Study of Heat Pump with Multi-Heat Source and Solar Energy for Lumber Drying

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Abstract The combination heat supply System of heat pump with multi –heat source and solar energy, chief technical parameters of equipments, heat engineering properties of heat pump with multi-heat source, and experiment results of drying lumber with heat pump or heat pump –solar energy were presented.

The experiment results show that the properties of heat pump with multi-heat source are better than that with one source, the heat supply effect of heat pump for energy saving is better than that of vapor when the temperature is higher than a certain level, and the combination heat supply effect of energy saving with heat pump –solar energy is higher than heat pump.

1. Introduction

Wood drying is the largest energy consumption operation in furniture manufactory, taking about 70 percent of the total energy consumption. By means of reducing energy consumption, not only production cost can be cut down, but also environment pollution caused by soot and exhausted gas can be reduced. Hence, in recent decades, countries all over the world have attached much importance to energy saving drying techniques, such as heat-pump drying and solar energy drying. And research in this field has been carried out for almost twenty years in China.

Solar energy is a clean and regenerated energy source, and China is affluent in solar energy, that is, radiant intensity in more than two to thirds area of China is higher than 6×10^6KJ / m^2(Bao Y.1993). However, solar energy has to be combined with other energy sources in wood drying for the limit of climate condition and storage problem. Two kinds of combination wood drying equipment of heat pump and solar energy have been developed by Beijing Forestry University in 1990 and 1995. Working principle of combination drying system, characteristics and performances of heat pump with multi-heat source and examples of drying wood with this system will be presented in this paper.

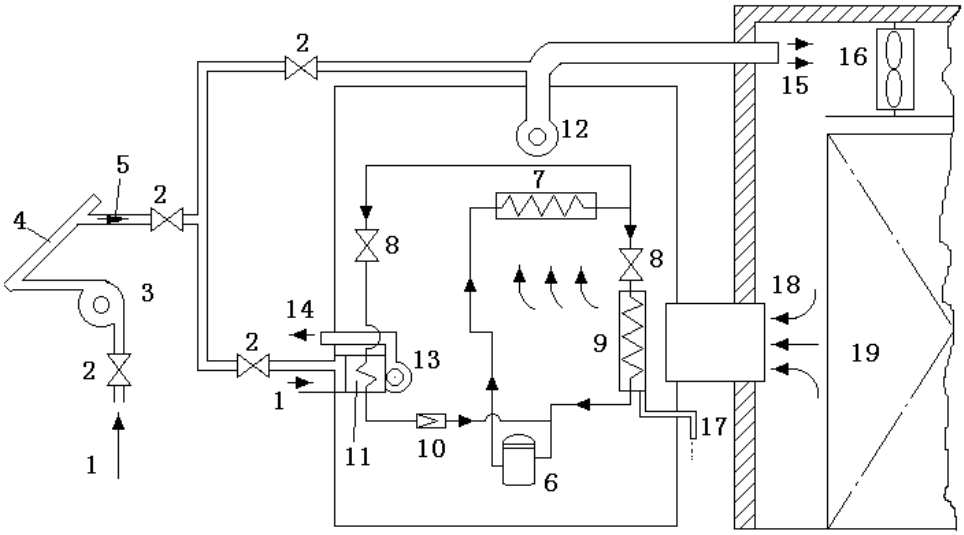
2.Combination drying system of heat pump with multi-heat source and solar energy

2.1 Heat pump dryer with single heat source

Working principle of heat pump dryer (dehumidifier) with single heat source is shown in Figure 1, which has one dehumidify evaporator, one heat source (moisture air in kiln) and one refrigeration cycle. When relative humidity of air in kiln is higher than set value, moisture air will be dehumidified by dehumidify evaporator and its temperature will become lower and will be heated up by the heater before send back into the kiln, and this is one work cycle. This heat pump with single heat source increases temperature of kiln by electrical heater when needs to do so according to the drying schedule, and so electricity consumption is higher.

