A PART LOAD OPERATION FOR SMALL SCALE DIRECT FIRED ABSORPTION CHILLER

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ABSTRACT

Part load is a usual operation condition. It is somehow difficult in adjusting load when a small scale direct fired absorption chiller has only one burner. A part load operation by turning on and off the burner intermittently is an effective method for a small scale direct fired absorption chiller. The dynamic performance of the system and some components has been investigated. The coupling relationship between pressure, temperature and concentration of the lithium bromide solution have been analyzed. The result obtained indicates that the pressure of the high pressure generator and the temperature of the exhaust are the most sensitive parameters. It is also found that the transition time from a full load to a part load condition is quite long, and the relative cooling capacity of part load is almost near to the intermittent running time ratio and oil consumption ratio.

KEYWORDS

direct fired, absorption chiller, part load, dynamic performance

1. 0 INTRODUCTION

Oil or gas powered direct fired absorption chiller has the advantage of not using ozone-depleting refrigerants. The Chinese government is encouraging natural gas exploitation and utilization. So the direct fired absorption chiller has more wide application prospect. The absorption chiller is not always under full load operation condition in practice, especially for air conditioning system. As the load demand usually varies according to the user and the weather, the running condition of the chiller should be adjusted to guarantee the constant of the outlet temperature of the chilled water. Therefore, the chiller is usually running under the part load condition.

The part load condition usually runs by controlling the heat supplied. Ogasawara[1] studied a steam driven unit. By adjusting the steam flow rate, he made the input heat quantity decrease with indicial response. S. Jeong[2] adjusted the hot water flow rate of a solar powered unit. Jun Sano[3] adjusted the gas flow rate of a gas fired unit, which changed in a sine wave. In all these cases, the system cooling capacity and COP are studied but the dynamic performance of component and coupling relationship between the parameters are not analyzed in detail.

The heating equipment of the direct fired absorption chiller is the burner. When the load changes, the fuel consumption should be adjusted. A medium or large scale absorption chiller usually adopts the burner with two oil injectors or proportionally adjustable. The fuel consumption of the burner can be controlled so that the load of the chiller can be adjusted from 25% to 100%. A small scale chiller has only one burner, which can not adjust the fuel consumption. In order to change the load, intermittently turning on and off the burner is a useful method.

With experiments, the part load performance of a small scale direct fired absorption chiller through adjusting the fuel consumption by intermittently turning on and off the burner has been investigated.

2.0 EXPERIMENTAL INSTALLATION AND PROCEDURE

Figure 1 shows a schematic diagram of the experiment installation and the measuring points of the temperature, the mass flow rates and the pressure. It is a direct fired lithium bromide absorption chiller of double effect refrigeration cycle with reverse series solution circuit. It consists of absorber, evaporator, condenser, throttling device, high pressure generator (HPG), low pressure generator (LPG), high temperature exchanger (HTX), low temperature exchanger (LTX), mixer, solution pumps and the pipes, which connects the components. The temperature (T) is measured with platinum resistance or thermocouples. The pressure (P) in the absorber and evaporator assembly, low pressure generator and condenser assembly and high pressure generator are measured with the capacitance pressure detectors. These signals of these parameters are all connected to a FLUKE data acquisition system. Flow rates (m) are measured by rotor flow meters.

The nominal cooling capacity of the chiller is 30 kW. In the experiment procedure, at first the chiller works in stable state, then the time is counted. After 3 minutes, disturbing signal is input. The period of disturbing signal is 20 minutes, in which the burner turns off for 5 minutes and turns on for 15 minutes. It is shown in figure 2. When the burner works, the fuel consumption is a constant. The purpose of this control method is to adjust the heat supply from 100% to 75%.

