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Simulation and Experimental Study of Hydraulic Wind Heating System

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Abstract: In the overall system of wind powered heating, the design of hydraulic wind powered heating system is widely used due to its excellent performance. Due to the stability and timeliness of the hydraulic system itself, as well as its ability to effectively improve the reliability and intelligence of the overall wind powered heating system, this design not only achieves smoother and more reliable braking of the high-speed shaft, but also maximizes the utilization of the excellent characteristics of the hydraulic system, thereby effectively improving the energy conversion efficiency of the wind powered heating system. This article establishes an experimental platform for a hydraulic wind energy heating system through project implementation, and simulates and measures the energy conversion efficiency of the system under different wind conditions; Simultaneously using different system cycle working fluids as heat transfer media to conduct comparative system experiments and determine the heat transfer effects of different working fluids. Finally, operate within a limited time and space to increase the temperature of the heat transfer working fluid, in order to study the energy conversion efficiency when using hydraulic wind energy for heating. Through systematic simulation and experimentation, the hydraulic wind powered heating system has been studied, effectively improving the energy conversion efficiency of the wind powered heating system and enhancing its economic value and strategic objectives.

Keywords: Hydraulic wind power heating; Different wind conditions; Different heating materials; System efficiency.

1. Introduction

In response to global climate change, the Paris Agreement was signed by 178 contracting parties in 2016. Since its entry into force, renewable energy has accounted for approximately 60% of the world's new electricity generation[1]. Major economies around the world are actively promoting low-carbon development, with over 130 countries and regions including China, the European Union, the United States, and Japan setting carbon neutrality targets. Therefore, the development of clean and low-carbon energy is facing new opportunities and challenges. Against the backdrop of China becoming the world's largest energy producer, consumer, and carbon emitter for several consecutive years, China is actively promoting the goal of peaking carbon emissions before 2030 and achieving carbon neutrality before 2060[2]. Therefore, more efficient and reliable comprehensive utilization technologies for renewable energy sources such as wind, solar, hydro, biomass, and geothermal energy urgently need to be actively explored.

The efficient utilization of wind and solar energy resources has always been a key focus in China's new energy system construction plan. At present, the main way of utilizing wind energy is to convert it into electrical energy, thermal energy, mechanical energy, etc. through wind turbines. Compared with other forms of wind energy utilization, wind energy heating has higher energy conversion efficiency and has good development prospects[3]. However, research on direct heating technology using wind energy in China is still in its infancy, and there are relatively few demonstration applications related to it. Therefore, promoting the application of wind energy heat pump direct heating technology is of great significance for improving China's energy structure, increasing energy utilization efficiency, and reducing greenhouse gas emissions.

2. Simulation System for Hydraulic Wind Heating

Hydraulic heating, also known as hydraulic damping hole heating, mainly utilizes the combination of hydraulic pumps and damping holes to obtain energy[4].

The power of the wind turbine is transmitted to the hydraulic pump by the transmission mechanism, and the working medium (such as oil, etc.) is pressurized, and then the mechanical energy is converted into pressure energy of the working medium. Subsequently, the working medium with increased pressure is ejected at high speed from the narrow damping hole. The pressure energy of the working medium can be instantly converted into the kinetic energy of the working medium. Due to the fact that the wake pipe of the damping hole is also filled with working medium, the high-speed sprayed working medium will collide with the low-speed working medium in the wake pipe, and the high-speed working medium will mix with the low-speed working medium before returning to the normal flow velocity inside the pipe. Throughout the entire transmission process, the kinetic energy of the working medium is converted into thermal energy through the impact and friction between liquids, causing the temperature of the working medium to rise. Finally, the heat of the working medium is transferred to the user through a heat exchange device.

The hydraulic wind energy heating system is shown in Figure 1. The hydraulic wind energy heating test simulation system mainly consists of a frequency converter, an electric energy meter, a motor (instead of a wind turbine), a gear pump, an oil tank, a filter, an oil temperature gauge, a heater, a water tank, a radiator, a water temperature gauge, and pipelines. The motor is the power source, and its operation drives the hydraulic gear pump to work. The heating medium enters the heater through the pipeline under the operation of the hydraulic gear pump. Due to the high-speed jet motion of the heating medium, friction and heat generation will occur between the working medium and between the working medium and the heating chamber wall, thereby achieving the goal of increasing the temperature of the heating medium. The high-temperature heater transfers some of the heat to the water in the water tank, while the cooled heating medium enters the oil storage tank through pipelines for the next round of circulation, thus replacing the wind turbine with a motor simulation to achieve heating and warming effects.

