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GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

EXPERIMENTAL INVESTIGATION OF SPLIT AIR CONDITIONER INDOOR UNIT WITH FRESH AIR

by

Erdem SARICA

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İZMİR

EXPERIMENTAL INVESTIGATION OF SPLIT AIR CONDITIONER INDOOR UNIT WITH FRESH AIR

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Erdem SARICA

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İZMİR

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"EXPERIMENTAL INVESTIGATION OF SPLIT AIR CONDITIONER INDOOR UNIT WITH FRESH AIR"** completed by **ERDEM SARICA** under supervision of **PROF. DR. DİLEK KUMLUTAŞ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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EXPERIMENTAL INVESTIGATION OF SPLIT AIR CONDITIONER INDOOR UNIT WITH FRESH AIR

ABSTRACT

The aim of this study is to examine and develop fresh air intake systems in split air conditioners with experimental methods. In this sense, the effects of a fresh air intake module on the split air conditioners' airflow structure and air conditioning performance were examined.

Within the scope of this study, firstly, the amount of fresh air needed by the indoor environments where people live was calculated with the help of the tables and equations in the globally accepted standards. Using these values, the amount of fresh air to be transported to the indoor area, which is the usage area of the people, and centrifugal fans capable of carrying this fresh air to the indoor environment were determined, and these fans were brought from the fan supplier companies. A fresh air intake module suitable for centrifugal fans has been designed, and the most suitable place and row arrangement has been calculated for unique filter systems that will clean the fresh air. This fresh air intake module was designed and produced as a prototype and added to the split air conditioner. The flow structure of the split air conditioner and fresh air intake module was tested experimentally by the Particle Image Velocimetry (PIV) method. Development and optimization studies were carried out for the fresh air intake module by evaluating the results. With this developed fresh air intake module, the whole split air conditioner unit was tested in Performance Test Laboratories (PTC) regarding air conditioning capacity. As a result of the study, the most efficient design of the fresh air intake module and its integration into the split air conditioner was made. A new product has been added to the product range of the industrial institution where the study was conducted, and a study has been made that will make valuable contributions to the academic community and literature.

Keywords: Particle image velocimetry (PIV), indoor air quality and hygiene, fresh air systems, split air conditioner fresh air intake,

TAZE HAVA ALMALI SPLİT KLİMA İÇ ÜNİTESİNİN DENEYSEL OLARAK İNCELENMESİ

ÖZ

Bu çalışmanın amacı, split klimalarda taze hava alma sistemlerinin deneysel yöntemlerle incelenmesi ve geliştirilmesidir. Bu anlamda split klima ünitesine ek bir taze hava alma modülünün, split klima akış yapısına ve iklimlendirme performansına etkileri irdelenmiştir.

Bu çalışma kapsamında ilk etapta, insanların içinde yaşadığı kapalı ortamların ihtiyaç duyduğu taze hava miktarı, global ölçekte kabul görmüş olan standartlarda yer alan tablolar ve denklemler yardımıyla hesaplanmıştır. Elde edilen bu değerler kullanılarak, kişilerin kullanım alanı olan iç ortama taşınacak olan taze hava miktarını ve bu taze havayı iç ortama taşıyabilecek yeterlilikte santrifüj fanlar belirlenmiştir ve fan tedarikçisi firmalardan getirtilmiştir. Santrifüj fanlara uygun bir taze hava alma modülü tasarlanmıştır ve taze havayı temizleyecek olan özel filtre sistemleri için en uygun olan yer ve sıra düzeni hesaplanmıştır. Devamında tasarlanan ve prototip üretimi yapılan bu taze hava alma modülü split klimaya eklenerek, split klima ve taze hava alma modülünün akış yapısı Parçacık Görüntülemeli Hız Ölçümü (PGHÖ) yöntemiyle deneysel olarak incelenmiştir, sonrasında sonuçlar değerlendirilerek taze hava alma modülü için geliştirme ve optimizasyon çalışmaları yapılmıştır. Geliştirilen bu taze hava alma modülü ile split klima ünitesinin bütünü, Performans Test Laboratuvarlarında (PTC) kapasite yönünden testlere alınmıştır. Çalışma sonucu taze hava alma modülünün en verimli tasarımı ve split klimaya entegrasyonu yapılmıştır. Çalışmanın yapıldığı sanayi kuruluşunun ürün gamına yeni bir ürün kazandırılarak ticari fayda sağlanmakla beraber, akademik camiaya ve literatüre değerli katkılar sağlayacak bir çalışma yapılmıştır.

Anahtar Kelimeler: Parçacık görüntülemeli hız ölçümü yöntemi (PGHÖ), iç ortam havası ve hijyen, taze hava sistemleri, split klima taze hava alma,

CONTENTS

Page

M.Sc THESIS EXAMINATION RESULT FORM....ii
ACKNOWLEDGMENTS....iii
ABSTRACT iv
ÖZ v
LIST OF FIGURES viii
LIST OF TABLES xi

CHAPTER ONE - INTRODUCTION 1

1.1 Literature Survey 2

1.2 Aim and Motivation 7

CHAPTER TWO - DESIGN OF FRESH AIR INTAKE SYSTEM 8

2.1 General Pathway 8

2.1.1 Basic Structure for Fresh Air Intake System 9

2.1.2 Determining the Suitable Location for The Fan and Filter 11

2.2 Sub-Components of Fresh Air Intake System 12

2.2.1 Fresh Air Requirement for Living Areas 12

2.2.2 Fresh Air Carrier Tool 14

2.2.3 The Filter Assembly of Fresh Air Intake System 14

2.2.4 The Fan of Fresh Air Intake System 15

2.3 Design Alternatives and Assembly of Subcomponents 16

CHAPTER THREE - EXPERIMENTS AND METHODOLOGY 19

3.1 Design for Test System to Determine the Suitable Centrifugal Fan 19

3.1.1 Design and Prototype of Fan Test Setup 21

3.1.2 Design of Filter Housing and Blowing Mouth for Fan Test Setup 22

3.2 Experiments with Fan Test Setup 23

3.2.1 Adjusting the Voltage and Speed of the Fan by Using Variac 23
3.2.2 Measurement of Fan Revolution Frequency by Using Tachometer 24
3.2.3 Measurement of the Air Speed by Using Anemometer 24
3.3 Particle Image Velocimetry (PIV) 26
3.3.1 Working Principle of PIV 26
3.3.2 Components of PIV Setup 27
3.3.1 Experiments of Fresh Air Intake Module with PIV method – Side Position Module 32
3.3.2 Experiments of Fresh Air Intake Module with PIV method – Top Position Module 34
3.4 Performance Test Chamber (PTC) 37
3.4.1 Experiments of Split Air Conditioner with Fresh Air Intake Module at PTC Laboratory 40

CHAPTER FOUR - RESULTS AND DISCUSSION 42

4.1 Fan Selection Results 42
4.2 PIV Results 44
4.2.1 PIV Results – Side Position Module 44
4.2.2 PIV Results – Top Position Module 48
4.3 Performance Test Results 54

CHAPTER FIVE - CONCLUSION 56

REFERENCES 58

LIST OF FIGURES

Page

Figure 1.1 3D model and meshing for numerical study 3
Figure 1.2 Result of velocity vector plots for various heat exchanger types 3
Figure 1.3 Bedside personalized ventilation system and environmental chamber 4
Figure 1.4 Schematic of heat pump fresh air exchanger study 5
Figure 1.5 PIV velocity vector results and 3D representation of investigation planes 6
Figure 1.6 Numerical and experimental investigation of split air conditioner a) CFD results b) PIV results 7
Figure 2.1 Schematic illustration of the initial state 8
Figure 2.2 Schematic illustration of fresh air system 10
Figure 2.3 Illustration of fan and filter locations 11
Figure 2.4 Selected carrier tool – hose 14
Figure 2.5 Filter assembly, a) Dust Filter b) Activated Carbon Filter c) Special Filter 15
Figure 2.6 Centrifugal fan 15
Figure 2.7 Positioning the fresh air intake module on the side of the split air conditioner indoor unit -CAD data 16
Figure 2.8 Positioning the fresh air intake module on the side of the split air conditioner indoor unit –Prototype 17
Figure 2.9 Positioning the fresh air intake module on the upper-part (top) of the split air conditioner indoor unit CAD data 17
Figure 2.10 Positioning the fresh air intake module on the upper-part (top) of the split air conditioner indoor unit Prototype 18
Figure 3.1 Centrifugal fan catalogue for chosen fan 20
Figure 3.2 Fan curve and desired working point 20
Figure 3.3 CAD design and prototype of fan test setup with split air conditioner 21
Figure 3.4 Fan test setup 22
Figure 3.5 Design of housing and blowing mouth a) Filter Housing b) Blowing mouth apparatus 22
Figure 3.6 Adjusting the voltage and speed of the fan by using variac 23
Figure 3.7 Centrifugal fan revolution per minute (rpm) measurement with tachometer 24

Figure 3.8 Centrifugal fan air speed measurement with anemometer 25
Figure 3.9 Components and specification of PIV system 28
Figure 3.10 Illustration of PIV setup used in the current study 28
Figure 3.11 Laser equipment 29
Figure 3.12 Camera equipment 29
Figure 3.13 Seeding particles - fog fluid 30
Figure 3.14 Calibration Target 31
Figure 3.15 CAD of the module positioned to the side of split air conditioner a) Closed module b) Open module with inner components 32
Figure 3.16 Experiment planes on blowing mouth and prototype of the fresh air intake module positioned to the side of split air conditioner a) Experiment planes on blowing mouth b) Prototype module 33
Figure 3.17 Picture of fresh air intake module and split air conditioner ready for PIV experiment - side position module 34
Figure 3.18 CAD data of fresh air module positioned to the top side of split air conditioner a) Module with split air conditioner b) Transparent module to show the components inside 35
Figure 3.19 Experiment planes on blowing mouth and prototype of the module positioned to the top of split air conditioner a) Experiment planes on blowing mouth b) Prototype module 35
Figure 3.20 Picture of fresh air intake module and split air conditioner ready for PIV experiment - Top position module 36
Figure 3.21 Inside view of Performance Test Chamber 37
Figure 3.22 Duct sensors inside PTC chamber 38
Figure 3.23 Sensors inside PTC chamber 38
Figure 3.24 Back side of the room and ducts nozzles 39
Figure 3.25 Terminal computer of PTC laboratory 39
Figure 3.26 Comparative PTC laboratory tests a) Without fresh air module b) With fresh air module 40
Figure 3.27 Thermocouple line-up to air outlet of split air conditioner 41
Figure 3.28 Duct connection of fresh air intake split air conditioner 41
Figure 4.1 Tested centrifugal fans a) Fan-Ref b) Fan-1 c) Fan-2 d) Fan-3 42

Figure 4.2 Selected centrifugal fan images - Fan-3 42
Figure 4.3 Fresh air intake module with split air conditioner - side position module 44
Figure 4.4 Investigation planes a) Fresh air intake module blowing mouth b) Investigation planes on fresh air intake module 45
Figure 4.5 PIV test results for side positioned module - velocity data 46
Figure 4.6 Fresh air intake module with split air conditioner - top position module. 48
Figure 4.7 Investigation planes a) Fresh air intake module blowing mouth b) Experiment planes on fresh air intake module 48
Figure 4.8 PIV test results for top positioned module - velocity data a) Angular view camera b) SPIV result 51
Figure 4.9 Detailed view of velocity vectors in 6th plane z=150mm 53
Figure 4.10 SPIV results of 6th plane z=150mm a) SPIV image with vectors b) Resultant velocity vector graph at line 1 53

LIST OF TABLES

Table 2.1 ANSI/ASHRAE 62-2001 required ventilation rates 13
Table 4.1 Fan selection results 43
Table 4.2 Performance test results (PTC laboratory tests) 55

CHAPTER ONE
INTRODUCTION

Split air conditioners are widely used and one of the most preferred air conditioning devices in present times. Split air conditioner units consist of two separate units, an indoor unit and an outdoor unit, that work in conjunction. The indoor unit contains a component called the evaporator, which cools and dehumidifies the environment. The outdoor unit of the split air conditioner contains the compressor component that circulates the refrigerant in the system and allows the heat to be thrown out. The two units are connected using copper pipes that carry the refrigerant fluid, electrical cables that enable the device to operate, and drainage hoses that provide water discharge.

Intake of fresh air into an air-conditioned environment is critical in some aspects. Meeting the needs of the people who will use the environment, such as ventilation, health, and comfort, is becoming increasingly important in addition to the air conditioning of the environment.

Split air conditioners require an indoor environment where the air will be kept. Therefore, when adequate ventilation is not provided in the indoor environment where split air conditioners are used, indoor air quality will deteriorate and cause an increase in indoor pollutants such as carbon dioxide, volatile organic compounds, and other harmful airborne particles. When fresh air is introduced into closed environments, it helps to provide ventilation and reduce the negative effects of this polluted air in closed areas. Providing fresh air to this indoor environment where the split air conditioner operates will help reduce respiratory problems that may arise from poor indoor air quality. In addition, it will increase comfort by reducing odor and moisture levels. At the same time, when fresh air is supplied to the environment where the split air conditioner operates, the workload on the system can be reduced.

1.1 Literature Survey

Split air conditioners are becoming more popular among consumers, and this preference of people is based on various reasons. Split air conditioners have high energy efficiency in contrast to other types of competitor devices in the air conditioning industry. Split air conditioners are less noisy because the compressor is placed in the outdoor unit. This ensures that the loud noise of the compressor stays in the outdoor unit environment away from the indoor environment to be air-conditioned. Split air conditioners are easy to install, and they require minimal modification over the years. For all these reasons and more, researchers worked on the development and improvement of various fields and different parameters on split air conditioners in the past (N. Liu et al., 2016; Wu et al., 2012; Zhang et al., 2016).

Researchers have consistently studied methods to enhance the energy efficiency of split air conditioner systems. Chen et al. (2018) investigated the integration of energy-saving devices (ESD) into these systems. Thermohydraulic and condensing phase change methods were the focus of analysis by Shih, Tsao, and colleagues (2022; 2020) in relation to small-scale split air conditioners. An experimental approach was taken by Zhang and the research team (2016) to examine explosion properties of a split air conditioner, utilizing R290 refrigerant. Liu et al. (2016) used numerical methods to optimize heat exchangers in indoor units of split air conditioners, examining performance for varying parameters, as illustrated in Figures 1.1 and 1.2.

Efforts to mitigate noise from the outdoor unit in split air conditioners were undertaken by Zhao et al. (2013). Their approach involved optimizing the geometric structure of the axial fan within the unit, leading to a substantial reduction in noise levels.

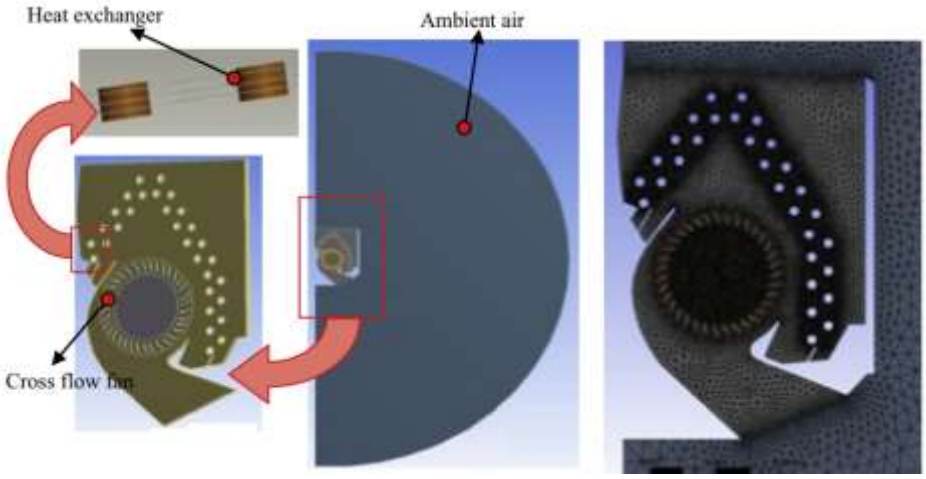


Figure 1.1 3D model and meshing for numerical study (N. Liu et al., 2016)

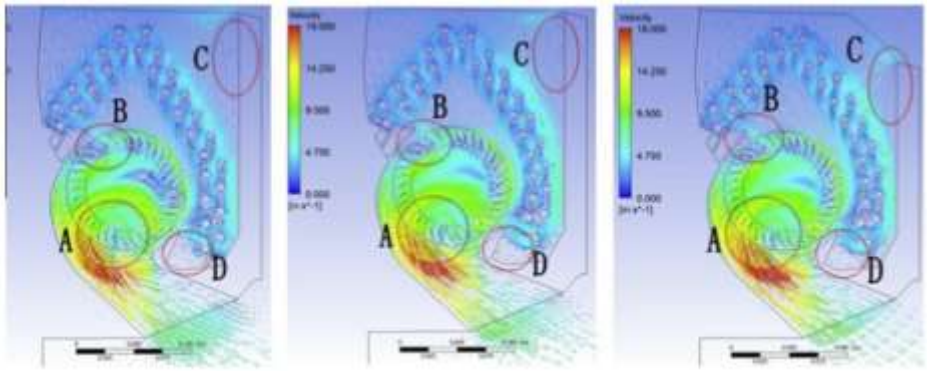


Figure 1.2 Result of velocity vector plots for various heat exchanger types (N. Liu et al., 2016)

Studies show that people spend more than 80% of their time indoors (Mannan & Al-Ghamdi, 2021). Therefore, it has become a necessity to improve indoor air quality. Apart from the parameters in the study subjects described in the previous paragraph, the fresh air system is important in the Heating Ventilation and Air Conditioning sector (HVAC), and the fresh air intake systems in the split air conditioner indoor unit were examined within the scope of this thesis. Air conditioning devices provide air conditioning by circulating the air in the room repeatedly, but it is also known that in environments where sterilization needs to be provided, such as hospitals, the air also needs to be clean (Fonseca et al., 2022; Kang et al., 2017). Humidity occurring during heating-cooling processes causes the proliferation such as bacteria and dust particles (Yuan et al., 2022). Balocco (2011) demonstrated the effectiveness of one-way laminar flow ventilation in controlling particles. Zhou et al. (2014) conducted

experiments on personalized bedside ventilation to cater to individual ventilation needs during sleep and rest, as depicted in Figure 1.3.