The experiment conditions is follows:

Flow rate of solution	0.24 m3/h
Flow rate of cooling water	9000 kg/h
Flow rate of chilled water	4100 kg/h
Flow rate of spraying refrigerant	0.60 m3/h
Oil consumption	2.51 kg/h

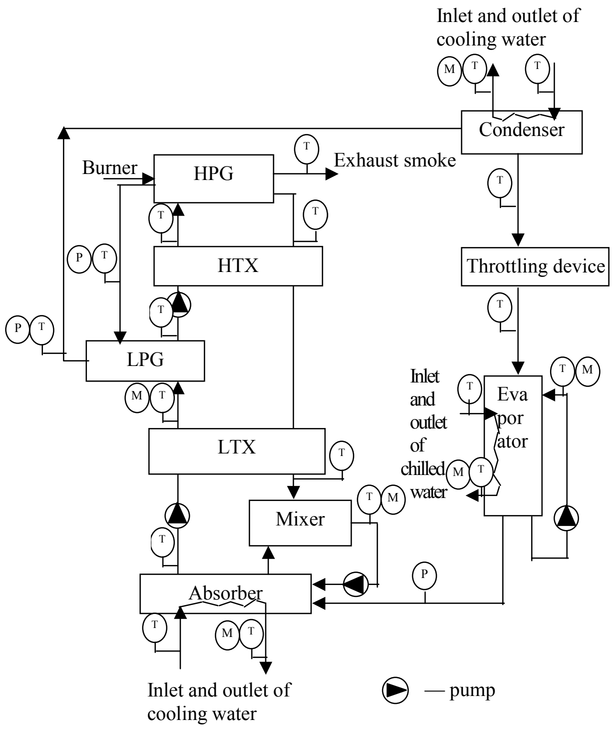

Fig.1 Schematic diagram of the small scale direct fired absorption installation

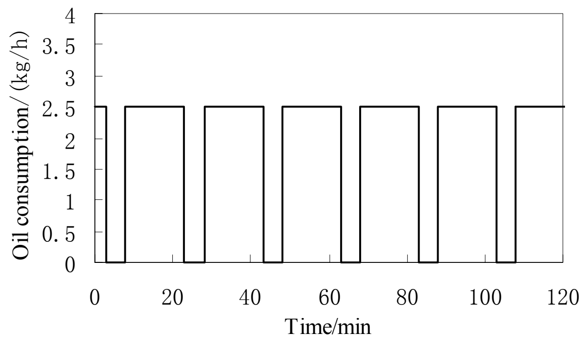

Fig. 2 Input disturbing signal of system

3.0 EXPERIMENTAL RESULTS AND ANALYSIS

3.1 High pressure generator

Figure 3 shows the variation of the pressure in the HPG and figure 4 shows the inlet and the outlet solution temperature of the HPG. In stable state, the pressure is $612*10^2$ Pa, the outlet temperature is 148°C. In the transition process, the pressure and the outlet solution temperature periodically changes with the burner on and off. The first disturbing signal is input after 3 minutes, the burner turns off, then the pressure decreases promptly with no time delay. The lowest value is $395*10^2$ Pa. Then another signal is input, the burner turns on and the pressure increases with no time delay either. But the increasing rate is smaller than the decreasing rate. When the first running period finishes, the highest pressure is 568 $*10^2$ Pa, smaller than the original stable value. This is the description about the first period. The variety of the later period is similar to the first one.

Owing to the original solution having high concentration, the HPG generates the vapor with high temperature and pressure. If the burner turns off, i.e. no heat is supplied, the trend of generating vapor attenuates in HPG immediately. The quantity of the vapor in the HPG reduces rapidly and the pressure decreases correspondingly, so do the difference of temperature and concentration between the inlet and the outlet solution. Therefore the outlet temperature and concentration is smaller than the original stable value. At this time, vapor pressure is balanced to the temperature and the concentration of the solution. When the burner turns on again, heat is supplied, the state is unbalanced at once and vapor generates promptly. As the temperature and concentration of the solution is lower than the value of the original stable state, the temperature and pressure of the vapor is lower than the original stable value. Along with the vapor accumulating in the HPG, the longer the burner works, the higher the temperature and the concentration are.