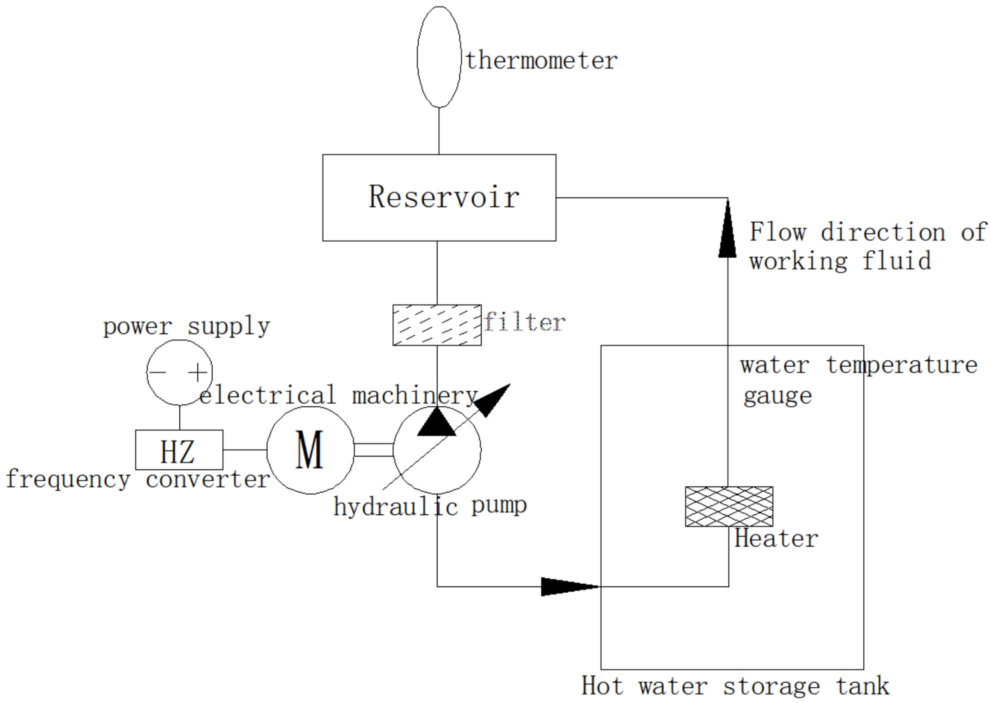

Figure 1. Process diagram of hydraulic wind energy heating system

Table 1. Performance Parameters of Hydraulic Wind Energy Heating Device Parts

Name	Frequency converter	Electrical machinery	Hydraulic pump	Fuel tank	Thermometer	Hot water storage tank	Filter
Model	SPOL-1	YLNP121-2	HPG220Y		WPSS-11	/	RRT390
Parameter	0.75Kw	0.55Kw+2900s	25mL/r, 20Mpa	20L	0-120℃	50L	0-20KPA

As shown in Table 1, in the experiment, high-temperature heat transfer oils of L-HL and L-HV types were used as the thermal fluids. L-HL and L-HV high-temperature heat transfer oils are made from Dongfeng Weishiton brand solvent refined base oil (white oil) as raw material, with the addition of selected antioxidants, preservatives, anti foaming agents and other functional agents. They have stable quality and excellent performance, and have the advantages of non-toxic, pollution-free, high flash point, good fluidity, good thermal stability, fast heating, stable and safe operation, and long service life.

This experiment mainly measured the heating effect of the entire system by using different system cycle working fluids as heating media under different wind input conditions. By summarizing and analyzing the experimental data, the general rules of the system's heating efficiency are identified. Then, through the analysis and research of these rules, the optimal heating efficiency utilization point is found, which is the point where the fan can operate under the most stable conditions and produce the highest heating effect. Due to the fact that the output speed of the fan varies with the wind speed in actual operating conditions[4], variable operating conditions should be adopted in the experiment to simulate the real operating conditions.

3. Heating Efficiency of The System Under Different Wind Conditions

Due to the low output speed of wind turbines during actual operation, it is necessary to match a variable speed mechanism at the output end of the wind turbine to increase the output speed, so that the thermal working fluid can generate more heat under high-speed operating conditions[5-6]. Based on the technical parameters of the variable frequency motor, the operating conditions of the simulated fan will be obtained, and experimental research will be conducted according to the corresponding operating conditions.

