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Experimental Study of Fouling Performance of Air Conditioning System with Microchannel Heat Exchanger

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Experimental Study of Fouling Performance of Air Conditioning System with Microchannel Heat Exchanger

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ABSTRACT

Microchannel heat exchanger (MCHX) has many advantages compared with traditional heat exchanger. The research and application of it also develop fast in recent years. However, in the stationary and commercial air conditioning field, it has not been widely used yet. One of the obstacles is the dust fouling. The affect of dust fouling problem on air conditioning systems with louver fin and wavy fin was researched in this article. The results show the fouling problem of the MCHX can cause drastically performance degradation of the system, the cooling capacity decreased by 23% and 17.2%, the energy consumption increased by 52.5% and 28.4%, and COP decreased by 49.5% and 35.6% for air condition systems with louver fin and wavy fin MCHX respectively after they run for 3 months in the factory environment. Based on this situation, a fan blowback control strategy was introduced into the air conditioning system. After added the control strategy, the cooling capacity decreased by 5.5% and 2%, the energy consumption increased by 7.8% and 2.3%, and COP decreased by 12.3% and 4.3% for the systems with louver fin and wavy fin MCHX respectively.

1. INTRODUCTION

Microchannel heat exchanger (MCHX) has been widely used in mobile air conditioning system because of its advantages of lower weight, more compact, higher efficiency, and smaller inner volume for refrigerant charge reduction. It also has a good prospect in the stationary and commercial air conditioning field. However, because the air face velocity in the stationary air conditioning is relative lower than mobile system, MCHX is easier to have dust choked, which results the drastically decreasing of the performance of the system. This problem is the main obstacle that MCHX is widely used in household air conditioners. Many researchers have studied about the foul problem of the MCHX. Ali and Ismail (2008) experimentally investigated evaporator air-side fouling of room air-conditioners showing that COP decreased by more than 57% due to 300g of real fouling collected from various evaporator coils. Ian and Echhard (2011) studied about the air-side pressure drop of MCHX because of particulate fouling and found that the air-side pressure drop of the MCHX can increased over 200% for a dust injection of 267g.

It's difficult to solve the problem because the compact design of the MCHX and fin -flat tube network structure, like grill, makes the fibers dust easy to block between the fins. In this paper, we put forward a novel control strategy: after a period of running time, the condenser fan reversely blows for a few minutes to blow away the fibers dust on the surface. And its performance was compared with the original system.

2. TEST SAMPLES AND EQUIPMENTS

2.1 Test sample

As shown in figure 1, two types of MCHX were tested in this experiment. One is louver fin MCHX(#1), the other is wavy fin MCHX(#2). As their different shapes and structures of fins, the fouling condition on the surface of MCHX will be different after a period of time, so will be their performance. The parameters and specifications of the two samples can be observed in table 1

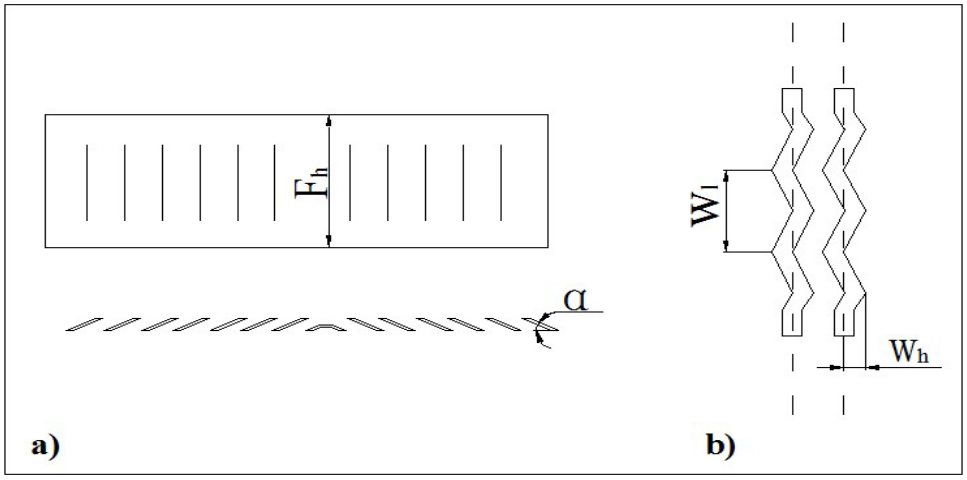


Figure 1: Simple structure diagram of louver fin (a) and wavy fin (b)

