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Investigation of Fresh Air-Intake Split Air Conditioner Indoor Unit

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Abstract: Clean air is a necessity for physical and mental health. Today, many people cannot get enough fresh air because they have to live and work in closed environments. Especially in single-volume heating or cooling, the indoor air is reconditioned several times, and the air regresses to an insufficient level of air quality over time. The users can only overcome the situation by simply opening the windows and getting fresh air but unfiltered and unconditioned air. In this study, a fresh air supping unit was developed for split air conditioners to create healthier and more comfortable living environments. For the selection of the fan in the fresh air intake module, the amount of fresh air needed in the living room according to the ASHRAE standarts, the ability to change the fan speed, and the ability to overcome pressure drop caused by hose and filter were evaluated. In addition, a filter group was utilized in the unit against particles that may come from the outside environment. The prototype of the designed unit was produced and tested in terms of temperature and performance. The obtained results were investigated in detail.

Keywords: Split Air Conditioner, Fresh Air, Indoor Air Quality, HVAC

Introduction

Split air conditioners are essentially heat pumps with two units, one indoor and one outdoor unit. One of the two units has heat exchanger plates that act as an evaporator and the other as a condenser. The refrigerant circulating between these two units is driven by the compressor and conditions the environment according to the simple cooling cycle. Split air conditioners are devices that condition the indoor environment to the desired air temperature as their main function. The American Society of Heating, Refrigerating, and Air-conditioning Engineers established the standards required per person in the room for comfort and health in neighbourhoods that are living spaces today (ASHRAE, 2015). In addition to air conditioning, the requirements for providing comfort conditions in indoor environments are factors such as room temperature, relative humidity, odour, oxygen and amount of fresh air in the environment.

The importance of fresh air from comfort conditions has been understood once again with the Covid-19 pandemic (Aviv et al., 2021). While split air conditioners climatize the indoor air, they provide the desired air conditioning temperatures by subsequently circulating the indoor air. The fact that the air circulated for climatization is indoor air means that dust, particles, dirt, bacteria, and viruses that can be found in this air are circulated many times (Kang et al., 2017). The traditional method of cleaning this air, is to ventilate the environment. The fact that Covid-19 is a virus transmitted directly by breathing and affects the respiratory system revealed the importance of having a system that will provide fresh air to the ambient air in split air conditioners in the air conditioning sector. Researchers showed that fresh air intake plays a vital role in the indoor air quality of living areas (Yang et al., 2021). Ho et al. (Hoa et al., 2021) investigated the position of fresh air vent effects on airflow to maintain the room at 22 ºC for cooling function. Hsieh and coworkers (Hsieh et al., 2018) proposed a heat-pump fresh air exchanger design to reduce energy consumption during cooling applications. Apart from indoor air quality, Liu et al. (Liu et al., 2019) reviewed a comparative study on fresh air supply technologies for zero-energy buildings. In this study, a split air conditioner with a fresh air intake function is developed. This product is being studied experimentally. The fan, filter, hose used for the fresh air intake function, and a fresh air intake module were designed. Studies were carried out to examine this module regarding performance and efficiency in the PTC laboratory.

Method

A fresh air intake module, which will work integrated with the split air conditioner, has been designed to provide the fresh air requirement of an indoor environment climatized with a split air conditioner unit. The prototype of this designed module was made and shown in Figure 1.

Figure 1. Fresh air intake module

Filters

The module, which will feed fresh air to the split air conditioner indoor unit, will filter the air it feeds from outside before it is fed into the system, so inside the module; There is a hose to supply air from outside and a filter assembly at the outlet of the hose. In the filter assembly, a multi-layer filter structure is used based on traditional air cleaner products.

Hose

A split air conditioner with a fresh air intake module will be used for a living room with an area of 30 m^2. In order for this module to take fresh air into the room, a hose extending out of the room will be used.Flow rate calculations that can be provided with different sizes of hoses have been made for the options of mounting the split air conditioner in different areas in the room. The selected hose is 30mm in diameter and 2m in length.

Centrifugal Fan

During the development of the fresh air intake module, it is important to choose the right fan that can meet the system requirements. The type of fan to be used in this system has been determined as a centrifugal fan, both due to its structure and its ability to provide the airflow required to be fed to the system (Eck, 1973).