According to the operating conditions of the motor, take the L-HL hydraulic oil volume L=20 liters and water volume L=50 liters from Dongfeng Weishiton brand. The motor runs for two hours at different speeds, and the constant temperature of the hydraulic oil and water are measured separately. Then, the absorption efficiency of water and the total absorption efficiency of water are calculated based on the relationship between the energy possessed by hydraulic oil after transferring a portion of the energy to water and the total energy consumption, as shown in Table 2.

Table 2. Heating efficiency at different speeds

Rotational speed r/min	Initial temperature of thermal fluid ℃	Final temperature of thermal fluid ℃	Hydraulic oil temperature difference ℃	Initial temperature of water tank ℃	Final temperature of water tank ℃	Water temperature difference ℃	Power consumption kW.h	Water absorbs heat energy KJ	Heating efficiency %
1000	18.5	23.3	4.8	18.8	22.7	3.9	1.2	819	18.9
1100	18.2	23.4	5.2	18.6	22.8	4.2	1.32	882	18.5
1200	18.6	23.9	5.3	19.0	23.4	4.4	1.46	924	17.6
1300	18.0	23.5	5.5	18.6	23.2	4.6	1.59	966	16.9
1400	18.3	24.2	5.9	18.0	23.1	5.1	1.72	1071	17.3
1500	18.0	24.6	6.6	18.5	24.4	5.9	1.87	1239	18.4
1600	18.4	26.2	7.8	18.8	25.8	7.0	2.13	1470	19.2
1700	18.9	28.2	9.3	18.9	27.3	8.4	2.26	1764	21.7
1800	20.0	30.8	10.8	20.2	30.2	10.0	2.41	2100	24.2
1900	20.3	32.4	12.1	20.5	32.0	11.5	2.57	2415	26.1
2000	20.1	33.7	13.6	20.6	33.6	13.0	2.72	2730	27.9
2100	21.4	36.3	14.9	21.4	35.7	14.3	2.86	3003	29.2
2200	18.2	34.8	16.6	18.5	34.6	16.1	3.01	3381	31.2
2300	18.6	37.4	18.8	18.6	36.9	18.3	3.18	3843	33.6
2400	18.5	38.9	20.4	18.8	38.8	20.0	3.36	4200	34.7
2500	18.4	41.3	22.9	18.9	41.5	22.6	3.50	4746	37.7

Based on the data analysis in Table 2, it can be seen that the overall heating efficiency shows a trend of first decreasing and then increasing with the increase of rotational speed. When the speed is 2500r/min, the total absorption efficiency and water absorption efficiency both reach their maximum values of 37.7%; When the speed is within the range of 1000r/min to 1300r/min, the heating efficiency will show a decreasing trend; When the speed is increased to above 1400r/min, the heating efficiency will show a trend of improvement again; And when the speed is above 1700r/min, this growth trend will become even faster. This is because, on the one hand, in the early stage of operation, the viscosity of the working medium is the highest. High viscosity hydraulic oil, under high-speed impact, will generate more heat due to the violent movement inside the hydraulic oil and the friction between the hydraulic oil and the heater, pipeline inner wall, etc.[7-8]; On the other hand, during the initial operation, the system has relatively little heat exchange with the outside world, which can theoretically be considered adiabatic. So during the initial operation, more heat will be generated, resulting in higher absorption efficiency. However, as the rotational speed continues to increase, the viscosity of the oil will gradually decrease, and there will be more and more heat exchange between the system and the outside world, so the growth trend will become slower.

4. Heating Efficiency of The System Under Different Heating and Thermal Conditions

The impact of different heating materials on heating efficiency is the most critical factor in the entire heating system, which mainly depends on the physical and chemical properties of the heating materials[9]. In this experiment, three different types of thermal fluids were selected, namely water and L-HL and L-HV high-temperature thermal oils from Dongfeng Weishiton brand. To investigate the impact of different heating materials on heating efficiency, the physical properties of different heating materials are shown in Table 3.

Table 3. Different Thermal Processes

Name	Model	Density g/cm^3	Viscosity (Mm^2/s@40℃	Viscosity (Mm^2/s@100℃	Temperature
Hydraulic oil	L-HL	0.865	19.22	5.3	-25℃-200℃
Hydraulic oil	L-HV	0.885	29.32	6.5	-30℃-300℃
Water		1	2.98	1.005	0℃-100℃

The experiment involves taking a hydraulic oil volume of L=20 liters and a water volume of L=50 liters, setting the motor speed to n=2500r/min, and operating the system normally for two hours under these conditions. Calculate the heating efficiency based on the measured final temperature data of hydraulic oil and water as shown in Table 4.