The temperature and concentration of the solution before 3 former periods gradually declines. Figure 1 shows that the peak and the valley value of the second period are lower than the value of the first period, and the value of the third are lower than the second. Since the third period, the peak and the valley value tend to stable. It means that in former 3 periods, the temperature and the concentration of the solution in one period are lower than in former period, so the pressure declines. Since the third period, the temperature and the concentration oscillate at the same range, the pressure varies between 346 $*10^2$ and 493 $*10^2$ Pa.

Figure 4 shows the outlet solution temperature varies with a same manner, whereas with some time delay. The delay time is 1 minute. The reason of delay is the heat capacity of large solution quantity and the shell tube. The irregular variation of the inlet temperature may be induced by the fluctuation of the solution level in HPG. The flow rate of solution depends upon the pressure difference between the HPG and the absorber. In the intermittent running process, the pressure fluctuation make the flow rate varies all the time. Hence, the valve in pipeline must be controlled frequently to adjust the flow rate.

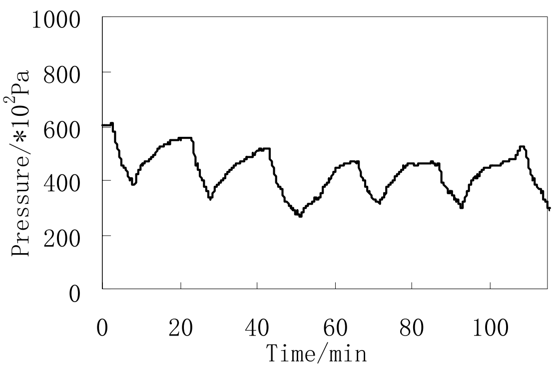

Fig.3 Pressure in the HPG

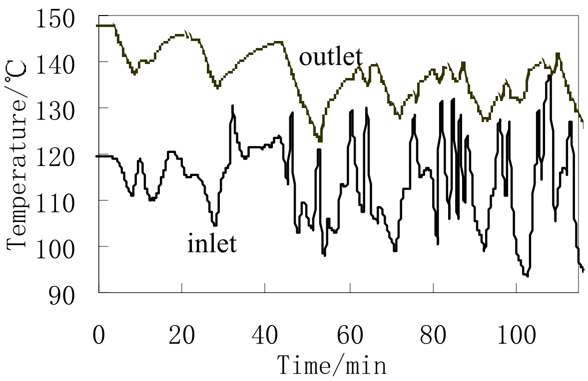

Fig.4 Temperature of inlet and outlet solution of the HPG

Figure 5 shows the variation of the temperature of the exhausted smoke. In stable state, the temperature is about 150°C. In the transitional process, the periodical change of the temperature is most obvious. Figure 5 shows that this system is an inertial link for the exhausted smoke. The period is the same as the pressure and without time delay either.

In absorption chiller the HPG is the most directly influenced component by the burner. Compared with the solution, the heat capacity of the refrigerant vapor and the smoke are excessive less. Hence, the variety of the pressure in the HPG and the variety of the exhausted smoke temperature lead to that of the temperature of the solution. The pressure in the HPG and the temperature of the exhausted smoke varies almost simultaneously. The time from one stable state to a part load state will take more than 50 minutes.

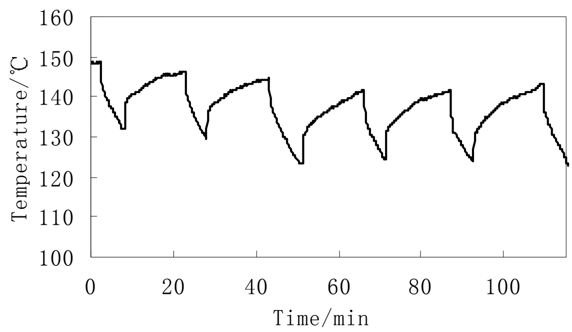

Fig.5 Temperature of exhausted smoke

3.2 Low pressure generator

Figure 6, 7 shows the variation of the pressure in the LPG and the inlet and the outlet solution temperature of the LPG respectively. In stable state, the pressure in the LPG is 65 $*10^2$ Pa, the outlet temperature is 85°C. When the first disturbing signal is input, the time delay of the pressure is 0.5 minute and the time delay of the temperature is 1.5 minutes. Compared with the parameters in the HPG, the change of the pressure in the LPG is gentle. The peak and the valley value only can be seen in the former periods. The outlet solution temperature varies with the pressure, but the inlet solution temperature varies irregularly.