2.2 Combination heat supply system of heat pump with multi-heat source and solar energy

Dehumidification work cycle of heat pump with multi-heat source is the same as that of heat pump with single heat source. Work principle of combination heat supply system of heat pump with multi-heat source and solar energy is shown in figure 2. Heat supply and dehumidify of kiln can be carry out either by both heat pump and solar energy heat supply system or by only one of them. When solar radiant intensity is high in the fine day and solar supply temperature is higher than temperature in kiln, solar energy system supply heat solely. In night or cloudy day, heat is supplied entirely by heat pump and in this condition heat pump evaporator absorbs heat from environmental air and then sends hot air into kiln via refrigeration system. When the solar supply temperature is 10 ℃ higher than that of environment, but lower than that of kiln, combination heat supply by solar energy system and heat pump should be carried out. But in this condition, hot air of solar energy collectors is sent directly to heat pump evaporator instead of directly into kiln. Thus heat source temperature of heat pump is increased remarkably for the solar supply



1. environmental air 2. damper 3. fan of solar energy 4. solar energy collector 5. hot air from collector 6. compressor 7. condenser 8. throttle valve 9. dehumidifying evaporator 10. check valve 11. evaporator of heat pump 12. main fan 13. fan of heat pump 14. cold air exhausted from heat pump 15. hot air 16. fan in kiln 17. condensed water 18. moisture air in kiln 19. stack

Figure 2. Combination heat supply system of heat pump with multi-heat source

temperature is higher than that of environment, and hence the heat supply efficiency of heat pump is improved. Thus it can be seen that this kind of heat pump has three heat sources that is, environmental air, hot air from solar collector and moisture air in kiln, two evaporators (evaporator of heat pump and that of dehumidifier), two refrigerators (dehumidify system and heat pump system), one condenser and one compressor is used commonly.

3. Chief technical parameters of experimental equipments

3.1 Chief parameter of heat pump

Type of heat pump dryer used in experiment is REG15. Its main technical parameters are :

Power of compressor 3.75KW refrigeration medium R22

Power of main fan 2×0.4KW capacity 6000m^3/h

Power of fan of heat pump 0.4KW capacity 3000 m^3/h

Exchange area of evaporator of dehumidifier and that of heat pump 40m^2

3.2 parameters of solar energy heat supply system

Type: PK1570 panel air heat collector, consists of three collector arrays and its total sunshine area is 75m^2. Total power of fan of these three collector arrays is 1.5Kw. When hot air of collector is used as heat source of heat pump, only one of these three collector arrays is turned on.

Between April and November, it is usually fine day or fine of part cloudy day, and average heat supply of solar collector varies from 7 KW to 29 KW.

4. Experiment of performance of heat pump with multi-heat source

Heat engineering performance of heat pump for multi-heat source shows in table 1. In table 1:Ts-temperature of heat source, Sou-heat source in which 1-environmental air as heat source,2-hot air from heat collector as heat source 3-moisture air from kiln as heat source, Tv, Tc-evaporate and condense temperature of refrigeration respectively, P-total power consumption of compressor and fans,Q_1-quantity of heat supplied to kiln by heat pump,COP^0, COP-theory and practice heat supply coefficient of heat pump(H.L.Von Cuhe et.al. 1981).

$$COP^0 = \frac{(t_v + 273)}{(t_c + 273) - (t_v + 273)}$$

$$COP = Q_1 \big/ P$$

Performance of heat pump is evaluated by the heat supply coefficient COP. The higher the COP is, the better the performance is. According to related information (Zhang B.1999), average heat efficiency of industry boilers (include pipe net) in China is 0.6, efficiency of electricity generation and electricity supply net is 0.33. Thus if COP of heat pump is higher than 1 then electricity can be saved, if COP higher than 2 then superior to supply heat by boiler steam,

higher than 3 then primary energy resource can be saved.