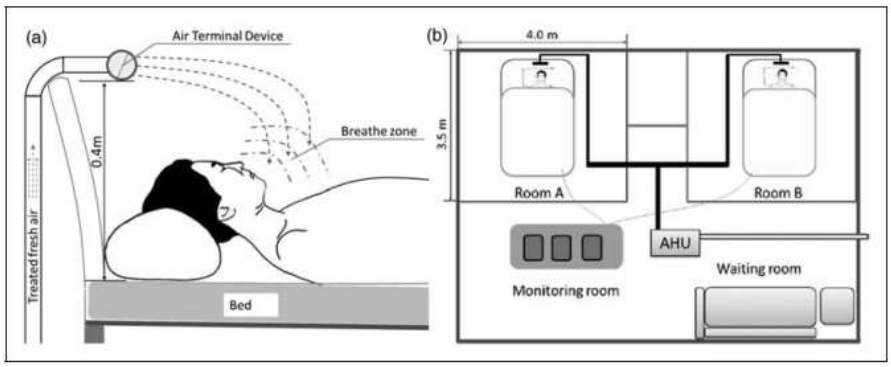


Figure 1.3 Bedside personalized ventilation system and environmental chamber (Zhou et al., 2014)

In addition, with the effects of the COVID-19 virus, the necessity of increasing the air quality in indoor environments for human health in respiratory diseases has been well understood (Aviv et al., 2021). In the standards created by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the values of the fresh air requirement per person in the indoor environment for the comfort and healthy living spaces are calculated and indicated, considering the criteria of temperature, humidity, and fresh air (ASHRAE, 2004). Experimental studies show that fresh air intake in indoor environments is critical in determining the ambient air quality in the living area (Yang et al., 2021). Examining the effects of fresh air on indoor air flow, Ho et al. (2021), recognized experts in the field, optimized outcomes while considering energy consumption during the cooling process. In a parallel effort, Hsieh et al. (2018) conducted a thorough investigation, focusing on energy consumption and Coefficient of Performance (COP) parameters. Noteworthy is their study, which integrated a heat pump fresh air exchanger, showcasing efficiency with minimal energy consumption and a high COP value during the cooling process. Figure 1.4 visually presents the findings from this research. From a broader perspective, academic and industrial research on fresh air technologies is increasing in zero buildings studies, which aim to minimize energy dependence (Z. Liu et al., 2019).

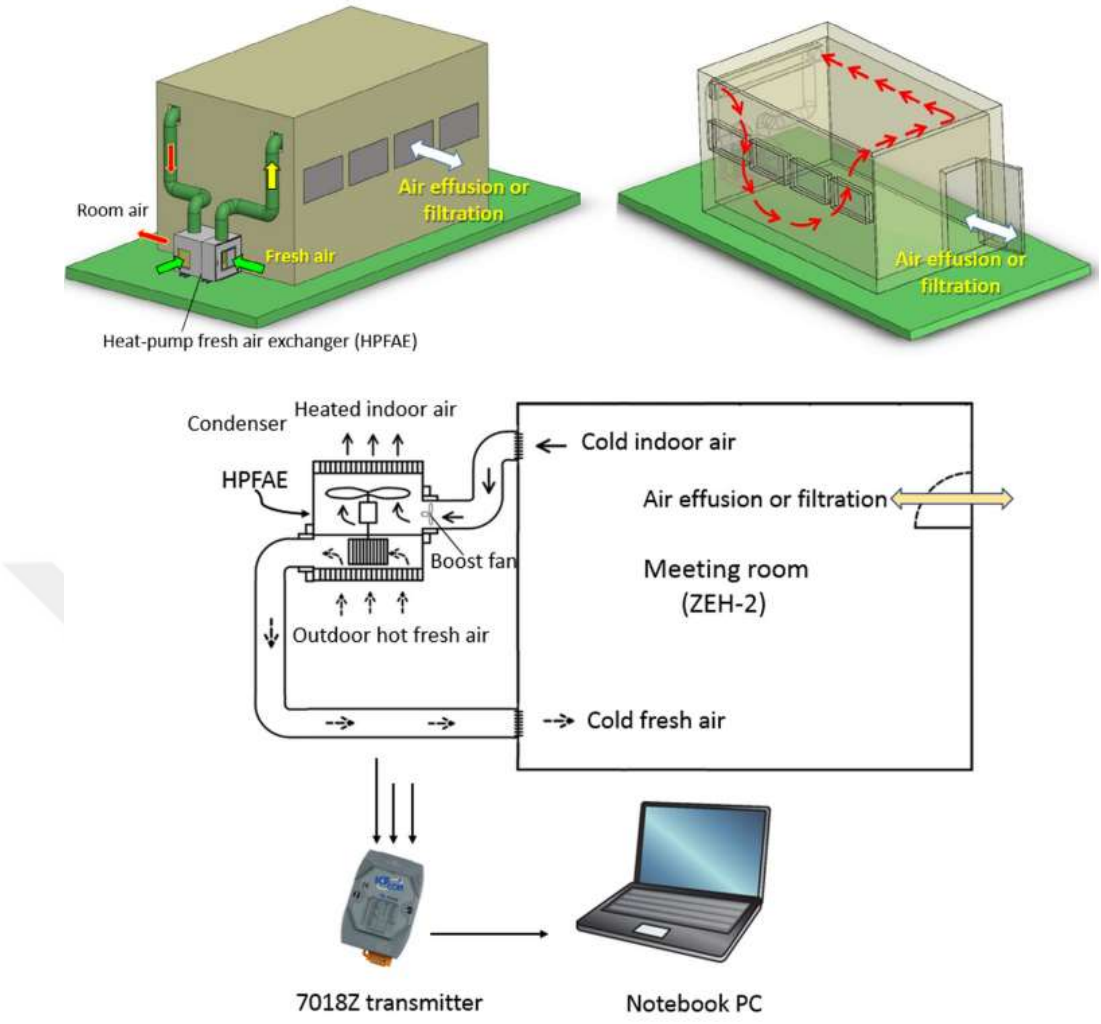


Figure 1.4 Schematic of heat pump fresh air exchanger study (Hsieh et al., 2018)

Compared to the experimental methods used to verify theoretical and numerical calculations in all these studies, there are studies in the literature that use the Particle Image Velocimetry (PIV) method as an experimental method for verification and investigation of systems. (Karadeniz et al., 2013; Kumlutaş et al., 2013; Özer & Kumlutaş, 2017). Kumlutaş et al. (2013) used Computational Fluid Dynamics (CFD) and PIV methods to examine the flow structure and heat transfer characteristics of the split air conditioner, the Stereo Particle Image Velocimetry (SPIV) results and investigation planes used in PIV experiments of split air conditioner in the study is shown with Figure 1.5.

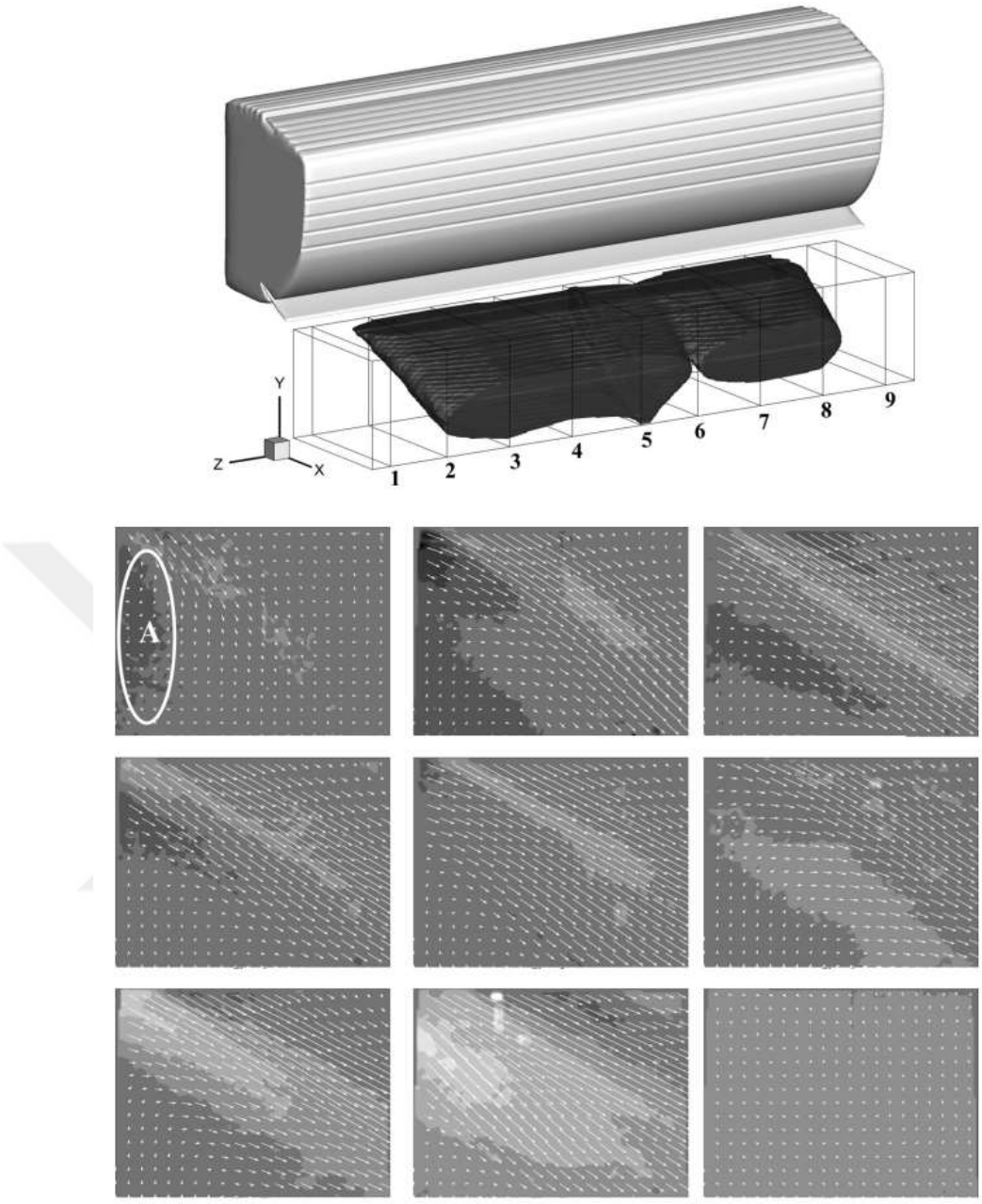


Figure 1.5 PIV velocity vector results and 3D representation of investigation planes (Kumlutaş et al., 2013)

Zou et al. (2022) studied the internal flow structure of the cross fan in split air conditioners using numerical methods. The subsequent analysis of the results was conducted utilizing the PIV method. Figure 1.6 displays images from the studies conducted using CFD and PIV methods in this research.

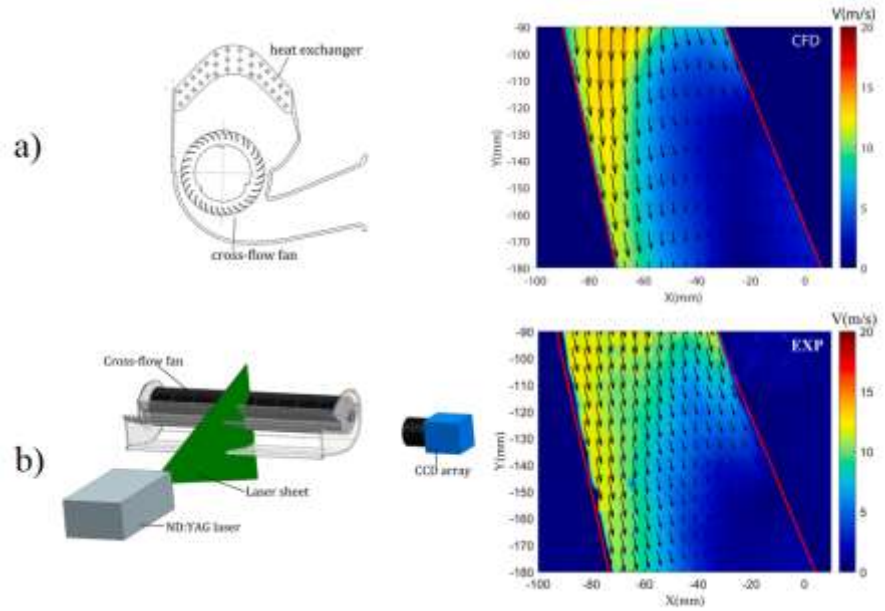


Figure 1.6 Numerical and experimental investigation of split air conditioner a) CFD results b) PIV results (Zou et al., 2022)

1.2 Aim and Motivation

The aim of this study is to develop a fresh air split air conditioner using experimental methods. In this context, a fresh air intake module was developed, and this module was examined with experimental methods. In contrast to the existing literature, the fresh air intake module integrated into the split air conditioner, the prototype of which is produced within the scope of the thesis, is analyzed with SPIV and fan test setup and the results are presented.

The fresh air to be blown by the fresh air intake module to be developed within the scope of this study should not have a negative effect on the indoor air conditioning performance of the split air conditioner. In addition, it is required that all the fresh air to be blown from the fresh air intake module can be absorbed by the split air conditioner without mixing with the already conditioned ambient air and sent to the ambient air after it has been air-conditioned.

It is expected to meet both the sectoral needs, end-user expectations, human health, and comfort parameters with the developed fresh air intake split air conditioner.

CHAPTER TWO
DESIGN OF FRESH AIR INTAKE SYSTEM

2.1 General Pathway

As explained in the previous section, the purpose of the study is to design a split air conditioner with a fresh air intake. In order to do this, the structure and components required by the system will be explained in this section.

The schematic illustration is in Figure 2.1. shows an outdoor environment, a split air conditioner outdoor unit in this outdoor area, an indoor environment, a split air conditioner indoor unit in this indoor area, and the fresh air in the outdoor environment.

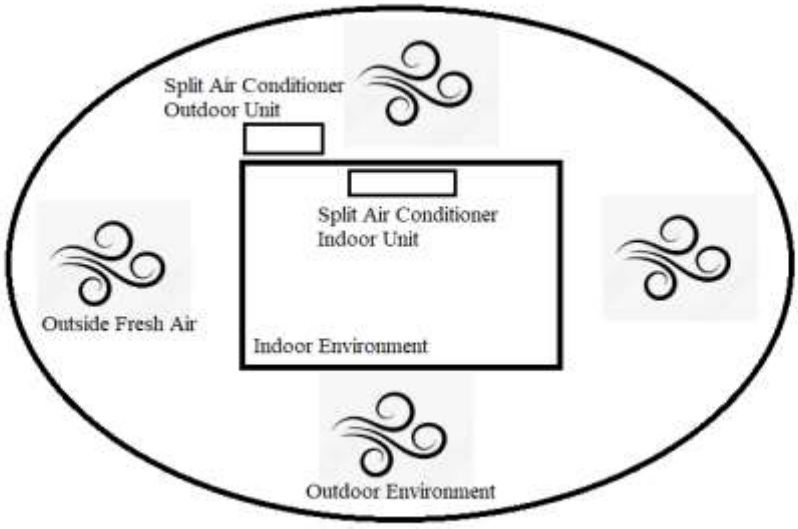


Figure 2.1 Schematic illustration of the initial state

In this system, the process of transporting the fresh air that is free from the outdoor environment to the indoor environment can be done in various ways.