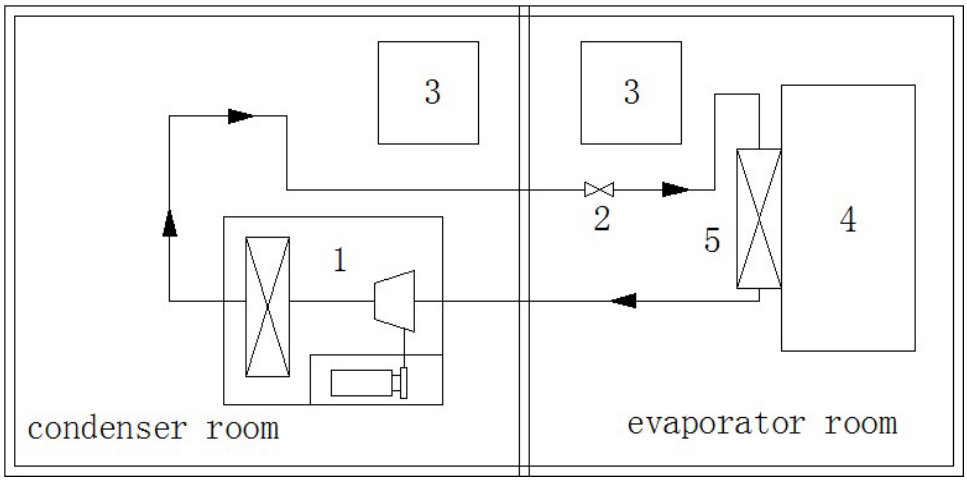
Table 1: Comparison of different parameters of samples

Heat exchanger	**#1(louver fin MCHX)**	**#2(wavy fin MCHX)**
Dimentions(mm)	575×500×16	550×500×20
Fin thichness(mm)	0.1	0.1
Fin pitch(mm)	1.4	1.4
Fin height(mm)	8	8
Size of tube(mm)	16×2	20×2
Number of tube row	1	1
Wavy length/height(mm)	-	6/2.6
Louver angel(°)	27	-

2.2 Test equipment

In the test, we replace the condenser of the traditional air conditioning system into the MCHX. To test whether the fan blowback control strategy works or not, we prepare two groups of experimental systems. Each group contains two air conditioning systems with louver fin and wavy fin respectively. The group running just as traditional air condition called group one. The other group called group two, their condenser fan will blowback 5 minutes every day according to the control strategy.

The performance of the systems was tested on the enthalpy difference method test bench. The initial performance was tested and recorded as baseline without fouling on the condenser. Then they were installed in the real room for long-term running to observe the fouling problem and its impact on the system performance. After a period of time, the systems were sent back to test again. The test condition was set according to the requirement of Chinese national standard GB/T7225 (QSIQ, 2004). As shown in figure 2, the test bench includes evaporator and condenser chamber, and each chamber owns a set of air condition unit which is responsible for controlling the room air condition. The wind tunnel in the evaporator chmber can measure air volume flow rate and outlet enthalpy, which are used to calculate the refrigeration capacity of tested air conditioning system. The test accuracy of each parameter can be observed in table 2



1 outdoor unit with condenser; 2 expansion valve;
3 environmental control; 4 wind tunnel; 5 evaporator
Figure 2: Schematic of enthalpy difference method test bench

Table 2: Test accuracy of different parameters

Measures Parameters	Testing range	Accuracy
Temperature	(a) -10~50℃	±0.1℃
	(b) -10~120℃	±0.5℃
Power	0~5000 W	±5 W
Air-pressure drop	(a)-50~500 Pa	±2.5 Pa
	(b) 0~1000 Pa	±2.5 Pa
Analyzed parameters	Uncertainty	
Heat transfer rate	±3%	
COP	±3%	