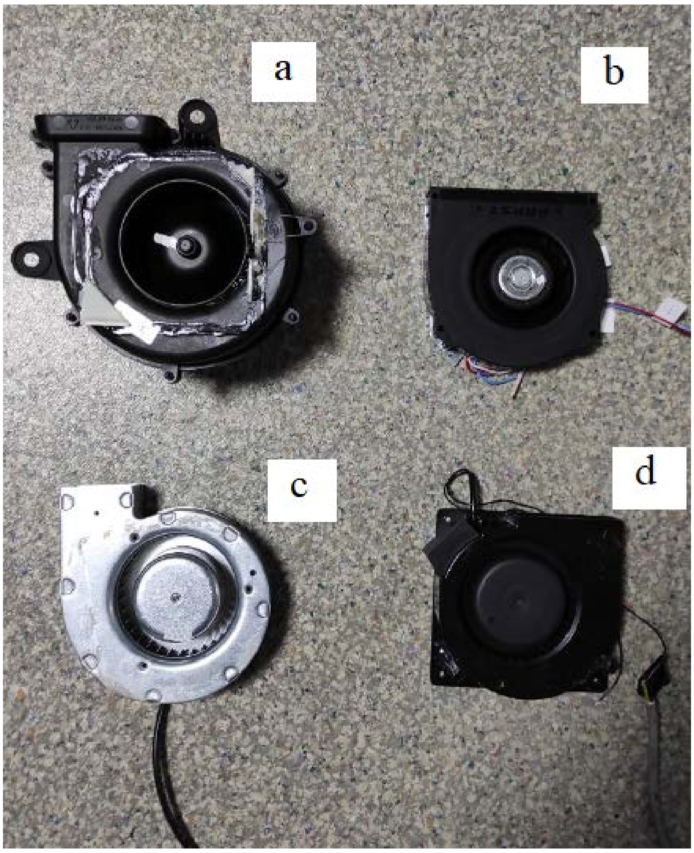

Figure 2. Tested centrifugal fans a)Fan-Ref b)Fan-1 c)Fan-2 d)Fan-3

Experimental Study

Performance Test

Figure 3. Comparative PTC laboratory tests a) without fresh air module b) with fresh air module

The fresh air intake module, in which the final state of the design was determined with the test results taken from the fan trial setup, was tested in terms of performance, efficiency and heat transfer in the Psychrometric Test Chamber (PTC) laboratory. The fresh air intake module is integrated into the split air conditioner. Tests were carried out with and without modules on it, and the results were evaluated comparatively. Thermocouples were placed at the air outlet section of the split air conditioner at regular intervals, and the temperature differences due to the fresh air supplied to the split air conditioner were examined.

Results

Fan Selection Results

The results obtained from the centrifugal fans, which were tested with the help of the fan test setup, are as given in Table 1. The centrifugal fan in the row indicated in green in the table has been selected. The fan given as the Fan-Ref in the table is the fan whose fan curve is known and used in the calculation of the required flow rate for the pressure drop. When the test results were evaluated Fan-3 was chosen as the fan of the system for performance tests, due to its ability to feed the amount of fresh air needed in the room, variable-speed motor and size advantage.

Table 1. Fan selection results

Fan	Volumetric Flowrate [m³/h]	Mass Flowrate [kg/h]	Density [kg/m³]	Velocity [m/s]	Diameter [m]	Area [m²]	Fan [rpm]	Fan [voltage]
Fan-Ref (known fan characteristic curve)	37,36	45,76	1,225	2,35	0,075	0,004416	1560	230V
	32,59	39,92	1,225	2,05	0,075	0,004416		
	34,97	42,84	1,225	2,2	0,075	0,004416		
	35,61	43,62	1,225	2,24	0,075	0,004416		
	38,79	47,51	1,225	2,44	0,075	0,004416		
	42,92	52,58	1,225	2,7	0,075	0,004416		
	33,22	40,7	1,225	2,09	0,075	0,004416	860	125 V
	31,79	38,95	1,225	2	0,075	0,004416	2485	120 V
Fan-1	14,31	17,53	1,225	0,9	0,075	0,004416	1200	
	23,84	29,21	1,225	1,5	0,075	0,004416	1750	
	42,13	51,6	1,225	2,65	0,075	0,004416	2650	
	50,87	62,31	1,225	3,2	0,075	0,004416	3250	
Fan-2	45,62	55,89	1,225	2,87	0,075	0,004416	3127	
	39,74	48,68	1,225	2,5	0,075	0,004416	2800	
	31,79	38,95	1,225	2	0,075	0,004416	2400	
Fan-3	61,36	75,17	1,225	3,86	0,075	0,004416	2830	230 V
	32,11	39,34	1,225	2,02	0,075	0,004416	1900	