Table 4. Heating experimental data of different heating materials

Thermal quality control	Initial temperature of hydraulic oil ℃	Final temperature of hydraulic oil ℃	Initial temperature of hot water storage tank ℃	Final temperature of the hot water storage tank ℃	Water temperature difference ℃	Power consumption kW.h	Water absorbs heat energy KJ	Heating efficiency %
L-HL Hydraulic oil	18.6	41.5	18.8	41.6	22.8	3.50	4788	36.6
L-HV Hydraulic oil	18.4	42.6	18.6	42.0	23.4	3.55	4914	38.7
Water	18.0	23.6	18.3	19.7	1.4	3.38	294	3.6

Based on the experimental data in Table 4, it can be seen that under the same heating time and motor speed conditions, the heating efficiency of hydraulic oil as the heating medium can reach over 35%, while the heating efficiency of water as the heating medium is only about 3.6%. It can be seen that the heating efficiency of hydraulic oil as the heating medium is significantly higher than that of water as the heating medium. Compared to hydraulic oil, water has a higher density but lower heating efficiency. When hydraulic oil is selected as the heating medium, the density of L-HL hydraulic oil is higher than that of L-HV hydraulic oil, but the heating efficiency is slightly lower. This indicates that the heating efficiency is not significantly affected by the density of the heating medium. In addition, when hydraulic oil is selected as the heating medium, the viscosity of L-HL hydraulic oil is slightly lower than that of L-HV hydraulic oil, while the heating efficiency is higher. This indicates that the heating efficiency is directly proportional to the viscosity of the heating medium, that is, the higher the viscosity of hydraulic oil, the higher the corresponding heating efficiency. This is because the heating medium flows at high speed, and when passing through the oil holes of the heater, it is subjected to the resistance of the oil holes, which reduces the flow velocity of the heating medium, resulting in a decrease in the kinetic energy of the heating medium and an increase in internal heat energy, thus achieving the corresponding heating effect. When the viscosity of the heating medium is higher, the friction and collision between the heating medium and the heater are correspondingly more frequent, and the heating medium converts kinetic energy into more thermal energy through friction, collision, etc. during the flow process. Therefore, the heating efficiency will increase as the viscosity of the heating medium increases.

5. Conclusions

This article uses hydraulic wind energy heating system for heating, which has many advantages on its own, but the heating efficiency is also affected by many external factors. Through this experimental study, the following conclusions can be drawn:

a) Compared to other systems, hydraulic wind energy heating has excellent stability, which can ensure the stable operation of the overall wind power generation system, and its driving efficiency is superior to other driving systems.

b) Due to the directness and rapid response capability of hydraulic transmission systems, equipment installed with hydraulic braking systems is more automated, greatly reducing manual use and operation.

c) Hydraulic systems have the ability to be widely produced and standardized in the long-term development process, and will be more convenient in future manufacturing and use processes. Under current conditions, research and optimization of wind power heating systems are constantly underway, and many more advanced application technologies have also been well developed. At present, the mainstream research and development direction is to combine hydraulic and mechanical systems more scientifically, in order to achieve more efficient full process monitoring, operation, and maintenance of wind heating systems. This method can achieve the effect of improving the safety, stability, and effectiveness of wind energy heating systems.

d) The heating efficiency of hydraulic wind energy heating system is influenced by many factors, mainly including wind conditions and heating quality. Through this experimental study, it is found that the wind speed needs to be within a certain range to ensure the operation of the system. In the early stage of operation, the viscosity of the hydraulic oil is the highest. Under high-speed impact, the intense movement inside the hydraulic oil and the friction between the hydraulic oil and the heater, pipeline inner wall, etc. will generate a lot of heat. If the speed continues to increase, the viscosity of the oil gradually decreases, and the system exchanges more heat with the outside world, the growth trend of heating efficiency will become slower. In addition, the selection of heating medium requires more consideration of its viscosity. The higher the viscosity of the heating medium, the higher the corresponding heating efficiency. Compared to the density of the heating medium, the viscosity of the heating medium has a greater impact on heating efficiency.

6. Supported Project Name

"Experimental Study on Hydraulic Wind Heating in Xizang" (XZ202201ZR0062G)

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