3. EXPERIMENTAL RESULTS AND ANALYSIS

3.1 The performance comparison of group 1 systems

As shown in figure 3 to 5, the long-term performance of two air conditioning systems with louver fin and wavy fin MCHX were experimentally studied in the factory environment, where fibers accounted for a large proportion of dust. We can find that one month later, the cooling capacity decreased by 3.2% and 0.7%, the energy consumption increased by 7.4% and 2.9%, and COP decreased by 10.1% and 3.4% for #1(louver fin MCHX) and #2(wavy fin MCHX) respectively. After 3 months later, the performance of the systems decrease drastically, the cooling capacity decreased by 23% and 17.2%, the energy consumption increased by 52.5% and 28.4%, and COP decreased by 49.5% and 35.6% for #1 and #2 respectively.

We can see both sytems have a decrease in performance because of fouling, and the decrease of system with #1 is quicker and more serious than #2, because the louver gap can capture the small fibers dust easier than the wavy gap. At the early stage of the experiment, the decrease of the performance of wavy fin MCHX is not apparent yet, however, after 3 months, its decreasing is still very serious because the compact design of the MCHX makes the fibers dust blocked. As shown in figure 6, we took photographs of two MCHX after they run for three months.).

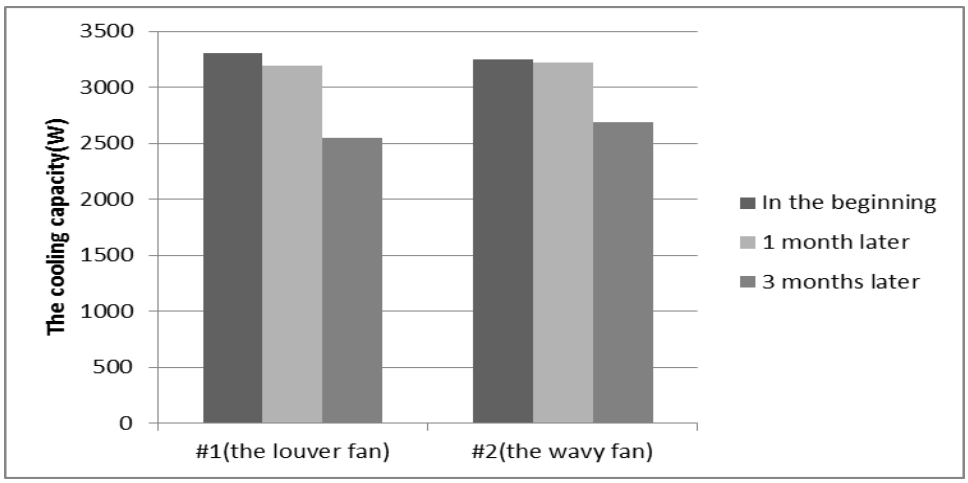


Figure 3: The comparison of the cooling capacity of group 1 on different time

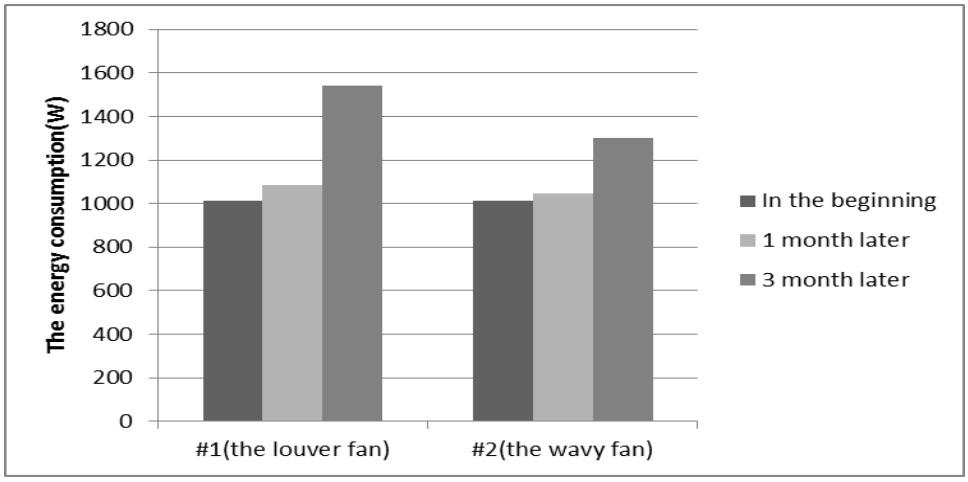


Figure 4: The comparison of the energy consumption of group 1 on different time

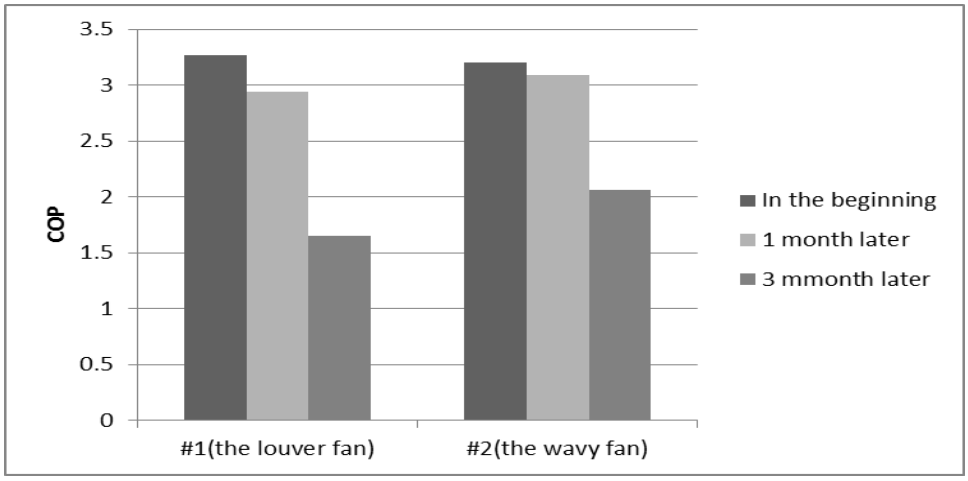


Figure 5: The comparison of COP of group 1 on different time

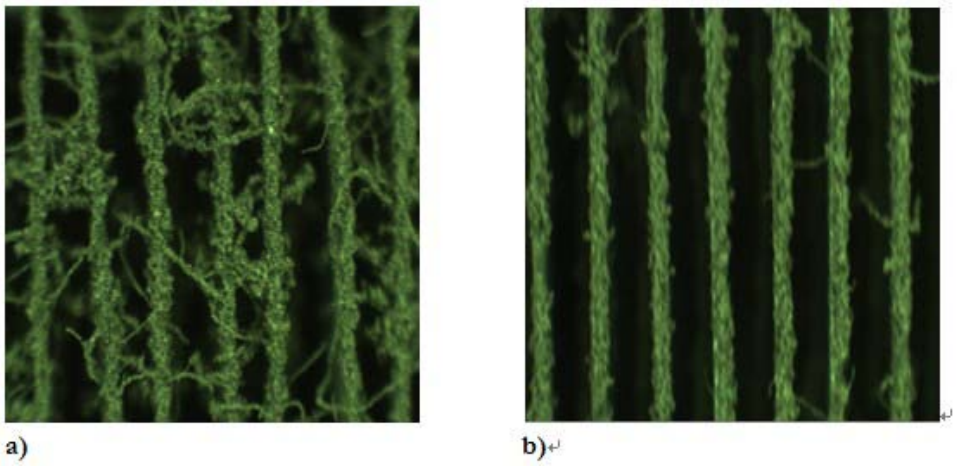


Figure 6: The dust on #1(a) and #2(b) of the group 1 air condition systems after 3 months

As shown in figure 7 and 8, the condensing temperature and discharge temperature of compressor were measured in the experiment. We can see as the dust choked the fin gap, the condensing temperature and the discharge temperature of the compressor both become higher.

This is mainly because the fibers dust choked the space between the fins, which results the drastically decreasing of the heat transfer efficiency of the condensor, so the heat transfer temperature difference and condensing temperature increases. Meanwhile, as the discharge temperature and pressure of condenser increases, the compression ratio becomes higher, which causes the increases of energy consumption and decreases of COP.