Performance Test Results

Table 2. Performance test results PTC laboratory

COOLING							
Test Number		1	2	Temperature difference [%]	3	4	Temperature difference [%]
Fresh Air Module		Yes	No		Yes	No	
Id fan motor speed	rpm	900	900		650	650	
Od fan motor speed	rpm	850	850		450	450	
Thermocouple-1	°C	14,73	14,67	-0,41	19,37	19,26	-0,57
Thermocouple-2	°C	13,89	13,83	-0,43	18,62	18,54	-0,43
Thermocouple-3	°C	13,72	13,71	-0,07	18,74	18,42	-1,74
Thermocouple-4	°C	14,14	14,25	0,77	18,92	18,87	-0,26
Thermocouple-5	°C	14,31	14,41	0,69	19,18	19,14	-0,21
Thermocouple-6	°C	15,17	15,22	0,33	20,2	20,12	-0,4
Thermocouple-7	°C	14	14,07	0,5	19,1	19	-0,53
Thermocouple-8	°C	14,63	14,71	0,54	19,9	20,1	1
HEATING							
Test Number		1	2	Temperature difference [%]	3	4	Temperature difference [%]
Fresh Air Module		Yes	No		Yes	No	
Id fan motor speed	rpm	1000	1000		650	650	
Od fan motor speed	rpm	850	850		500	500	
Thermocouple-1	°C	42,9	42,69	-0,49	33,45	33,42	-0,09
Thermocouple-2	°C	42,54	42,28	-0,61	33,15	33,17	0,06
Thermocouple-3	°C	42,54	42,41	-0,31	33,12	33,16	0,12
Thermocouple-4	°C	43,16	43,15	-0,02	33,85	34,01	0,47
Thermocouple-5	°C	43,46	43,49	0,07	34,02	34,2	0,53
Thermocouple-6	°C	42,5	42,5	0	33,6	33,71	0,33
Thermocouple-7	°C	42,8	42,79	-0,02	33,35	33,55	0,6
Thermocouple-8	°C	43,65	43,6	-0,11	34,33	34,5	0,49

Performance test results for split air conditioners with and without the fresh air intake module in PTC laboratory are given in Table 2. The tests were carried out both in the heating mode of the split air conditioner and in the cooling mode. When the test results in Table 2 were evaluated, it was observed that the use of the module did not cause a significant change in the performance and the outlet temperature of the indoor unit of the split air conditioner. The warmer air blown from the fresh air unit in the cooling mode and the cooler air blown from the fresh air unit in the heating mode is sucked from the area of the air conditioner suction area close to the fresh air unit. This situation causes the deviations of thermocouples between 1 and 4 to be negative. The fact that all deviations in Table 2 are less than 1% shows that the fresh air unit does not have a negative effect in terms of performance and temperature.

Conclusion

The fresh air intake split air conditioner unit developed in the study was calculated for the amounts specified in ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality in the literature and designed to meet these standards. By using the equations given in this standard, a module design has been made that can provide the 32.4m³/h fresh air intake requirement determined for a room with an area of 30m² and more if more is needed.

Since the fan used for the room is chosen as a fan whose speed can be changed and it is easy to drive with an electronic card, it is the fan that can best meet the fresh air requirement specified by the standards. The most suitable fan will easily meet the fresh air requirement of 32.4m³/h in the indoor area with an area of 30m². Also 32.11m³/h at the lowest fan speed and 62.36m³/h at the highest fan speed. If the need for fresh air in the room will increase for any reason (for example; an increase in the number of people, an increase in polluting factors in the room, etc.), the selected fan is selected at a level that can provide the required amount of fresh air.

Considering the test results of the PTC laboratory, the temperature difference does not exceed 1% even for the thermocouples which are closest to the part where the fresh air intake module is located. This result is a negligible value when considering the area of the dimensions where the system is used. When other thermocouples were evaluated at the same measurement time, it was observed that there was no change compared to the situation where the fresh air intake module was not used.

The developed module enabled the split air conditioners to be able to climatize the environment by adding fresh air to the indoor air without affecting the cooling and heating performances. The use of the developed module will provide the opportunity to provide fresh air with a higher level of hygiene, in addition to providing the comfort conditions of split air conditioners. Additionally, the compact structure of the developed module allows not disturb the aesthetic structure of the split air conditioner.

Scientific Ethics Declaration

The authors declare that they are responsible for the scientific, ethical, and legal aspects of the paper published in EPSTEM.

Acknowledgements or Notes

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