2.1.1 Basic Structure for Fresh Air Intake System

First of all, it is necessary to determine the path that the fresh air, which is free in the outdoor environment, will follow during the transition to the indoor environment. This transition of fresh air can be done by directing the air to an extension channel leaning from the outside environment to the inside environment.

It may also be possible to transport the fresh air without any tools depending on the region that the fresh air intake system is to be integrated. For example, in an area with a thin wall thickness, the wall can be pierced, and the air can be transferred from the outside to the indoor environment. Since the fresh air intake system to be used during this study is desired to operate independently of the region where it will be used, this passage has been determined as a hose.

After determining the channel where the fresh air will be carried, it is necessary to decide on the system that will drive this air. For the fresh air propulsion system, air moving systems such as compressors and fans can be used. Usage of fans compared to compressors are,

Usage of fans,

- Design is simplistic and less maintenance
- May handle large volumes of air
- Can be used for low-pressure applications
- Efficient at higher volume rates
- Relatively low noise

While the compressor usage,

- Complex design and higher maintenance
- Required specialized training to operate
- May be loud

- Can generate heat and require cooling
- Can be less efficient at low pressure ratios

Considering all these advantages, the use of fans in the fresh air intake system was preferred.

Fresh air is free in the outdoor environment in its initial state. The fresh air that is free in the outdoor environment may not be clean at first. This polluted fresh air may contain dust particles, diseases, and factors such as bad odor. The fresh air transported from the outdoor environment to the indoor environment will first need to undergo a cleaning process. This cleaning function will be done through filters.

To summarize these explanations, a hose will be used as a system through which the air will pass, a fan will be used as a system to drive the air, and filters will be used as a system to clean the air. By evaluating all this information, the schematic representation of the split air conditioner unit with fresh air will be shown in Figure 2.2.

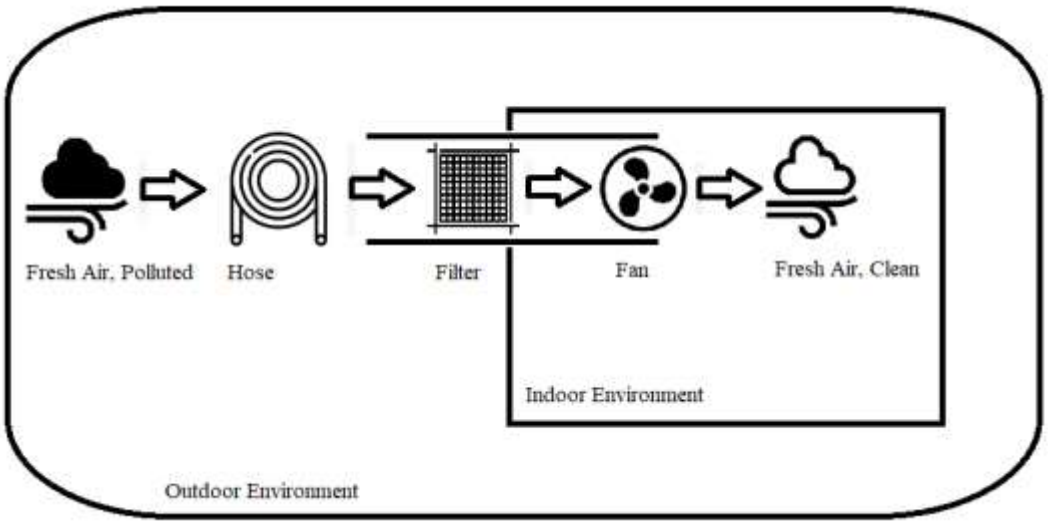


Figure 2.2 Schematic illustration of fresh air system

The fresh air system shown in Figure 2.2. can be evaluated in 2 different ways according to the way the air is delivered. One of them is the system where the fans and

filters are in the outside environment, and the other is the system where the fans and filters are in the indoor environment as shown in Figure 2.3. The hose to be used in both cases will remain the same as the connection for air transport between the indoor and outdoor environment.

2.1.2 Determining the Suitable Location for the Fan and Filter

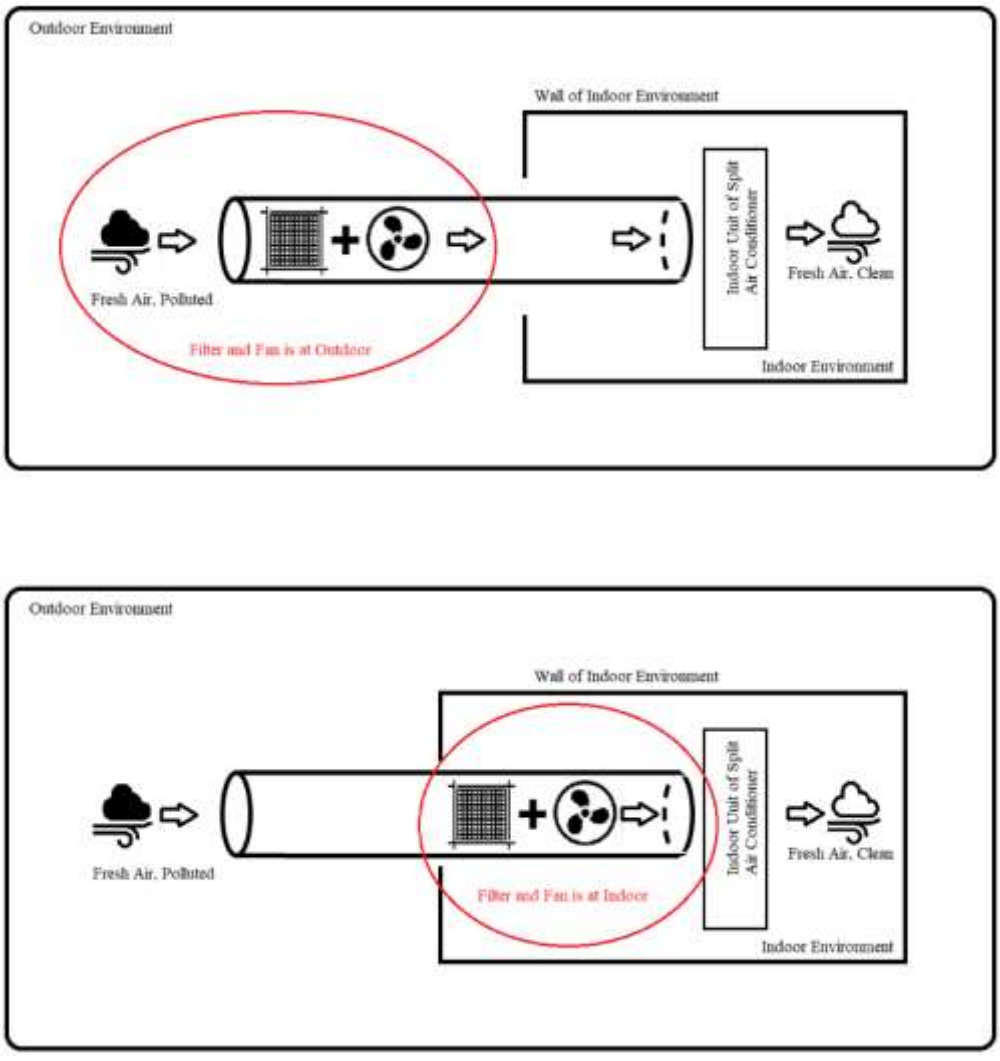


Figure 2.3 Illustration of fan and filter locations

The fresh air intake system can be designed according to the positioning of the fan and filter system indoors or outdoors for the initial design. While designing such a fresh air intake system, there will be different situations to be evaluated depending on whether the fan and filter are indoors or outdoors. These advantages are;

- Better access to clean the filters,
- Easier maintenance of fan,
- Easier maintenance of outer case,
- Better air directing capability to split air conditioner indoor unit,

The reasons for choosing fans and filters indoors in the design of the fresh air intake system are summarized with the given items. The determining factor here is that due to the fact that the speeds on the blowing side of the fan are higher than the speeds on the fan suction side, there is less pressure loss, and the air-guiding ability of the fan and filter assembly located indoors is greater. In addition, the fan and filter assembly located indoors will provide easier maintenance.

2.2 Sub-Components of Fresh Air Intake System

As explained in the previous section, the sub-components to be used in a fresh air intake system located indoors are the fan, hose, filters and outer casing. The dimensions, fan efficiency, and location to be used in these components must provide the fresh air intake flow rate, and these rates are determined by the globally accepted standards.

Therefore, firstly the fresh air flow rate values required by the standard must be found for the design of the sub-components.

2.2.1 Fresh Air Requirement for Living Areas

The factors to be considered when determining the fresh air requirement of a closed environment are the purpose of use of the environment, the number of people in the environment, the volume of the environment, air leaks in the environment etc.

ANSI/ASHRAE Standard 62-2001, a globally accepted source of ventilation systems, was used in this study to determine the fresh air requirement of living space

(ASHRAE, 2004). A suitable area of use was selected from the tables specified in the standard, and the calculation parameters for the amount of fresh air needed for this area were examined. Then, these parameters were written in the equation specified in the standard, and the required fresh air flow rate was calculated. The relevant parameters for the selected environment are shown in Table 2.1.

Table 2.1 ANSI/ASHRAE 62-2001 required ventilation rates (ASHRAE, 2004)

Occupancy Category	**People's Outdoor Air Rate R_P**		**Area Outdoor Air Rate R_A**		**Default Values**		
					Occupant Density	**Combined Outdoor Air Rate**	
	cfm/person	**L/s.person**	**cfm/ft²**	**L/s.m²**	**#/1000 ft² (#/100 m²)**	**cfm/person**	**L/s.person**
Office Space	5	2,5	0,06	0,3	5	17	8,5

$$V_{bz} = R_p P_z + R_a A_z \tag{2.1}$$

Where:

A_z = zone floor area: the net occupiable floor area of the zone m² (ft²).

P_z = zone population: the largest number of people expected to occupy the zone during typical usage.

R_a = outdoor airflow rate required per unit area

R_p = outdoor airflow rate required per person

According to the tables given in the standard document, the required fresh air amounts are given according to the environment type on the basis of a person or square meter area. For the product developed in this study, a living room with an average size of 30 m² and a split air conditioner indoor unit with a capacity of 18000 Btu/h are taken into account. Accordingly, the approximate amount of fresh air to be consumed for the specified environment is 0.3 L/s.m², and this value is calculated as 32.4 m³/h for this specified area.

2.2.2 Fresh Air Carrier Tool

An air conditioning unit that incorporates a fresh air intake system will be installed in a living area with a surface area of 30 m². A hose will be utilized extending out of the area to facilitate the intake of external air. Calculations of flow rate, considering various hose dimensions, have been performed to assess the feasibility of placing the air conditioning unit in different locations within the room. As illustrated in Figure 2.4, the chosen hose has a diameter of 30 mm and a length of 2 m.



Figure 2.4 Selected carrier tool – hose

2.2.3 The Filter Assembly of Fresh Air Intake System

The fresh air intake system, 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 blowing side of the hose. In the filter assembly, a multi-layer filter structure is used based on traditional air cleaner products. As shown in Figure 2.5. the first filter used in the setup is the "dust filter", which will filter the large particles such as dust, then the "active carbon filter", which will absorb the odour components such as cigarette smoke, and finally, the "special filter" to keep the very small particle sized pollutants away such as bacterias.

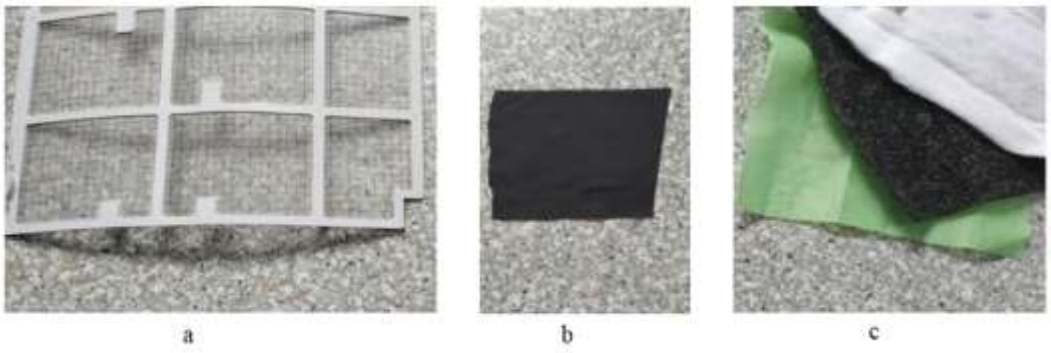


Figure 2.5 Filter assembly, a) Dust Filter b) Activated Carbon Filter c) Special Filter

2.2.4 The Fan of Fresh Air Intake System

During the development of the fresh air intake module, it is important to choose the correct fan that meets the system requirements. The type of fan used in this system is determined to be a centrifugal fan. The advantages of using centrifugal fans over the other types of fans on a fresh air intake system are high efficiency at high air volumes, less noise compared to axial fans, less maintenance required, ability to handle air with higher temperatures and pressures, can be installed on small and compact places. The centrifugal fan used in this study is shown in Figure 2.6.



Figure 2.6 Centrifugal fan (Xinruilian Science & Technology Co ; Ltd, 2021)

2.3 Design Alternatives and Assembly of Subcomponents

The fresh air intake module will bring the fresh air coming from outside to the indoor environment, and after cleaning it with its filters, it will direct it to the upper part of the split air conditioner indoor unit, which is the suction part for air conditioning.

The fresh air intake module, which will direct the fresh air to the split air conditioner indoor unit, can be positioned in certain areas of the unit. For the best air conditioning efficiency, it will be appropriate for the fresh air to be taken from outside to enter the split air conditioner through the suction vents in the upper area. One of the designs that can provide this situation is positioning the fresh air intake module on the right and left sides of the air conditioner. Computer Aided Design (CAD) data of side positioned fresh air intake module is shown in Figure 2.7. and the prototype of this module is shown in Figure 2.8.

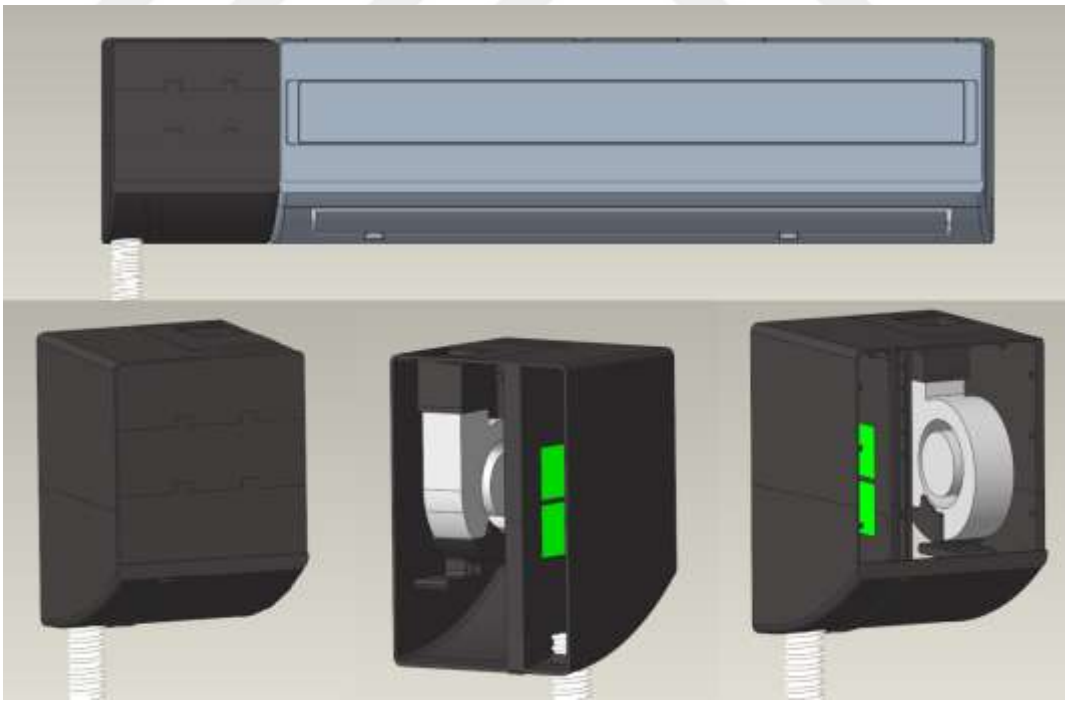


Figure 2.7 Positioning the fresh air intake module on the side of the split air conditioner indoor unit - CAD data



Figure 2.8 Positioning the fresh air intake module on the side of the split air conditioner indoor unit – Prototype

Another design method for the fresh air intake module, where the air can be efficiently directed to the air suction area of the split air conditioning unit, is to position the module on the upper parts (top) of the split air conditioner unit. CAD data of the top-positioned fresh air intake module is shown in Figure 2.9. and the prototype of this module is shown in Figure 2.10.