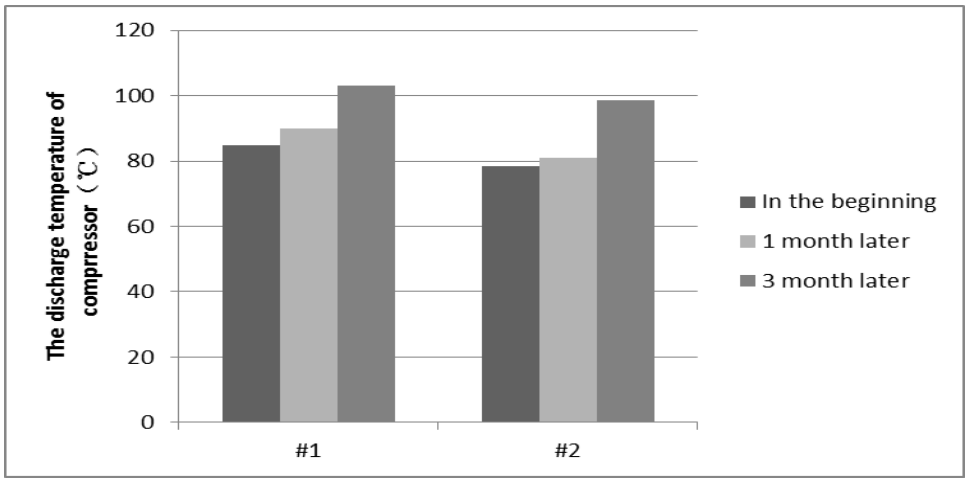


Figure 7: The discharge temperature of compressor of group 1 systems on different time

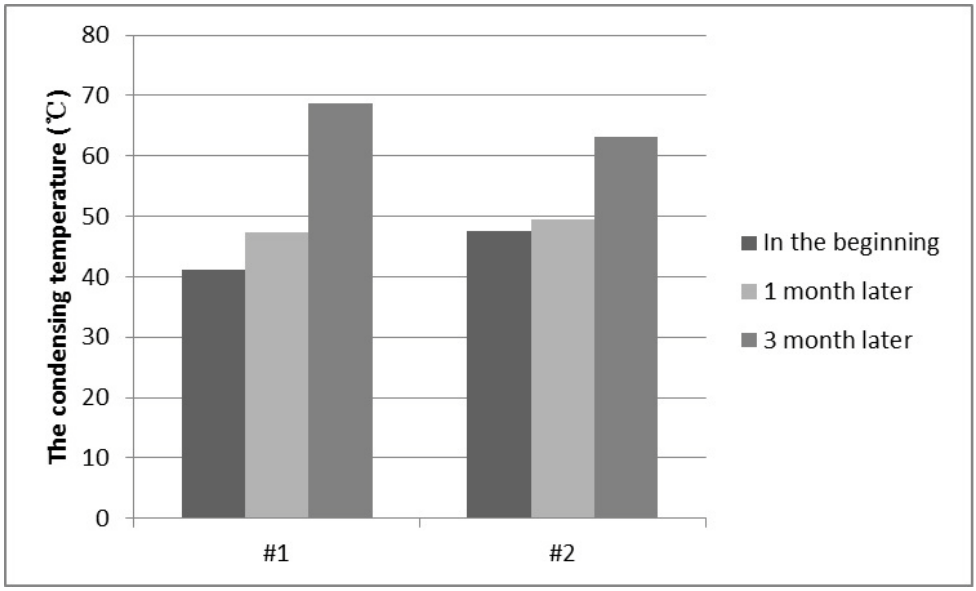


Figure 8: The condensing temperature of group 1 systems on different time

3.2 The performance comparison of group 1 and group 2

As described above, we added group 2 which run according to the control strategy to verify its effectiveness. We tested the perfoamance of group 2 and compared with group 1, which is shown in figure 9 to 11. We can see the performance of group 2 improved a lot compared with group 1. After they run for 3 months, the cooling capacity decreased by 5.5% and 2%, the energy consumption increased by 7.8% and 2.3%, and COP decreased by 12.3% and 4.3% for louver fin and wavy fin MCHX respectively. This is main because the regularly blowback of the fan can prevent the fibers dust depositing on the surface of the MCHX and the particulate dust blocking the flow channel of the air. Though there still have a layer of dust on the surface of the fin, it just affects the heat transfer coefficient and doesn't decrease the air volume of the condensor, so the decrease of heat transfer of the condensor is limited, which results the better performance of group 2. We can also find that the perfoamance of the system with wavy fin MCHX is better than the system with louver fin, this is main because the dust on the surface of the wavy fin can be blowed out more easily than the louver fin. This also proved by figure 12, which shows the detail condition of the fin.