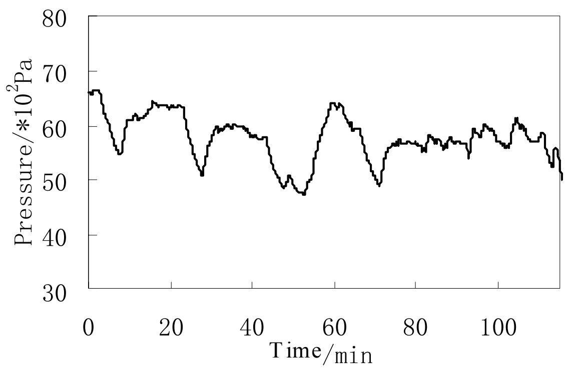

Fig.6 Pressure in the LPG

The pressure in the LPG depends upon the quantity and the temperature of the vapor generated in the LPG, i.e. the pressure in the LPG depends upon the inlet temperature and concentration of the solution. In the absorption chiller with reverse series solution circuit, the concentrated solution that flows from the HPG into the LPG must pass through the absorber, the HTX and the LTX. Therefore, the periodical change of the temperature and the concentration of the solution are delayed and attenuated by the heat storage and discharge heat from the shell tube of such components and from the long pipe line. The reason of the irregular change of the inlet solution temperature is the wave of the solution level in the LPG.

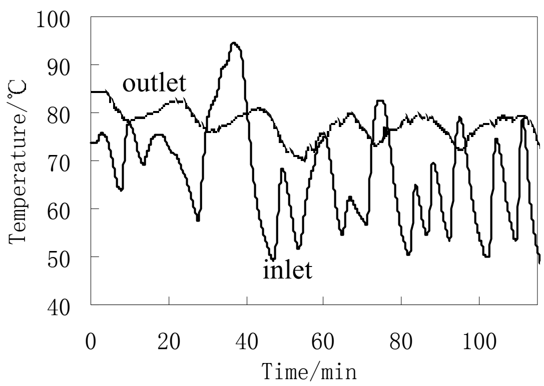

Fig.7 Temperature of inlet and outlet solution of the LPG

3.3 Absorber

Figure 8, 9 shows the variation of the inlet and the outlet solution temperature and the pressure in the absorber respectively. The inlet temperature of solution varies periodically with some irregular undulation of solution level, but the outlet temperature varies rather mildly. There is time delay in the pressure variety, which is 2 minutes. Since the vapor generated intermittently in the HPG, the concentration of the solution is strong and weak alternately, and the temperature is high and low alternately either. The irregular change of the inlet solution temperature is due to the wave of solution level in the absorber. The pressure change lags the temperature change, and the change scope is smaller than that in the HPG or in the LPG, which is within $1.3*10^2$ Pa. The inlet solution temperature gradually decreases along with the on and off operation, so does the outlet solution temperature. It shows that the average solution temperature in the absorber decreases, and the pressure of the absorber decreases simultaneously. According to the relationship of temperature, pressure and concentration of the solution, the concentration of the solution in the absorber decreases either.