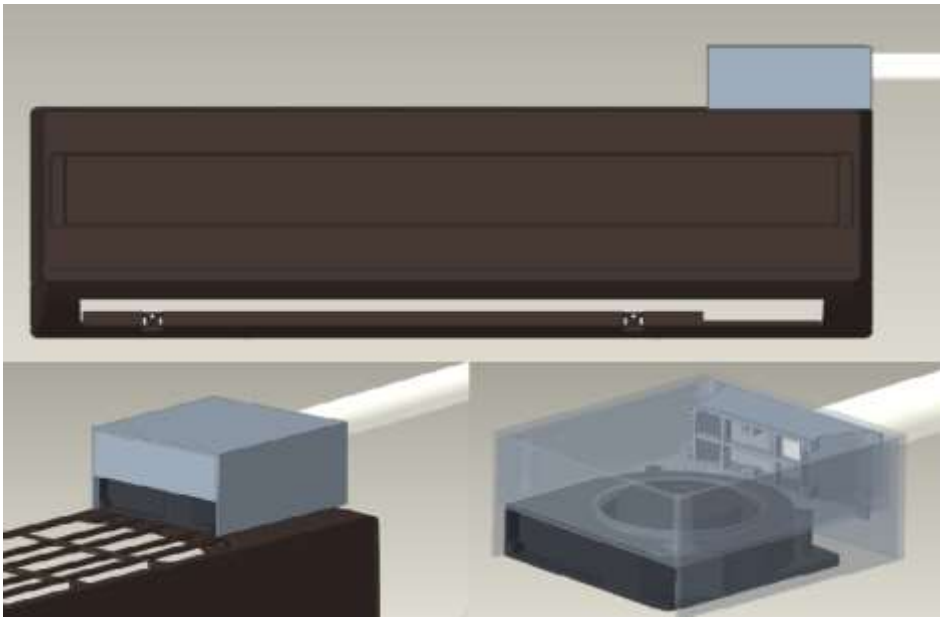


Figure 2.9 Positioning the fresh air intake module on the upper-part (top) of the split air conditioner indoor unit CAD data



Figure 2.10 Positioning the fresh air intake module on the upper-part (top) of the split air conditioner indoor unit Prototype

In this way, thanks to the positioning of the module in the most efficient position, the un-conditioned air leaving the fresh air intake module will be able to be sent to the air suction part of the split air conditioner unit without the need for any air direction tool. Thus, the air leaving the fresh air intake module will be fully air-conditioned and efficient heating-cooling will be provided.

CHAPTER THREE
EXPERIMENTS AND METHODOLOGY

The centrifugal fan will fulfill the function of taking the fresh air from the outside environment and transporting it to the indoor environment. For this reason, it is necessary to create an experimental setup where it will be tested to determine the appropriate centrifugal fan for the study.

Surrounding components will be placed after the centrifugal fan is decided. Next, the structure of the experimental system will be decided.

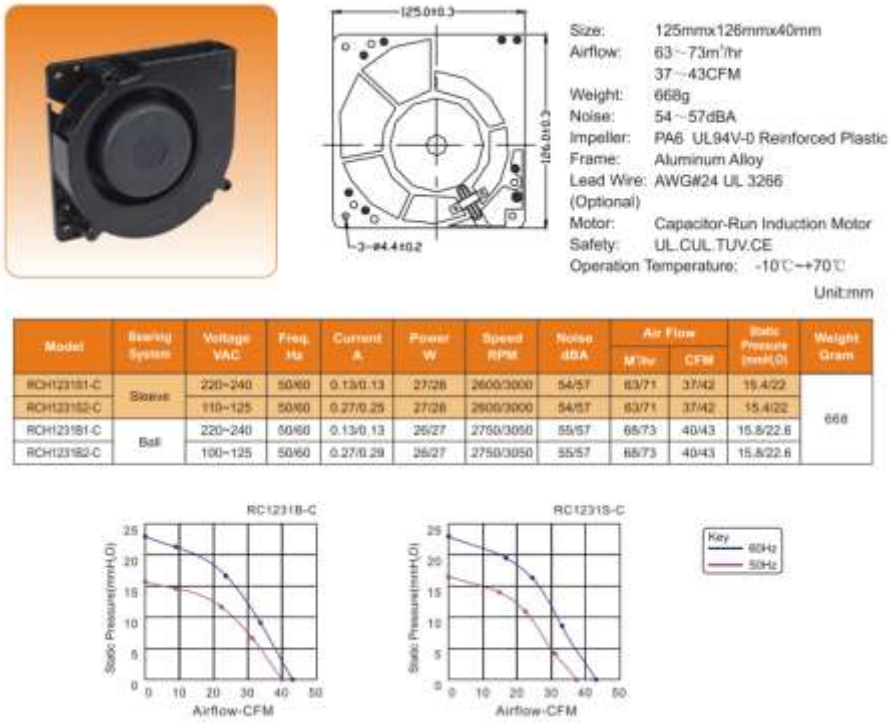
3.1 Design for Test System to Determine the Suitable Centrifugal Fan

In Chapter 2, Table 2.1. fresh air requirement for living areas is explained and calculated. Using the ANSI/ASHRAE Standard 62-2001, the fresh air flow rate that should be pumped by the centrifugal fan into the indoor area was determined (ASHRAE, 2004).

Fan curves were requested for the fans that are in the product catalogues of the fan supplier companies and whose size criteria are suitable for the desired dimensions. An example of this fan catalogue is shown in Figure 3.1.

In addition to the dimension characteristics for these fans, the fresh air flow requirement was calculated using the standards, and the pressure drops due to the filter and hose were taken into account. The minimum flow rate value that the fan must provide is calculated as 185±3 Pa pressure drop, corresponding to 32.4 m^3/h.

When the fan curves in the fan catalogues are examined, the intention is to choose the fans where the static pressure points corresponding to the airflow can be able to provide the desired value and above.



Model	Bearing System	Voltage VAC	Freq. Hz	Current A	Power W	Speed RPM	Noise dBA	Air Flow M³/hr	Air Flow CFM	Static Pressure (mmH2O)	Weight Gram
RCH1231B1-C	Sleeve	220~240	50/60	0.13/0.13	27/28	2600/3000	54/57	63/71	37/42	15.4/22	668
RCH1231S2-C		110~125	50/60	0.27/0.25	27/28	2600/3000	54/57	63/71	37/42	15.4/22	
RCH1231B1-C	Ball	220~240	50/60	0.13/0.13	26/27	2750/3050	55/57	68/73	40/43	15.8/22.6	
RCH1231B2-C		100~125	50/60	0.27/0.29	26/27	2750/3050	55/57	68/73	40/43	15.8/22.6	

Figure 3.1 Centrifugal fan catalogue for chosen fan (Xinruilian Science & Technology Co ; Ltd, 2021)

The point to be investigated in the curve and the table is 32.4m³/h flow rate against 185±3 Pa pressure drop. Values in this catalogue are given in mmH20 and CFM. This value corresponds to a flow rate of 19.1 CFM against a pressure drop of 18.9 mmH2O.

Fan curve and desired point of the fan is shown in Figure 3.2.

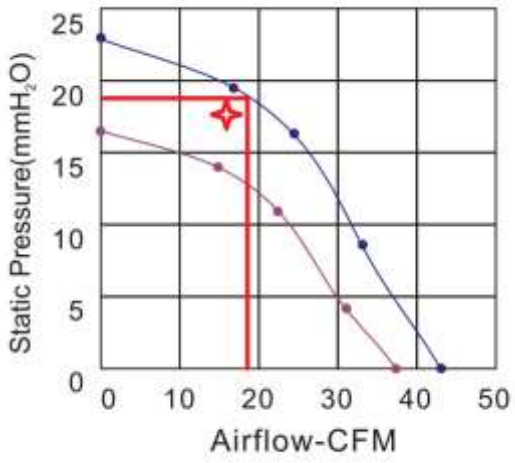


Figure 3.2 Fan curve and desired working point (Xinruilian Science & Technology Co ; Ltd, 2021)

Looking at the symbol indicated with red color over this curve, it is seen that this point can provide the desired static pressure and airflow values; therefore, this is a usable fan.

This and similar fans, which will provide the needed fresh air flow, have been determined and brought from fan supplier companies for experiments.

3.1.1 Design and Prototype of Fan Test Setup

Fans brought from suppliers are expected to overcome pressure drops under certain conditions. The pressure drop due to the hose, filter, nozzle and casing was calculated, and fans were comparatively examined in terms of airflow rate given under the same conditions in the same trial setup.

Firstly, the CAD design of the setup was made to create such a trial setup. While making this design, parameters such as filter chamber, airflow measurement mouth, and fresh air transporting hose were made to remain the same in all fan experiments. In this way, extra pressure drops that may occur due to these parameters and unpredictable inefficiencies have been prevented, and each fan has been tested to give the best comparison result. CAD and prototype design of the fan test setup with split air conditioner is shown with Figure 3.3. The image of fan test setup is given with Figure 3.4.

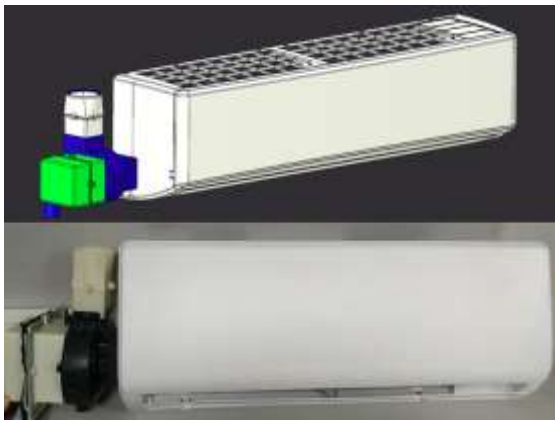


Figure 3.3 CAD design and prototype of fan test setup with split air conditioner



Figure 3.4 Fan test setup

3.1.2 Design of Filter Housing and Blowing Mouth for Fan Test Setup

A filter housing design has been made that can adapt to the suction nozzles of all centrifugal fans supplied by the fan suppliers and will show the same pressure drop for different fan sizes as long as the suction nozzle diameter does not change.

In addition, the blowing parts of the centrifugal fans may have different geometric shapes and dimensions from each other. A centrifugal fan-blowing mouth apparatus has been designed to adapt to all these different blowing regions and to keep the measuring mouth in which the anemometer can fit. The design of the housing and blowing mouth can be seen in Figure 3.5.

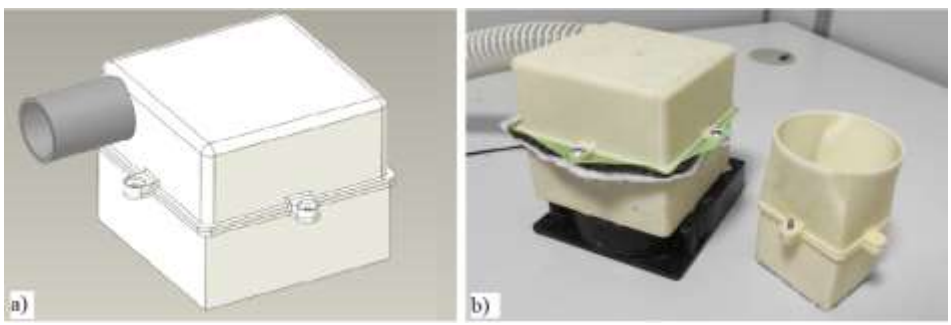


Figure 3.5 Design of housing and blowing mouth a) Filter Housing b) Blowing mouth apparatus

3.2 Experiments with Fan Test Setup

All fans brought from fan supplier companies were tested under the same conditions with the fan test setup, and their usability in the fresh air intake system was checked. In order to carry out this experiment, some auxiliary measuring devices and setting devices were used in the system.

Some measuring devices were used while conducting the experiments with the fan test setup. Tachometer used to measure fan rotation, anemometer is used to measure fan air speeds, a variac is used to change fan speed and similar measurement devices.

3.2.1 Adjusting the Voltage and Speed of the Fan by Using Variac

Variacs are a particular type of transformer characterized by a single winding structure. Transformers are electrical machines that operate without moving parts and can transfer the frequency of the voltage applied to its input to the output while keeping the power constant while also amplifying or reducing the voltage and current values. In essence, transformers function by converting magnetic energy. The absence of moving parts eliminates frictional losses, and under ideal conditions, the input power of a transformer is equivalent to the output power. However, practical applications of transformers experience losses that preclude 100% efficiency. Transformers have numerous applications, ranging from low voltage, weak current setups to high voltage power transmission lines. Additionally, measurement transformers, including current and voltage transformers, are commonly utilized (Özmen, 2014). The image of variac used in this current study is shown in Figure 3.6.



Figure 3.6 Adjusting the voltage and speed of the fan by using variac

3.2.2 Measurement of Fan Revolution Frequency by Using Tachometer

The revolutions of the centrifugal fan are measured manually with a tachometer. There is a reflective tape of the tachometer attached to the fins on the centrifugal fan. The light sent from the tachometer warns the tachometer by reflecting on the band at each rotation of the fan. This frequency, which is read in terms of Revolution Per Minute (rpm) on the tachometer, is recorded (Binark, 2019). The tachometer used in this study is shown in Figure 3.7.



Figure 3.7 Centrifugal fan revolution per minute (rpm) measurement with tachometer

3.2.3 Measurement of the Air Speed by Using Anemometer

The propeller-type anemometer utilizes a rotating propeller that is driven by the axial fluid flow. The rotational motion of the impeller, induced by the flow, is measured electrically, providing valuable information about the fluid flow characteristics. The propeller shaft, which rotates as a result of the fluid flow, is transmitted through a gear system and evaluated based on the degree of rotation. In modern anemometers, sensors detect the rotational motion of the propeller shaft, and the resulting signals are processed to yield speed values that can be displayed on digital indicators. Measurements with propeller-type anemometers can provide average flow

rates over a specific time interval. The measuring range of propeller-type anemometers typically falls between 0.3 m/s and 30 m/s (Küllü, 2008).

In the experiments carried out in the fan test setup; All parameters such as fan speed change operation, fan speed measurement and airspeed measurement in the blowing part of the fan are controlled for each fan. These fans are the fans that are taken from the suppliers and have suitable operating points considering the fan curves. As a result of the experimental values, the fan, which yields the ideal result and can be operated with the electronic circuit board, has been decided as the fan to be used in the split air conditioner that can take fresh air into the working environment. The anemometer used in this study is shown in Figure 3.8.



Figure 3.8 Centrifugal fan air speed measurement with anemometer

After all these test results were taken and the fan was determined, the prototype of the first fresh air intake module, the design of which was explained in Section 2.3. was made and tested.

3.3 Particle Image Velocimetry (PIV)

PIV is an advanced flow measurement technique that allows the measurement of fluid flow velocity and direction in a two-dimensional or three-dimensional plane. PIV involves introducing small tracer particles into the fluid, illuminating the particles with a laser sheet, and capturing the particle motion with a camera. PIV provides high spatial and temporal resolution, which enables the detection of small-scale flow features that may be missed by other flow measurement methods. PIV is versatile and can be used to measure flow in a wide range of fluids and flow configurations. Additionally, PIV does not interfere with the flow being measured, and there is no physical obstruction in the flow path that could cause measurement errors.

PIV also provides quantitative measurements of the flow velocity field, which can be used to validate numerical simulations and improve the understanding of flow physics. PIV can be extended to measure the velocity field in three dimensions by using multiple cameras and laser sheets. This technique is particularly useful for applications where conventional flow measurement techniques are insufficient or impractical, such as in complex flow geometries or turbulent flows. PIV is widely used in research and engineering applications, including aerodynamics, hydrodynamics, and biomedical engineering. To summarize briefly, PIV is a powerful and valuable flow measurement technique that provides detailed information on fluid flow with high resolution and precision without disrupting the flow being measured.