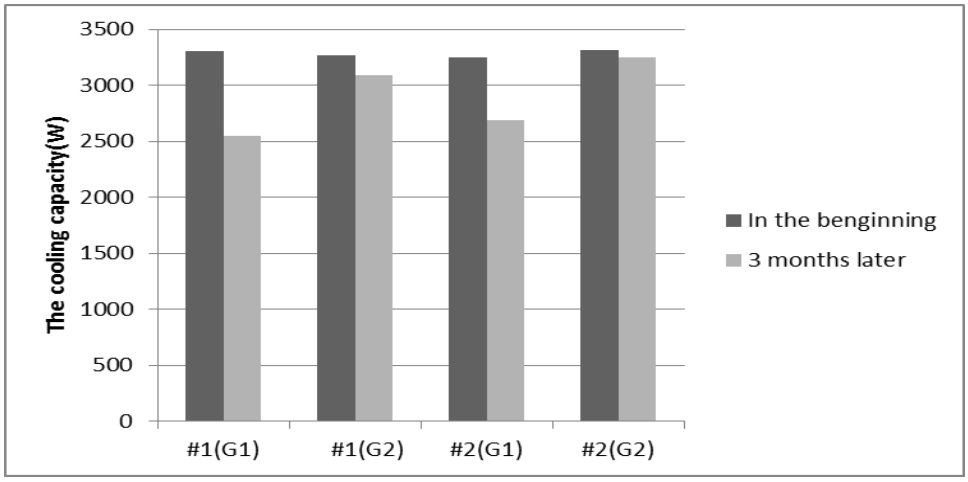


Figure 9: The comparison of the cooling capacity of two groups on different time

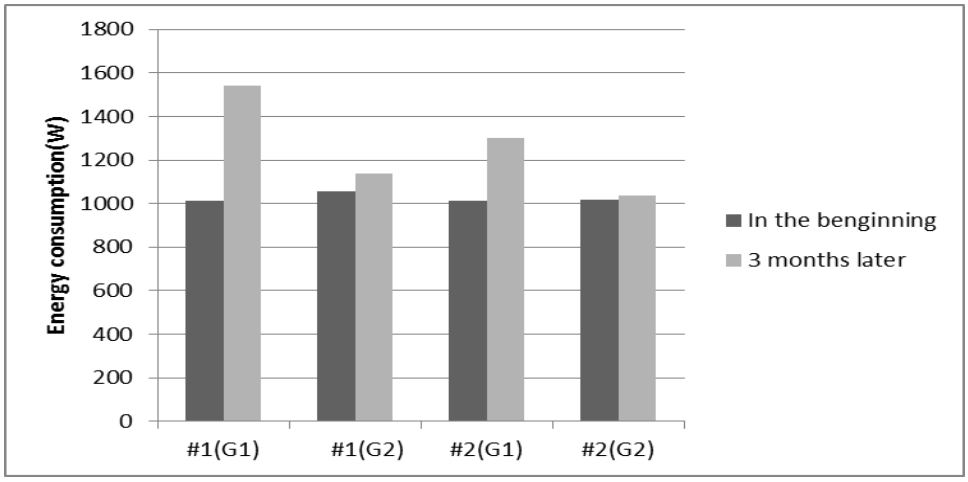


Figure 10: The comparison of the energy consumption of two groups on different time