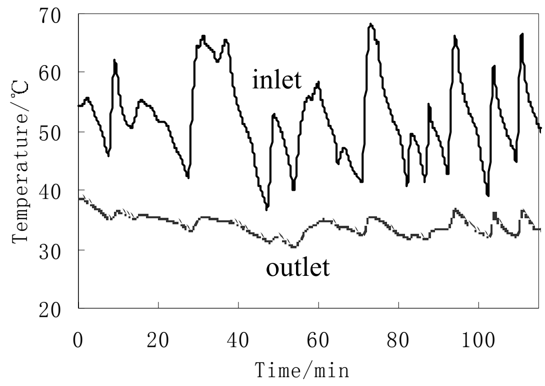

Fig.8 Temperature of inlet and outlet solution of the absorber

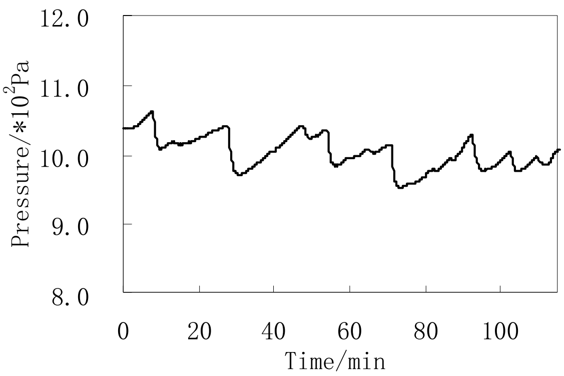

Fig.9 Pressure in the absorber

3.4 The system performance

Figure 10 shows the variation of the relative cooling capacity in the transitional process. As the average oil consumption is constant in this process, the variation of the COP of the chiller is the same as the relative cooling capacity. When the system works at full load, the relative cooling capacity is 1.0. In the transitional process, the relative cooling capacity fluctuates and decreases. In the transitional process, the average oil consumption is 1.85 kg/h, and the full load oil consumption is 2.51 kg/h, so the oil consumption ratio is 0.74. Figure 10 shows that the mean relative cooling capacity at the part load process is 0.7, which is almost near to the ratio of the oil consumption, and also near to the intermittent running time ratio. The stable time is longer than in the HPG and the LPG, and it will take almost 60 minutes. In running process, the burner runs intermittently, but the evaporator works continuously owing to exist of the refrigerant in the tank. The cooling capacity depends upon the ability of evaporating, which is influenced by the absorption capability. When the absorption chiller works intermittently, the temperature and the concentration of the solution in the absorber oscillate. When the scope of the variety of the solution concentration is unchanged, the cooling capacity will tend to stable. If the generating quantity is balance to the evaporating quantity of the refrigerant, the chiller can work continuously although the refrigerant is generated intermittently.

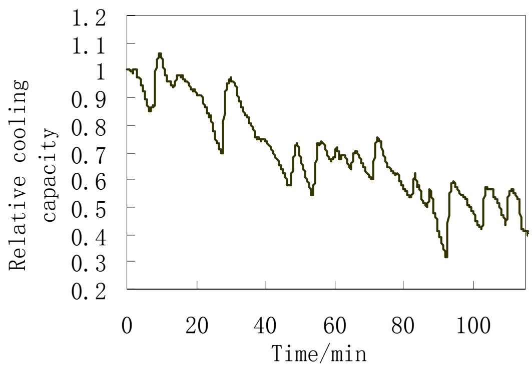

Fig.10 Relative cooling capacity

The important thing is how to control the time of turning on and off the burner. If the off time is too long, the refrigerant quantity generated will cut down continually, then the refrigerant level drops, and the suction head for refrigerant pump will not be enough finally. If the on time is too long, the refrigerant quantity generated will increase in case the cooling load decreases, then the concentration increases continually and results in the danger of crystallization of the solution.

4.0 CONCLUSIONS

(1) A part load operation can be achieved by turning on and off the burner intermittently for a small scale direct fired absorption chiller. The relative cooling capacity of a part load condition is almost near to the intermittent running time ratio and the oil consumption ratio. It takes a long time from a stable state to another part load stable state. In the above experiment conditions, the time is excess of two periods.

(2) In absorption chiller, the pressure in the HPG and the temperature of the exhausted smoke are the most sensitive parameters. These two parameters can be used as feedback signals for controlling the system efficiently and rapidly.

(3) Although the inlet solution temperature of the component usually varies irregularly, the outlet solution temperature can reflect the variety of the solution temperature with on and off operation because there is a large quantity of the solution exist in the component, and its large heat capacity act as a damper.

(4) In dynamic process, the coupling connection exist among components, and among pressure, temperature and concentration of each component. So, the whole view should be taken on studying the dynamic performance of the system.

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