In this study, the PIV method was used during the adjustment of the fresh air module positioned in the split air conditioner, the fresh air blowing rates and the efficient suction of the fresh air into the split air conditioner for air conditioning.

3.3.1 Working Principle of PIV

The working principle of PIV is based on tracking small particles suspended in the fluid flow. These particles act as trackers, allowing flow velocity to be measured by tracking their movement over time. Particles are typically injected into the stream in a

way that does not disrupt the stream structure, for example, by injecting a small amount of smoke, oil droplets or small reflective particles into the stream. The particles must be small enough to follow the flow, and the particles must not be affected by other types of motion.

After the particles are added, a laser plate is used to illuminate the flow area, causing the particles to scatter the light. A pair of cameras are then used to capture a series of images of particle motion over a given time interval. The displacement of particles between consecutive frames is then used to calculate the velocity field of the flow using specialized software.

3.3.2 Components of PIV Setup

The conventional PIV setup employed for flow measurements is a sophisticated and intricate system that necessitates meticulous calibration and setup procedures to ensure precise and dependable measurements. The components of the PIV system must be cautiously chosen and configured to ensure that the obtained measurements reflect the actual flow conditions. The precision and resolution of the measurements are directly correlated with the quality of the equipment used and the level of expertise of the operator in the setup and execution of the experiment.

The PIV system comprises several components, including lasers, cameras, optics, and seeding particles, each of which plays a crucial role in the accurate measurement of the air flow. The laser and optics provide illumination to the particles, and the camera captures the scattered light. The seeding particles are injected into the flow to enable the laser to visualize the flow pattern. The calibration of the PIV setup is a crucial step that involves ensuring that the laser sheet and the camera are positioned and focused correctly, the particle seeding concentration is optimal, and the camera exposure settings are optimized for the specific flow conditions.

In comparison to conventional flow measurement techniques, such as pitot tubes and hot wire anemometry, PIV provides a higher resolution and accuracy in measuring

flow fields. However, PIV can be more complex to set up and operate, and the equipment required can be very expensive. To summarize, conventional PIV setup for flow measurements is a complex system that necessitates careful calibration and setup procedures to ensure accurate and reliable measurements. The components and specification of PIV setup used in this study is shown in Figure 3.9.



Figure 3.9 Components and specification of PIV system

The schematic representation of the PIV experimental setup and the fresh air intake module in this current study is shown in Figure 3.10.

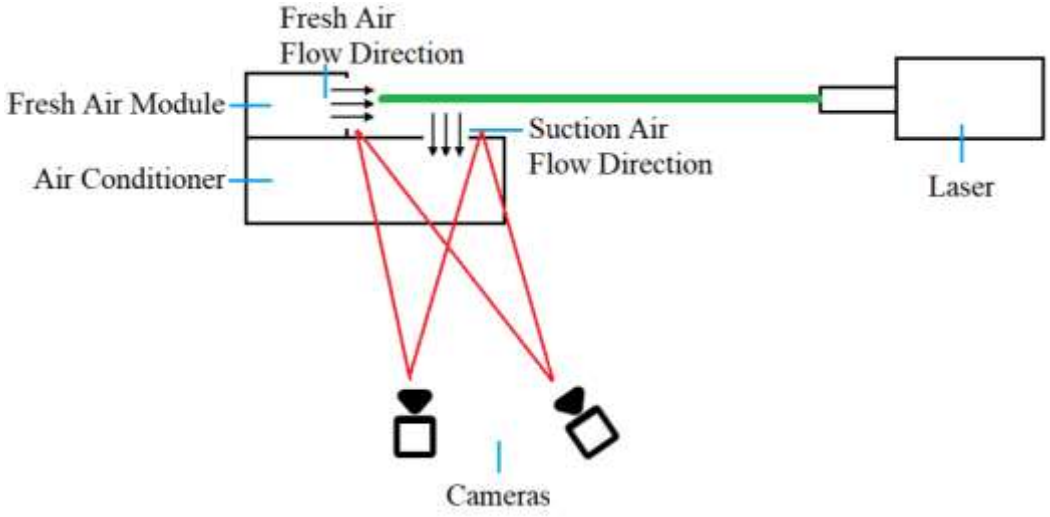


Figure 3.10 Illustration of PIV setup used in the current study

3.3.2.1 Laser

The laser is a crucial component of the PIV system that provides the illumination required to visualize the flow. Laser technology has advanced significantly over the years, with high-powered lasers capable of providing illumination in a variety of wavelengths. The choice of laser depends on the specific application and the desired level of accuracy. The laser used in this study is shown in Figure 3.11.

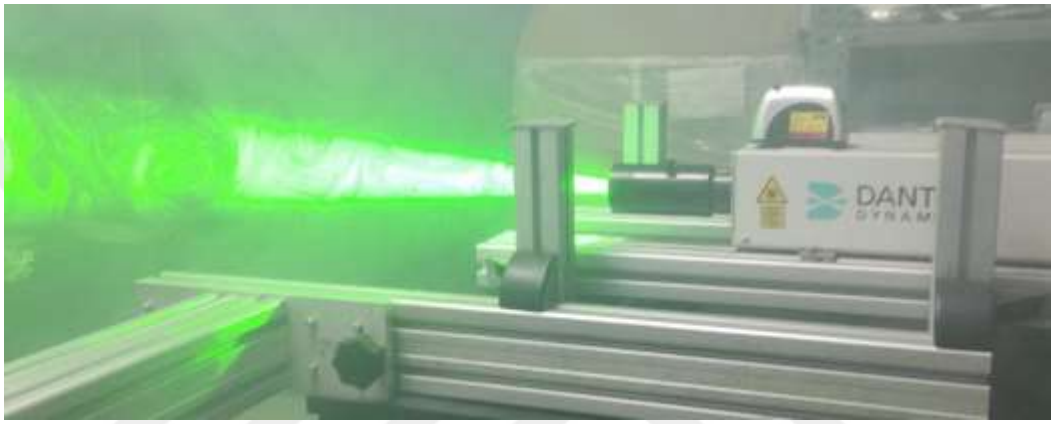


Figure 3.11 Laser equipment

3.3.2.2 Camera

The camera is an essential component of the PIV system that captures the images required to measure the flow. High-speed cameras are commonly used in PIV experiments to capture instantaneous flow fields. The camera resolution and image acquisition rate are critical factors that determine the accuracy and resolution of the measurements. The cameras used in this study are shown in Figure 3.12



Figure 3.12 Camera equipment

3.3.2.3 Seeding Particles

Seeding particles are small, light particles that are introduced into the flow to enable the laser to visualize the flow pattern. The choice of seeding particles depends on the particular application and the desired level of accuracy. Commonly used seeding particles include fog fluid, oil droplets, smoke and microspheres. The seeding particles used in this study are fog fluid as shown in Figure 3.13.

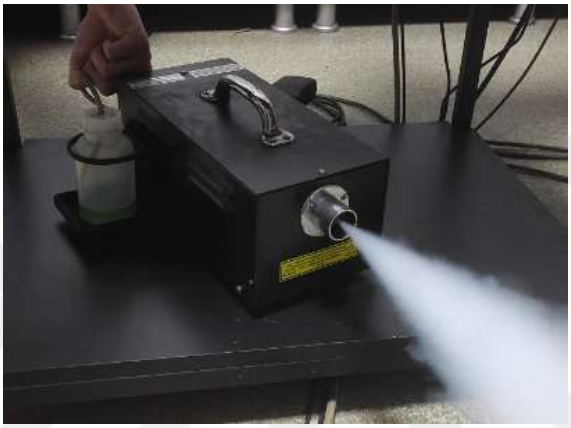


Figure 3.13 Seeding particles - fog fluid

3.3.2.4 Calibration Target

Calibration is a crucial step in the PIV setup process that involves ensuring that the laser sheet and camera are positioned and focused correctly, the particle seeding concentration is optimal, and the camera exposure settings are optimized for the specific flow conditions. Proper calibration is essential to obtaining accurate and reliable measurements.

In this study, a calibration target was used in the calibration phase. This target was aligned with the cameras and laser and brought into a position suitable for experimentation. The distance of this target to the cameras was optimized by providing the correct values on the machine where the test results were examined, and the studies were carried out in this way. The calibration target used in this study is shown in Figure 3.14.



Figure 3.14 Calibration target

3.3.2.5 The Synchronizer

The synchronizer is an important component in conventional PIV systems for flow measurements. It provides precise timing between the laser firing and the acquisition of the CCD camera image, with an accuracy of around one nanosecond. This timing ensures that the correct calculation is made between the two laser pulses, enabling accurate measurement of the flow rate. The synchronizer also ensures that the camera and laser are triggered simultaneously, allowing for straight image recording and proper lighting to observe the particles within the flow. Therefore, its role is essential in ensuring correct and reliable measurements can be made in flow experiments.

3.3.2.6 Computer and Software

The computer and software play an important role in conventional PIV systems for flow measurements by analyzing the images captured during the experiment. Cross-correlation techniques are commonly used to calculate the flow field's velocity vectors, involving dividing images into interrogation regions, and cross-correlating the particle images in consecutive frames. The accuracy of the analysis relies on the quality of the images and the software utilized, as well as the expertise level of the operator in setting up the experiment and configuring the software. Therefore, the computer and software

are indispensable components in PIV systems, enabling the analysis and interpretation of the acquired data.

3.3.1 Experiments of Fresh Air Intake Module with PIV method – Side Position Module

The first module considered for the design of a split air conditioner with a fresh air intake function is the design to be positioned on the right side of the unit (Figure 2.7. and Figure 2.8.). The blowing mouth part of this module, which is the air outlet, is divided into six equal plane intervals. The air-blowing efficiency of the module was tested by taking PIV data over these planes. In the images Figure 3.15. and Figure 3.16. the prototype and CAD data of this module have been shown.

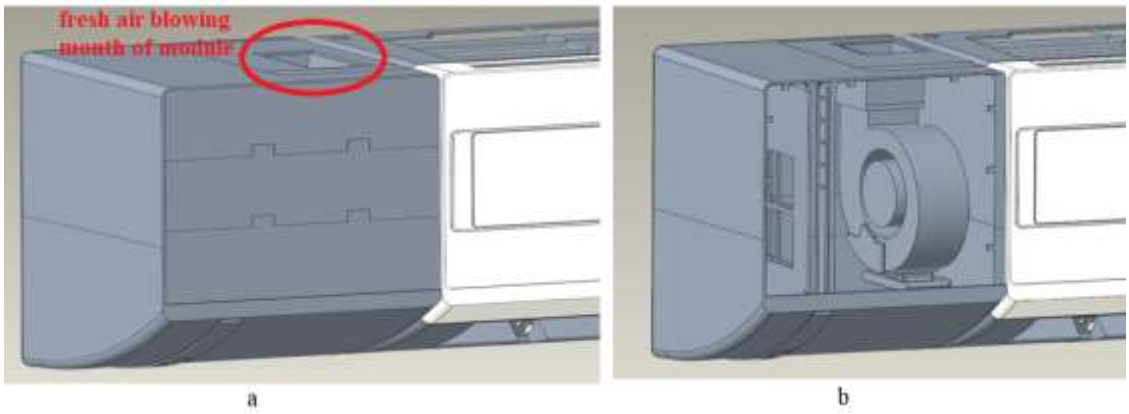


Figure 3.15 3D CAD of the module positioned to the side of split air conditioner a) Closed module b) Open module with inner components

In Figure 3.16. prototype of the module and the 6 decided investigation planes of blowing mouth for PIV experiments has been shown.

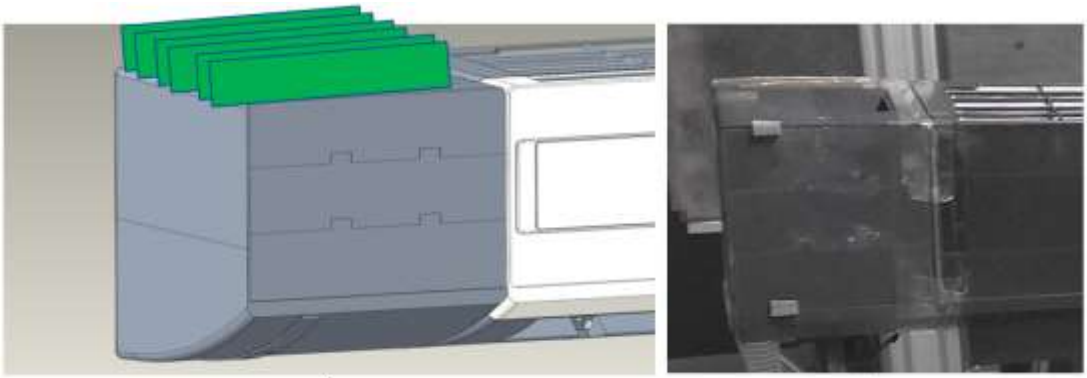


Figure 3.16 Experiment planes on blowing mouth and prototype of the fresh air intake module positioned to the side of split air conditioner a) Experiment planes on blowing mouth b) Prototype module

The fresh air intake module, which is located on the side of the air conditioner, is positioned on the traverse. The split air conditioner unit and the fresh air intake module are seen in the PIV test room shown in Figure 3.17. The air conditioner unit with fresh air intake module, which is mounted on the traverse, has been brought to its suitable position for the PIV experiments, taking into account its position relative to the cameras and laser of PIV experiment equipment.

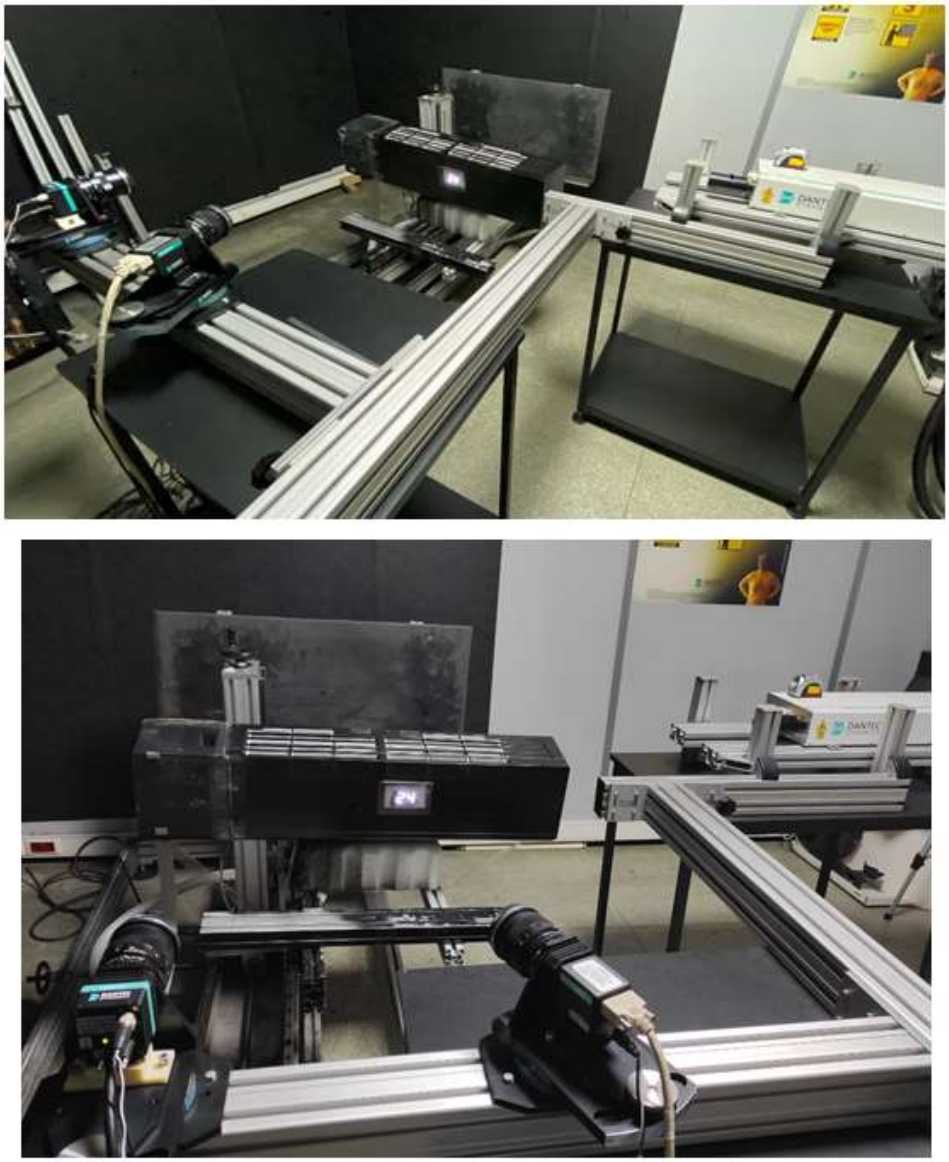


Figure 3.17 Picture of fresh air intake module and split air conditioner ready for PIV experiment - side position module

3.3.2 Experiments of Fresh Air Intake Module with PIV method – Top Position Module

When the test results of the fresh air intake module positioned on the side of the split air conditioner unit were examined, it was seen that the air-directing efficiency of the side-positioned module was not sufficient. In order to solve this situation, a second module positioned at the top of the split air conditioner has been considered, which can direct the fresh air to be taken from the outside environment into the split air

conditioner more efficiently. This top-positioned fresh air intake module is shown in Figure 3.18. and Figure 3.19.

