Other agricultural by-products as fuels

Most agricultural by-products including lots of agricultural residues contain abundant bio-energy. So most agricultural by-products, which are dried and grounded to an appropriate size, can be treated as fuel to the developed furnace. For example, peanut shell, corn cob, rice stalk and etc. can be used as bio-thermal mass (Sheng, 2009). But the important criterions for choosing appropriate bio-thermal mass are the calorific value of the raw material itself and the handling cost. The bio-thermal mass is used not only to be energy-rich raw material, but also to produce some other valuable products by properly controlling the burning process. For example, the biomass can be used to produce bio-charcoal. Figure 15 shows various bio-charcoals from different agricultural by-products.

Fig. 15. Bio-charcoals from different agricultural by-products. (Maywa Co., 2012)

CONCLUSION

The invention of rice husk furnace is a successful technology development case about bio-energy application in Taiwan, due to its significant economic benefits.

There are two aspects of assessment, such as reducing the overall drying costs and resolving the rice husk as trash problem. It will take about two years or two and a half years to reimburse the cost depending on the oil price. The other contribution to the furnace user is to convert the rice husk from the original headache waste to a valuable resource. Based on Taiwan's experience, past rice husk user such as broiler chicken farmer is free to use rice husk, but rice husk is currently priced at US$50/ton. Sometimes, the price will go up to $100/ton. It can totally create about $20 to 30 million yearly in Taiwan. In addition to the direct economic contribution, ecological and environmental benefits are even more obvious. The rice husk furnace can be used to produce the biomass carbon or bio-charcoal, which is a very good soil activator. It can significantly improve the soil physical properties.

Biomass carbon has more uses, such as for a good environment deodorant. The other social benefit is to convert the rice husk efficiently to become resource, and will further reduce the burden on the society to deal with rice husk waste. The successful adoption of rice husk furnace in rice center actually achieves the effect of energy saving and carbon reduction. In the successful use and promotion of rice husk furnace in Taiwan, it has great meaning of education about biomass energy utilization and development. It is currently the best example of biomass energy application in Taiwan.

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