Table 1. Heat engineering performance of heat pump with multi-heat source

No.	T_S ^0C	Sou	T_V ^0C	TC ^0C	P KW•h / h	Q_1 KW	COP^0	COP
1	15	1	1	44	5.6	17.5	7.37	3.12
2	15	1	1	46	5.7	17.9	7.07	2.96
3	15	1	1	47	5.7	16.1	6.69	2.82
4	19	1	3	50	5.8	16.4	6.87	2.83
5	30	2	4	51	6.0	17.8	6.89	2.97
6	35	2	6	52	6.1	18.7	7.07	3.16
7	37	2	8	54	6.2	19.2	7.11	3.10
8	39	2	12	58	6.4	20.3	7.2	3.17
9	35	3	6	53	5.9	18.2	6.93	3.08
10	35.7	3	7	52	5.8	19.3	7.22	3.33
11	36	3	8	53	5.8	19.8	7.24	3.41
12	37	3	12	57	6.0	21.4	7.33	3.57

They can be known in Table 1:

(1) Every COP of heat pump is higher than 1, and thus it is superior to supply heat by electrical heater of single heat pump. When temperature of heat source is more than 15 ℃ and COP higher than 2.9, it can save 40 percent energy compared with supply heat by steam (Zhao Z. et.al. 1995).

(2) Evaporate temperature increases with then increasing of temperature of heat source, and accordingly COP increases if condense temperature does not change much.

(3) The higher the theory heat supply coefficient is, the higher the practice heat supply coefficient is.

(4) When hot air from solar collectors as heat source, its average heat supply coefficient is 5 percent higher than gather heat from environment because the remarkably increase of temperature of heat source.

(5) When moisture air from kiln as heat source, its COP is the highest because the high humidity of air.

5. Experiment of wood drying

Experiments were practiced in Beijing and contrast experiment data of multi-heat source pump and combination of heat pump and solar energy is shown in Table 2.

In Table 2: V-volume of lumber, W_1, W_2-initial and final moisture content of lumber, D-drying time, P-energy consumption of drying, R-energy saving percent of drying with combination drying of heat pump and solar energy compared with drying with heat pump solely.

It can be known from data in the table:

Under the condition of same drying season (month), wood specie, lumber thickness, initial and final moisture of lumber, 16 to 25 percentage energy can be saved by using combination heat supply of heat pump and solar energy than by heat pump solely. Energy saving percent mainly relates to the condition of climate, for example, at June in Beijing, temperature is high and sunshine is good, and thus energy saving percentage is high, while energy saving percentage is

not so high at July for rain, although temperature is high, at April, although sunshine is good, energy saving percentage is low for the low temperature.

Table2. Experiment of heat pump drying and combination of heat pump and solar energy drying

drying method	Date (Month)	Specie	V (m3)	H (cm)	W_1 (%)	W_2 (%)	D (Day)	P (KWH/m^3)	R (%)
heat pump	4	*P.Strobus*	15	5.0	40	15	7	64	
	5	*U.Pumila L.*	15	4.5	40	10	13	117	
	6	*F.Mandshurica Rupr*	17	4.0	52	8	15	159	
	7	*Picea asperata Mast.*	16	3.0	66	13	7	85	
	9	*Picea asperata Mast.*	15	5.0	36	11	12	57	
Heat pump — solar energy	4	*P.Strobus*	15	5.0	40	15	7	55	16.7
	5	*U.Pumila L.*	15	4.5	40	10	13	96	21.9
	6	*F.Mandshurica Rupr*	17	4.0	52	8	15	127	25.2
	7	*Picea asperata Mast.*	16	3.0	66	13	7	72	18.1
	9	*Picea asperata Mast.*	15	5.0	36	11	12	46.5	22.6

6.Conclusion

6.1 Energy saving effect of heat pump with multi-heat source is superior to that of heat pump with single heat source.

6.2 Energy saving effect is remarkable if heat is supplied by heat pump instead of by steam. When temperature of heat source is higher than 15 ℃, more than 40 percent energy can be saved, and energy saving percentage increases with the increasing of humidity and temperature of heat source.

6.3 Between April and September in Beijing, energy saving percentage of combination drying of heat pump and solar energy is more than 16 percent compared with heat pump and energy saving percent is related to temperature and radiant intensity.

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