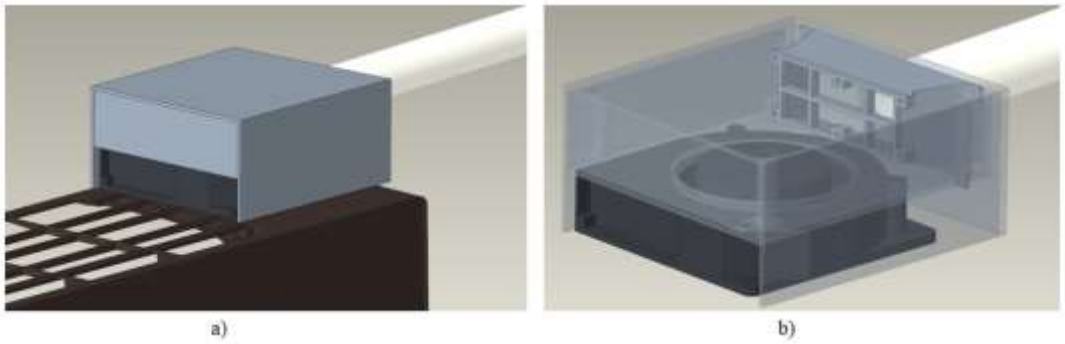


Figure 3.18 CAD data of fresh air module positioned to the top side of split air conditioner a) Module with split air conditioner b) Transparent module to show the components inside

In Figure 3.18. prototype of the module and the seven decided investigation planes of blowing mouth for PIV experiments have been shown.

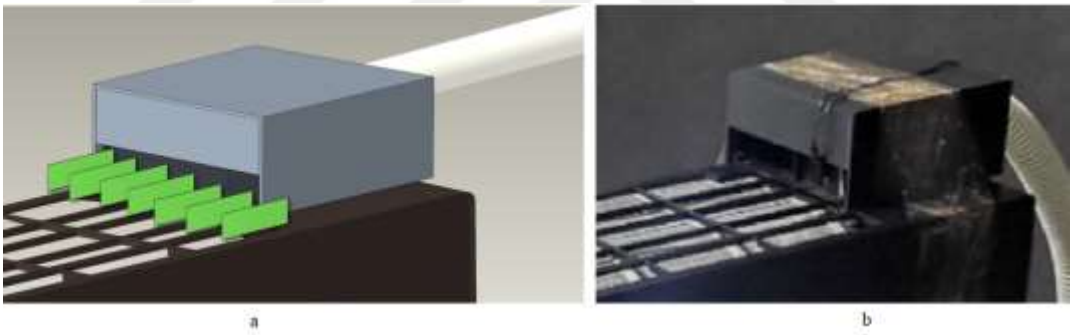


Figure 3.19 Experiment planes on blowing mouth and prototype of the module positioned to the top of split air conditioner a) Experiment planes on blowing mouth b) Prototype module

In the image given in Figure 3.20. the fresh air intake module, located on the side of the air conditioner, is positioned on the traverse, the inspection area. The split air conditioner unit and the fresh air intake module are in the PIV test room. The air conditioner unit with fresh air intake module, which is mounted on the traverse, has been brought to its suitable position for the PIV experiments, considering its position relative to the cameras and laser of PIV experiment equipment.



Figure 3.20 Picture of fresh air intake module and split air conditioner ready for PIV experiment - top position module

According to the PIV results, it has been seen that positioning the fresh air intake module on the upper parts (top side) of the split air conditioner unit is more advantageous than positioning it to the sides.

3.4 Performance Test Chamber (PTC)

The Performance Test Chamber (PTC) contains measuring devices such as an air duct, ambient, outdoor, and indoor sensors, dry and wet bulb thermometers. It has an algorithm that will output these values to meaningful results in a terminal computer where all these measuring devices work together, and the room values are transmitted. This algorithm evaluates the results from the room in psychometric diagrams and thermodynamic tables embedded in it. On the terminal computer, where the values of the room are reflected, meaningful results are read about the product connected to the room's duct.

At the same time, this performance test room can measure values such as power and current drawn by the product. Along with these values, it has the ability to calculate the product's efficiency and seasonal efficiency values. The inside of PTC is shown in Figure 3.21



Figure 3.21 Inside view of performance test chamber

PTC distributes the air homogeneously into the room with air tunnels, it is a specially designed tunnel with perforated structure in order to make the air distribution appropriately inside the room.

Ambient pressure sensor is the sensor that measures room pressure. At the same time, there are duct pressure sensors that measure pressure in the tunnel, pressure difference values are read using these sensors.

The psychometric duct takes a sample of air from the suction part of the product and accordingly directs this air to the wet and dry bulb thermometer of the environment. It is the component that performs the conditioning of the room.

The air duct is the mechanism that directs the output air of the product to the sensors. There are air-regulating flaps in the duct. These flaps ensure the homogeneous distribution of the air in the duct, and the correct reading of the sensor results. Sensors connected to the air duct are shown in Figure 3.22. and the sensors of the PTC chamber is shown in Figure 3.23.

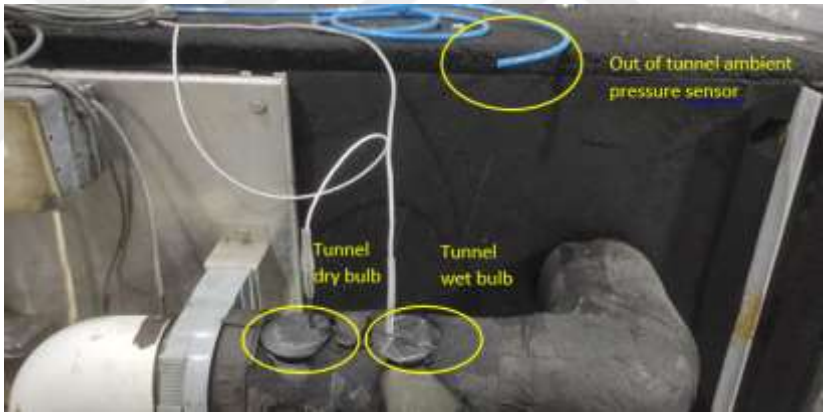


Figure 3.22 Duct sensors inside PTC chamber

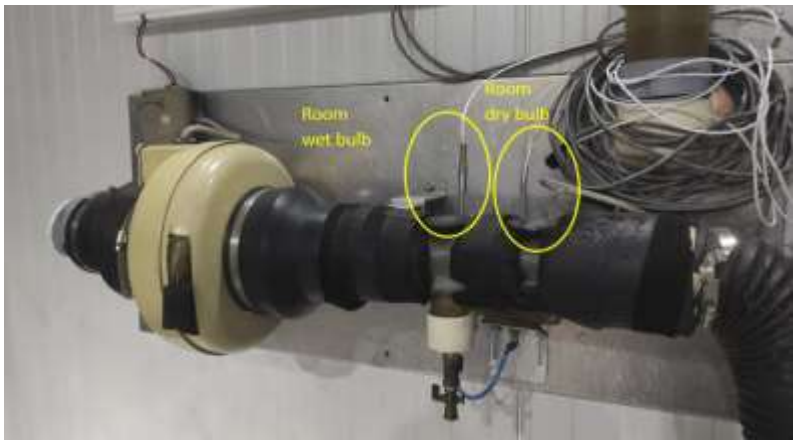


Figure 3.23 Sensors inside PTC chamber

At the back of the performance test chamber, there are nozzles of the duct where the pressure differences in the duct are adjusted. These nozzles are 3" 4" 5", and a second 5" nozzle. With these nozzles, correct measurement is ensured by setting the pressure difference between the product and the test room to appropriate values. The back side of room and ducts nozzles shown in Figure 3.24



Figure 3.24 Back side of the room and ducts nozzles

The terminal computer, in which the results of the measurements made in the performance test room are reflected, and which contains the thermodynamic tables and psychometric diagram in its algorithm, can be seen in Figure 3.25.

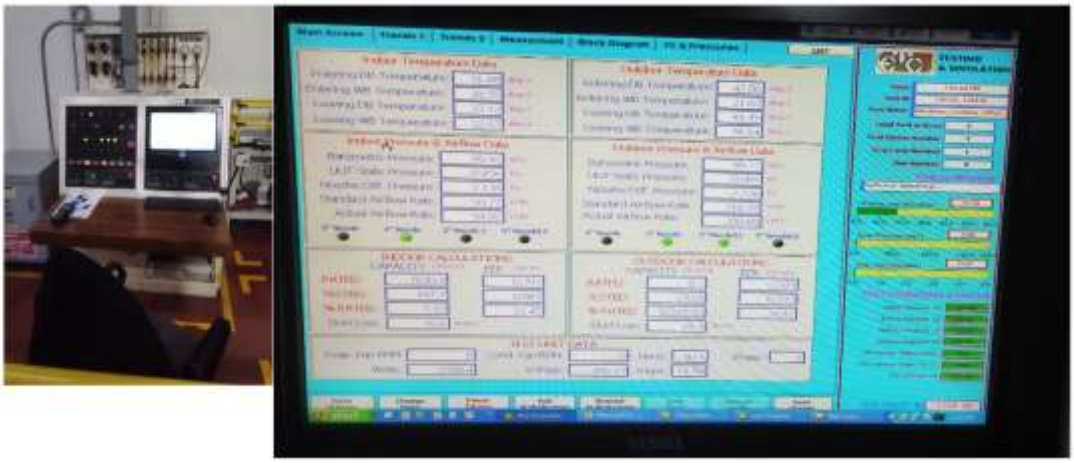
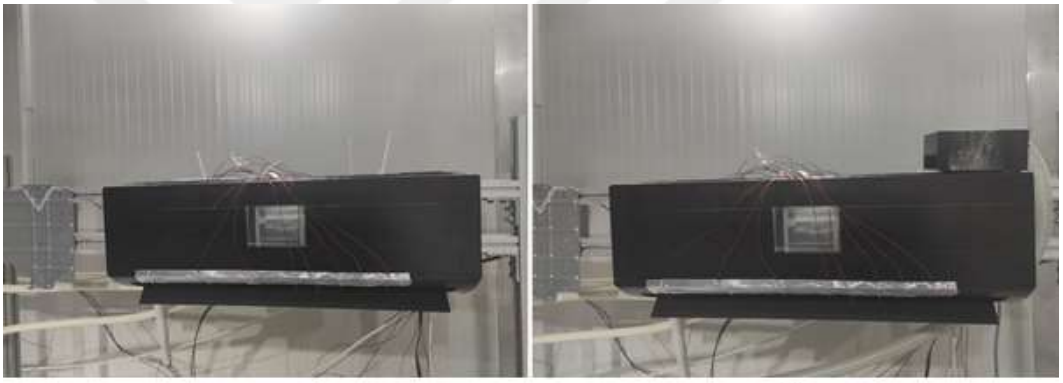


Figure 3.25 Terminal computer of PTC laboratory

3.4.1 Experiments of Split Air Conditioner with Fresh Air Intake Module at PTC Laboratory

After performing the PIV tests, it was decided to perform performance tests with the fresh air intake module located on the upper side (top position) of the split air conditioner unit, which was found to yield better results.

Performance tests were carried out comparatively in the performance test chamber as there is a fresh air intake module and there is no fresh air intake module. It is necessary to carry out the experiments at the same time and condition in order for this comparison to be healthy. Comparative tests in the PTC laboratory are shown in Figure 3.26.



a) b)

Figure 3.26 Comparative PTC laboratory tests a) Without fresh air module b) With fresh air module

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. Thermocouple line-up in PTC laboraty on split air conditioner can be seen in Figure 3.27. and 3.28.

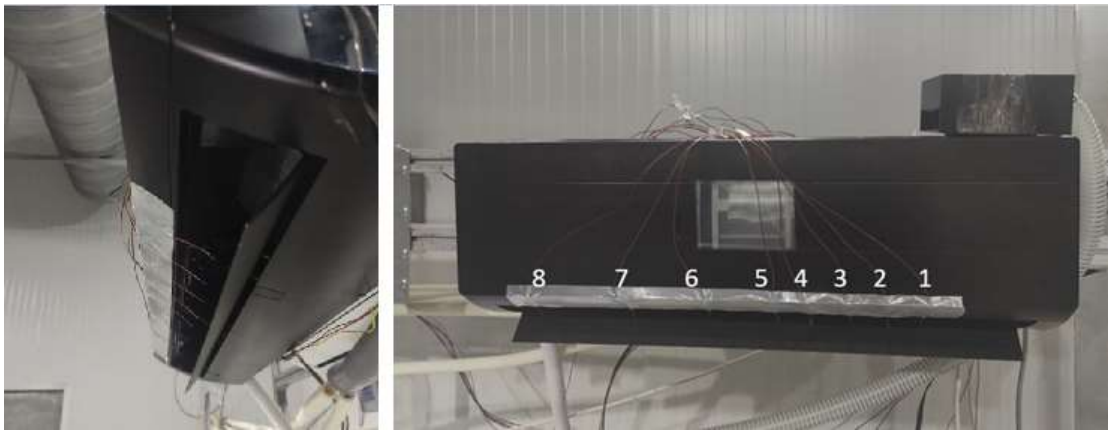


Figure 3.27 Thermocouple line-up to air outlet of split air conditioner

After the fresh air-intake split air conditioning system was prepared for performance tests, it was connected to the duct system, which included sensors that output the result values to be read from the computer of the performance test room and subjected to experiments.



Figure 3.28 Duct connection of fresh air intake split air conditioner

CHAPTER FOUR
RESULTS AND DISCUSSION

In this chapter, the experimental results of the fresh air intake split air conditioner, the design of which is described in Chapter 2 and the experimental setup and methodology are described in Chapter 3, will be explained.

4.1 Fan Selection Results

The image of the tested centrifugal fans is shown in Figure 4.1. and the close up images of the selected centrifugal fan is shown in Figure 4.2.

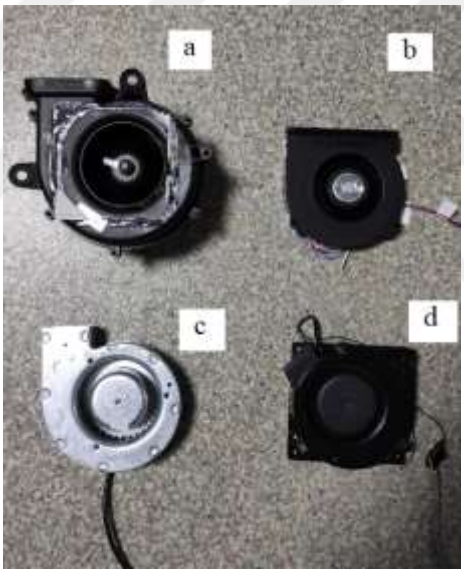


Figure 4.1 Tested centrifugal fans a) Fan-Ref b) Fan-1 c) Fan-2 d) Fan-3



Figure 4.2 Selected centrifugal fan images - Fan-3

The results obtained from the centrifugal fans, which were tested by using the fan test setup, are as given in Table 4.1. The centrifugal fan given as Fan-3 in the table is selected. The fan named 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.