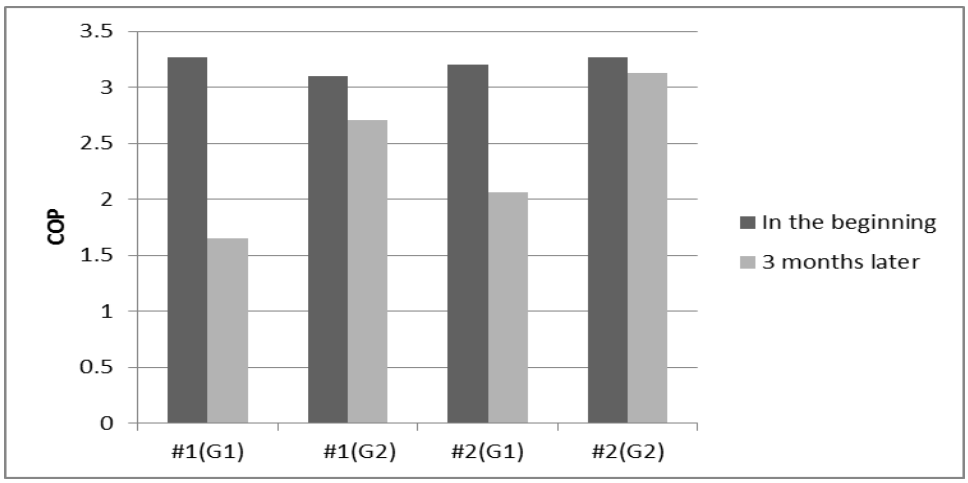


Figure 11: The comparison of COP of two groups on different time

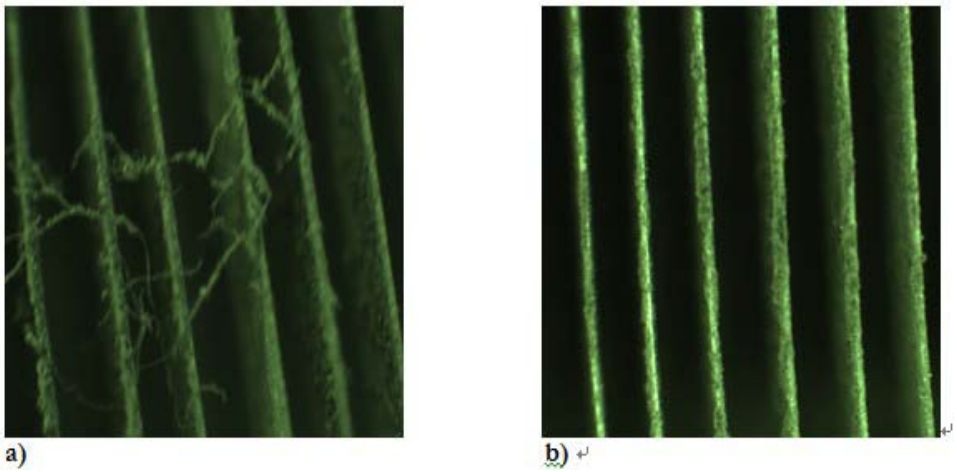


Figure 12: The dust on #1(a) and #2(b) of the group 2 air condition systems after 3 months

4. CONCLUSION

- From the test result and analysis above, we can conclude: Fouling problem of the MCHX can cause drastically performance degradation of the system, for the traditional air condition systems with MCHX which running in the factory environment, the performance of the systems decrease drastically, the cooling capacity decreased by 23% and 17.2%, the energy consumption increased by 52.5% and 28.4%, and COP decreased by 49.5% and 35.6% for louver fin MCHX and wavy fin MCHX respectively 3 months later. As the dust choked the fin gap, which results the decreasing of the heat transfer efficiency of the condenser, the condensing temperature and the discharge temperature of the compressor both become higher.
- The fan back control strategy can help to solve the dust fouling problem effectively, for the air condition systems added the control strategy, the cooling capacity decreased by 5.5% and 2%, the energy consumption increased by 7.8% and 2.3%, and COP decreased by 12.3% and 4.3% for louver fin and wavy fin MCHX respectively 3 months later.
- The performance of the air condition system with wavy fin is better than the louver fin in both conditons. Especially after added the control strategy, the perfoamance of the air condition system the wavy fan MCHX is much better than before. This can provide a soulution to solve the dust fouling problem and provide advices for the further researches.

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