Table 4.1 Fan selection results

Fans	Volumetric Flowrate [m³/h]	Mass Flowrate [kg/h]	Density [kg/m³]	Velocity [m/s]	Diameter [m]	Area [m²]	Hose Length [m]	Filter Order	Fan RPM and Voltage
Fan-Ref (known fan curve)	37.36	45.76	1,225	2,35	0,075	0,004416	10	Hose – Activated Carbon Filter – Special Filter	1560 rpm (230V)
	32.59	39.92	1,225	2,05	0,075	0,004416	10	Hose – Activated Carbon Filter – Special Filter	
	34.97	42.84	1,225	2,2	0,075	0,004416	8	Hose – Activated Carbon Filter – Special Filter	
	35.61	43.62	1,225	2,24	0,075	0,004416	6	Hose – Activated Carbon Filter – Special Filter	
	38.79	47.51	1,225	2,44	0,075	0,004416	4	Hose – Activated Carbon Filter – Special Filter	
	42.92	52.58	1,225	2,7	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	
	33.22	40.70	1,225	2,09	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	860 rpm (125 V)
	31.79	38.95	1,225	2	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	2485 rpm (120 V)
Fan-1	14.31	17.53	1,225	0,9	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	1200 rpm
	23.84	29.21	1,225	1,5	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	1750 rpm
	42.13	51.60	1,225	2,65	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	2650 rpm
	50.87	62.31	1,225	3,2	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	3250 rpm
Fan-2	45.62	55.89	1,225	2,87	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	3127 rpm
	39.74	48.68	1,225	2,5	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	2800 rpm
	31.79	38.95	1,225	2	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	2400 rpm
Fan-3	61.36	75.17	1,225	3,86	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	2830 rpm (230 V)
	32.11	39.34	1,225	2,02	0,075	0,004416	2	Hose – Activated Carbon Filter – Special Filter	1900 rpm

Fan-3 was calculated as the most suitable centrifugal fan for the fresh air intake module when all variables were considered. The variable speed of the fan, the ability of the fan to be driven with the circuit board in the split air conditioner, the losses of the 2m hose length to be used, and other loss coefficients within the module. This fan works in accordance with the fan curves taken into account when ordering from fan suppliers and was determined as the most effective centrifugal fan to be used in this study.

4.2 PIV Results

In this section, the general air flow direction and velocity vectors of a split air conditioner with a fresh air intake module will be examined using the PIV method. Two different experimental setups were investigated, as the fresh air intake module was positioned to side and to top of the split air conditioner unit.

4.2.1 PIV Results – Side Position Module

The picture of the fresh air intake module positioned on the side of the split air conditioner unit is shown in Figure 4.3.

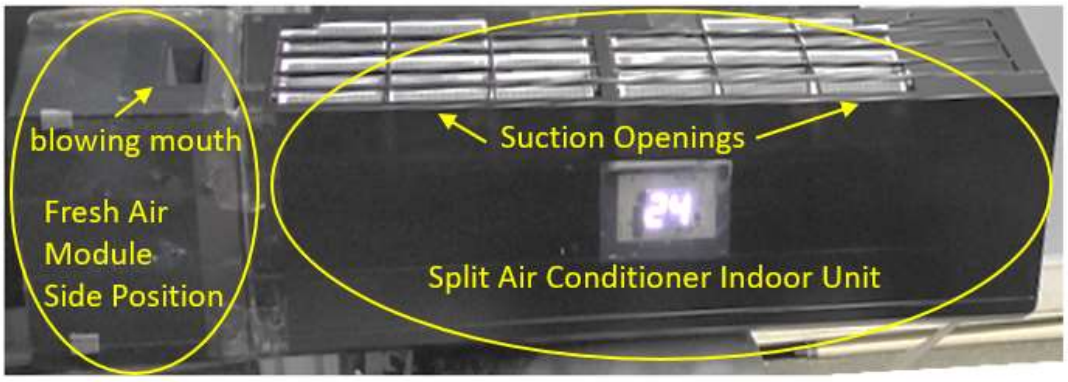


Figure 4.3 Fresh air intake module with split air conditioner - side position module

With the PIV method, laser shots will be made to the region where the air flow will be investigated. Laser shots illuminate the investigation area as a plane. The air flow coming out of the top of the fresh air intake module, which is the air outlet and called blowing mouth, will be examined by using this laser shot. Six planes including the blowing mouth section of fresh air intake module is divided into equal intervals were determined on fresh air intake module and the experiments were carried out on this region. This region is shown as CAD data in Figure 4.4.

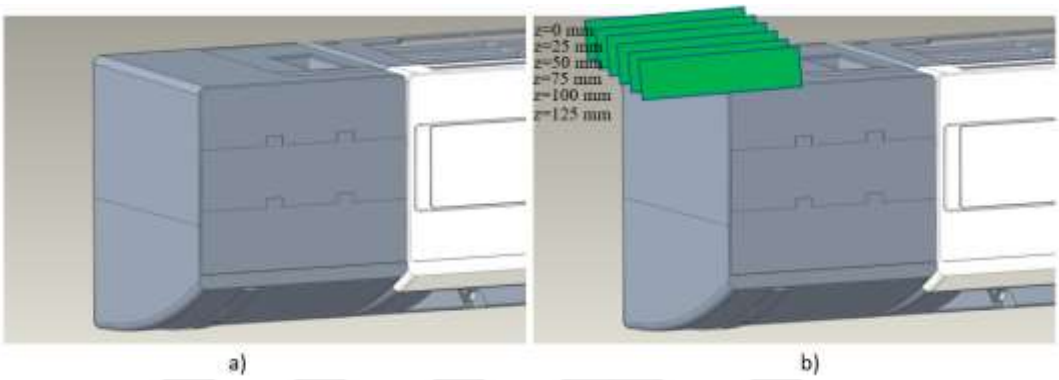


Figure 4.4 Investigation planes a) Fresh air intake module blowing mouth b) Investigation planes on fresh air intake module

It is desired to observe with the PIV method that the fresh air that will come out of the blowing mouth of the fresh air intake module is directed towards the suction opening area of the split air conditioner. Therefore, the laser shot must be able to see both regions in a way that there is no obstacle in front of it. These laser shots should be made to illuminate both the fresh air intake module and the split air conditioner. When all these are evaluated, the fresh air intake split air conditioner must be arranged slightly inclined in the experimental setup so that the laser shots can easily reach the examination area. This setup was shown at Section 3. Figure 3.17. The results obtained using six investigation planes in PIV tests are shown in Figure 4.5.

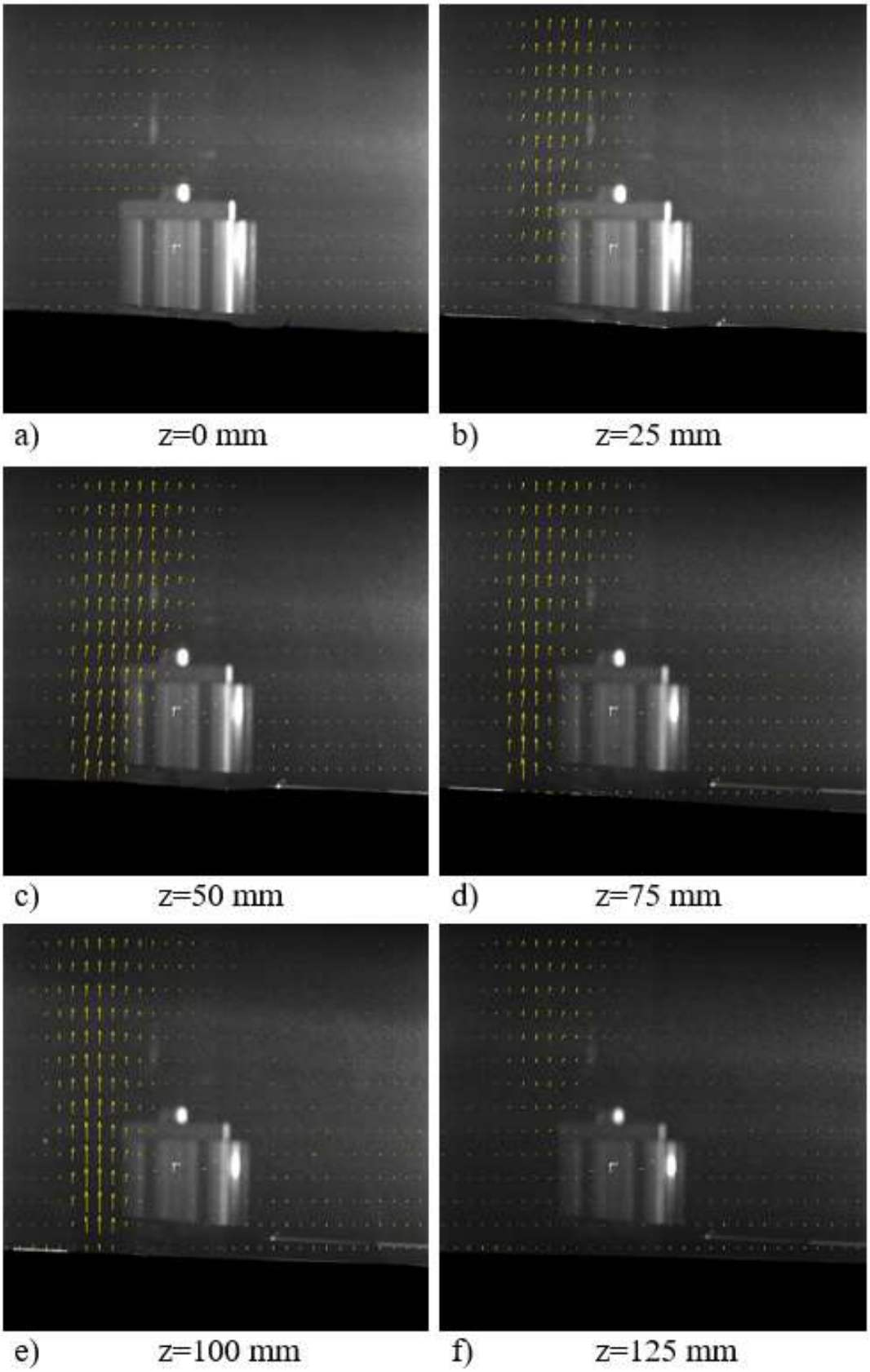


Figure 4.5 PIV test results for side positioned module - velocity data

In the PIV test setup of the fresh air intake module, the planes where the results can be read in the area are separated by planes 2,3,4,5. Because they are the planes where the laser beams coincide on the air outlet of the fresh air intake module. These planes correspond to z=25mm, z=50mm, z=75mm, z=100mm in the Z axis. Therefore, the velocity vectors seen in the test results of this region are clearer because the air flow takes place in this region. When looking at the areas that the laser beams pass over, there is an insignificant fresh air flow in the 1st and 6th planes. Therefore, the velocity data read from the 1st and 6th planes are not considered.

When the results from the z=25, 50, 75 and z=100 mm planes where the fresh air flow rate values are readable, examined; the air velocity of the fresh air intake module from the blowing mouth is comparatively high than z=0 mm and z=125 mm. This situation will cause the fresh air taken from outside without being conditioned to quickly mix with the ambient indoor air without being sufficiently absorbed by the split air conditioner suction zone. This will negatively affect the indoor air conditioning function of the split air conditioner.

The velocity of this air leaving the fresh air intake module should remain at the lowest 2 m/s because when all pressure drop factors of the module are calculated, it is the lowest speed value that can provide the fresh air intake flow requirement, which is calculated as at least 32 m^3/h. When it is desired to direct the fresh air to the suction area of the split air conditioner while maintaining this speed value, an air guiding apparatus can be designed. However, this apparatus will both disrupt the aesthetics by causing an undesirable appearance on the product, and increase the costs due to the material to be spent. Considering the air directing problem without using the apparatus, a whole new module design that will make it easier to direct the fresh air to the suction region of the split air conditioner unit and a new location will be required.

Because of this mentioned conditioning problem, the design alternatives described in Section 2.3, arose. If the side positioned fresh air intake module is described as first alternative, the second alternative is the fresh air intake module located at the top of the split air conditioner.

4.2.2 PIV Results – Top Position Module

The picture of the fresh air intake module positioned on the side of the split air conditioner unit is shown in Figure 4.6.

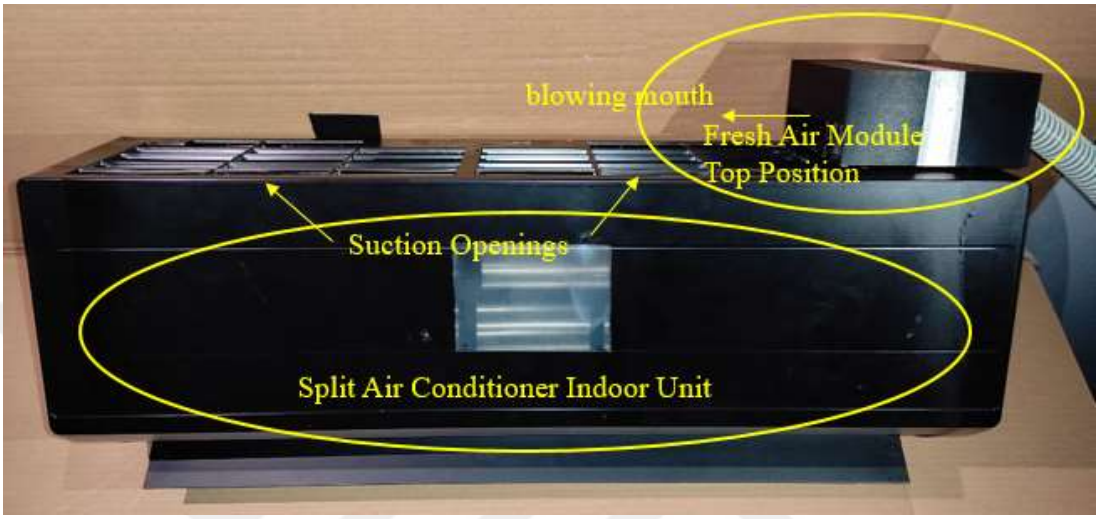


Figure 4.6 Fresh air intake module with split air conditioner - top position module

Top positioned fresh air intake module will be examined using seven investigation planes. Seven planes, including the blowing mouth section of the fresh air intake module are divided into equal intervals determined on top of the fresh air intake module, and the experiments were carried out on this region. This region is shown in Figure 4.7.

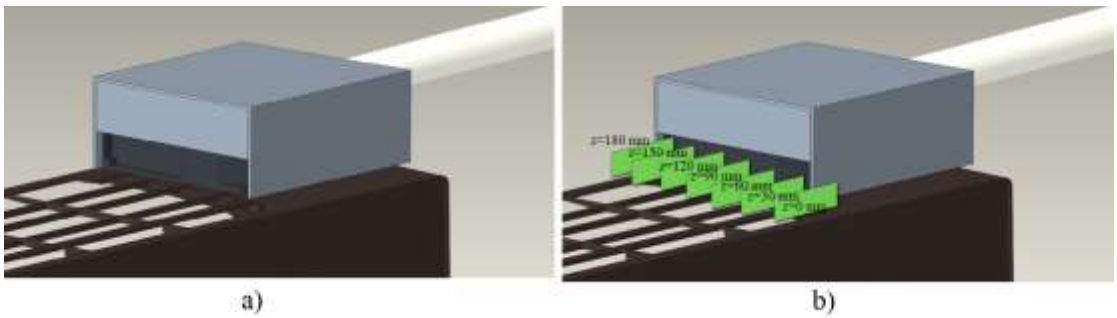


Figure 4.7 Investigation planes a) Fresh air intake module blowing mouth b) Experiment planes on fresh air intake module

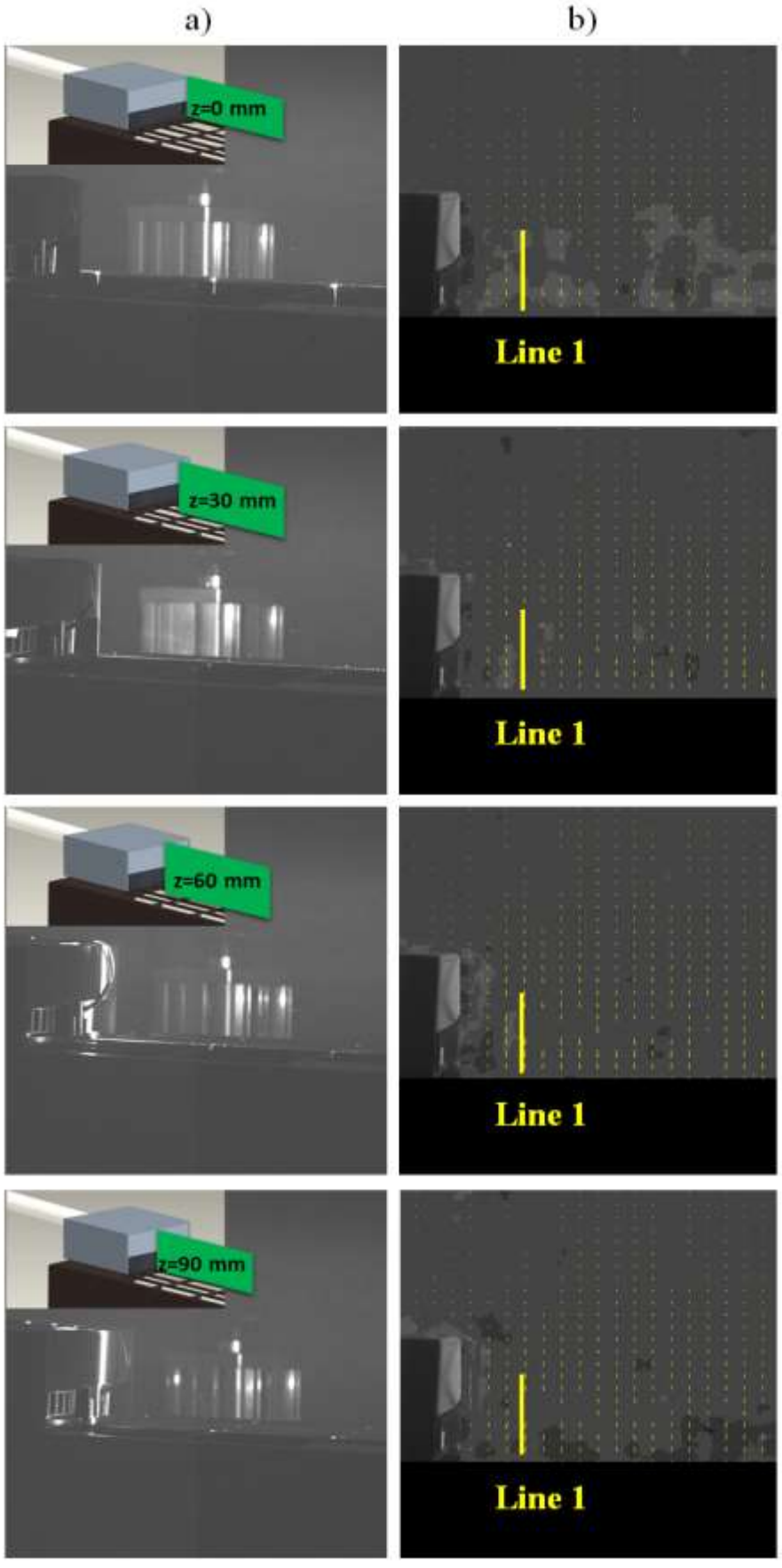
As explained previously in side position module PIV results in Section 4.2.1, the fresh air intake split air conditioner must be arranged slightly inclined towards the laser in the experimental setup so that the laser shots can easily reach the examination area.

The method used when examining the results of the side position module in Section 4.2.1, was traditional PIV. In traditional PIV method the examination of fresh air module was in two dimensional two components velocity vector. This time, the Stereo Particle Image Velocimetry (SPIV) method was used while examining the velocity vector results to obtain more accurate results since this model was likely to be the ultimate model.

In previous model, which is the side module, the general flow direction was found to be a jet flow and flows by-passing from the suction of the air conditioner. Therefore although two cameras were used in the experiments, the data was not post processed further since the two-dimensional data was enough to show the issues of the system. However, in the second experiment the general flow direction is directed successfully towards the suction of the air conditioner therefore the data is post-processed further to obtain three dimensional flow structure. The result of these studies explained in the further parts of this section.

SPIV results are the results used to examine the actual value of the air velocity exiting from the blowing mouth of the object by making use of the resultant of all two dimensional three components velocity vector. By combining the resultant values of the velocity vectors from both cameras, all three-dimensional vectors of velocity can be viewed on a single image.

The top position fresh air intake module on the split air conditioner in the PIV test setup was shown at Section 3, Figure 3.20. The results obtained using seven investigation planes in SPIV tests are as seen in Figure 4.8.


a)
b)
z=0 mm
Line 1
z=30 mm
Line 1
z=60 mm
Line 1
z=90 mm
Line 1

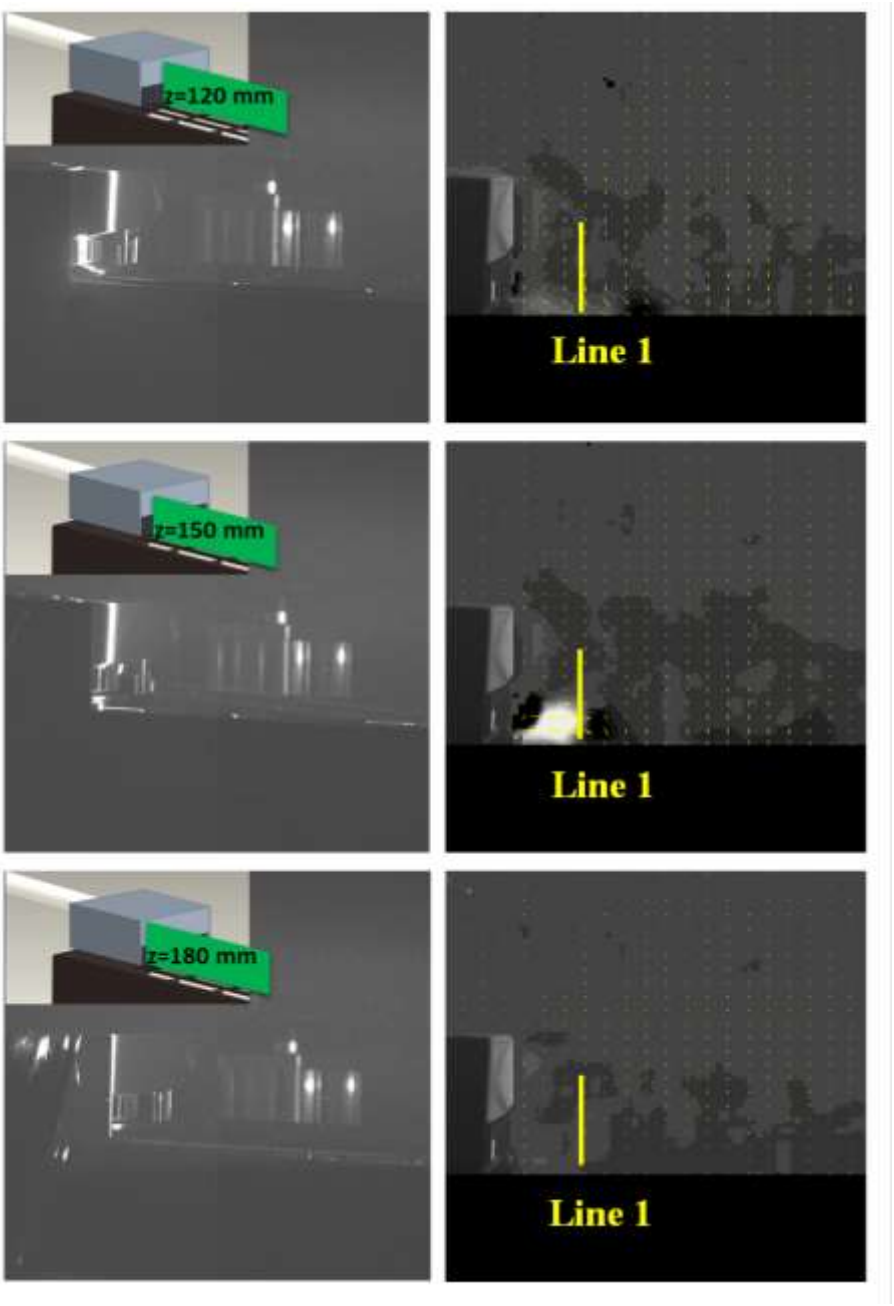


Figure 4.8 PIV test results for top positioned module - velocity data a) Angular view camera b) SPIV result

In the PIV test setup of the fresh air intake module positioned to the top side of the split air conditioner, the region where the results can be read in the area is separated by planes 5th and 6th. Because they are the planes where the laser shots coincide on the air outlet of the fresh air module, these planes correspond to z=120 mm and z=150 mm in the Z axis. Therefore, the velocity vectors seen in the test results of this region are clear because the fresh air intake module's air flow takes place in this region. When

looking at the areas that the laser shots pass over, just the air intake region of the split air conditioner and the velocity vectors of the sucked air can be monitored at 1st, 2nd, 3rd, 4th and 7th planes. Therefore, the velocity data of the fresh air intake module can not be seen in the PIV test results from the 1,2,3,4 and 7th investigation planes.

When the PIV test results are examined, z=0, z=30, z=60, z=90 and z=180 do not correspond to the air outlet part of the fresh air intake module. Laser shots do not coincide with the fan and, thus, the air outlet in these regions. Therefore, only the air suction area of the split air conditioner and the suction formed here can be seen in these parts. This can be easily understood by reflection of laser shots on the PIV image of angular camera. This situation can be seen at Figure 4.8. (a).

When the 5th and 6th planes, namely z=120 and z=150 are examined, these regions coincide with the regions where air outlet from the fresh air intake module can be observed with cameras while illuminated by the laser shots. And in these regions, it has been observed that the suction of the split air conditioner can absorb the air coming out of the fresh air intake module into the split air conditioner in an efficient manner.

Detailed test images of the fresh air coming out of the air outlet of the fresh air intake module, with the 6th test plane (z=150mm) is shown in Figure 4.9. The reason why this plane is preferred to be shown in detail is that it is the plane where the air flow can be observed in a way that more easily understandable.

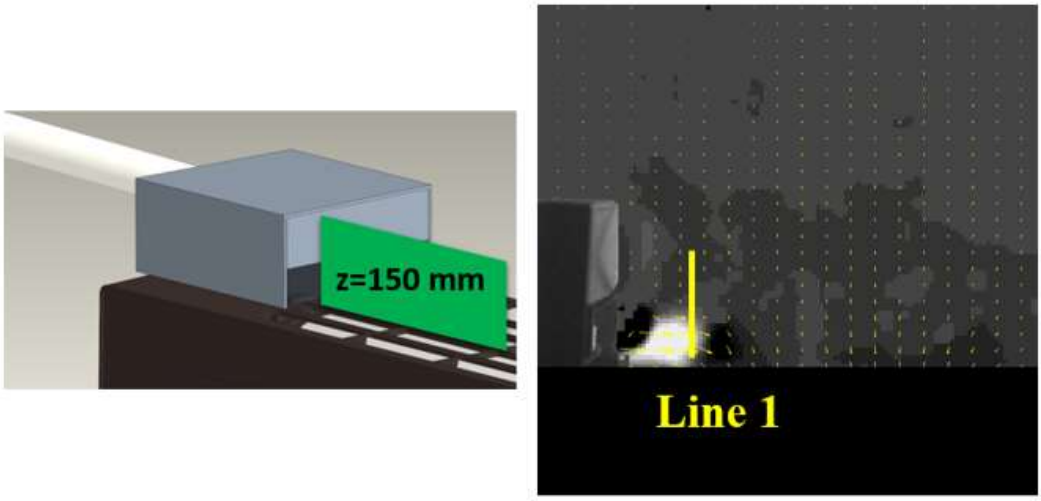


Figure 4.9 Detailed view of velocity vectors in 6th plane z=150mm

When all of these results are shown by converting them into curves, the graph given in Figure 4.10, is obtained. SPIV results of 6th plane (z=150mm) and resultant velocity components curve graph is shown in Figure 4.10.

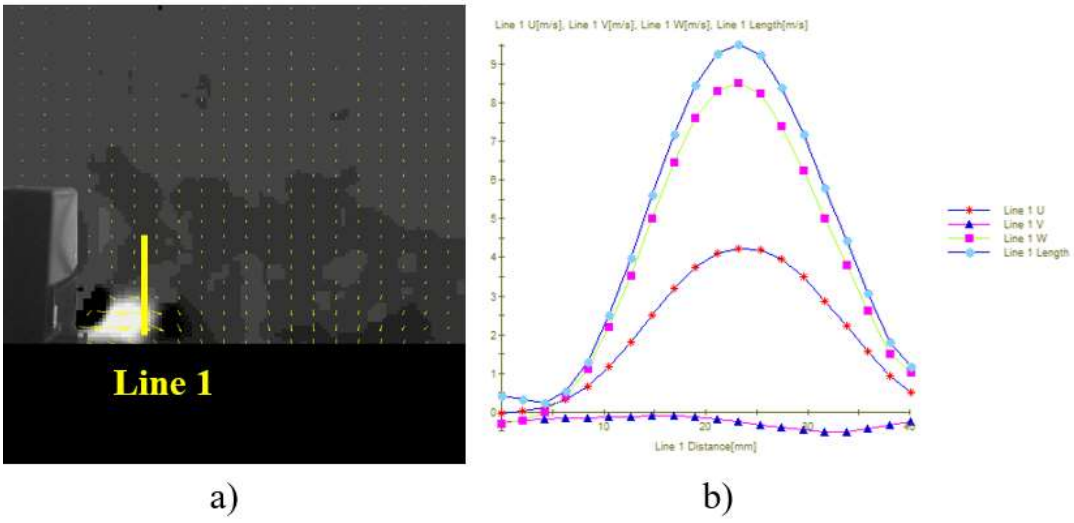


Figure 4.10 SPIV results of 6th plane z=150mm a) SPIV image with vectors b) Resultant velocity vector graph at line 1

In Figure 4.10. the values of the u, v and w components of the velocity vectors are given. Considering the plane in Figure 4.10. (a), by evaluating the values at graph in Figure 4.10 (b), it is seen that the x and w velocity components dominate on line 1. However, when the right side of line 1 is examined, it is seen that the velocity values have decreased, and the y-direction velocity has begun to dominate. This shows that the jet flow of fresh air blown from the fresh air intake module loses its dominant character after a certain point with the effect of the air intake zone of the split air conditioner and trends towards the suction region of the air conditioner.

When the air outlet characteristic of the side position fresh air intake module is examined, it is seen that this air outlet has a jet flow away from being exposed to the suction of the split air conditioner. However, in the top-positioned fresh air intake module, there is a jet flow parallel to the suction of the split air conditioner. In this case, it allows the fresh air to be directed towards the air conditioner suction region for air conditioning. In addition, in the case of using a top-positioned fresh air intake module, there is no need to direct the fresh air to the suction region of the split air conditioner with any apparatus. In this respect, it has been found appropriate to use a top-positioned fresh air intake module, which is a more advantageous design in terms of aesthetics, product cost and air conditioning efficiency.

4.3 Performance Test Results

Performance test results for split air conditioners with and without the fresh air intake module in PTC laboratory are given in Table 4.2.

Both the heating and cooling modes of the split air conditioner were tested. Performance tests were made comparatively according to whether the split air conditioner product has a fresh air intake module or not. In all performance tests, 8 thermocouple line-ups are described in Section 3.4.1. were applied to examine the air-conditioning effect of adding fresh air to the system. In addition, the experiment was repeated by changing the fan motor speeds for the air-conditioning effect of the air suction speed of the split air conditioner product after adding fresh air to the system.

Table 4.2 Performance test results (PTC laboratory tests)

COOLING							
Test ID		1	2	Temperature % difference	3	4	Temperature % difference
Fresh Air Module	Yes/No	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	-0,40%
Thermocouple-7	°C	14	14,07	0,50%	19,1	19	-0,53%
Thermocouple-8	°C	14,63	14,71	0,54%	19,9	20,1	1,00%
HEATING							
Test ID		1	2	Temperature % difference	3	4	Temperature % difference
Fresh Air Module	Yes/No	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	0,00%	33,6	33,71	0,33%
Thermocouple-7	°C	42,8	42,79	-0,02%	33,35	33,55	0,60%
Thermocouple-8	°C	43,65	43,6	-0,11%	34,33	34,5	0,49%

When the test results in Table 4.2. are 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 module in the cooling mode and the cooler air blown from the fresh air module in the heating mode is sucked from the air conditioner suction region area close to the fresh air module. This situation causes the deviations of thermocouples between 1 and 4 to be negative. The fact that all deviations in Table 4.2. are less than 1% shows that the fresh air unit does not negatively affect performance and temperature.

CHAPTER FIVE
CONCLUSION

In this study, the development of a fresh air split air conditioner was investigated using experimental methods. In this context, two different fresh air intake modules, which were prepared and positioned in different parts of the split air conditioner unit, and their air conditioning and ventilation efficiencies were examined experimentally. The amount of fresh air needed for a room environment was determined by using world-recognized standards (ASHRAE, 2004).The flow value corresponding to the pressure drop required for the centrifugal fan assembly in this fresh air intake module to provide the fresh air needed in a closed room, which is the living environment of people, was first calculated by numerical methods. Later, these centrifugal fans were brought from the fan supplier companies and experimentally verified, and the appropriate centrifugal fan was selected. In order for the fresh air to be supplied from this centrifugal fan to be cleaned properly, filter components have been determined and integrated into the system. The hose and module box, which are the peripheral parts of the fresh air intake module, are designed. While determining the location of the fresh air intake module and designing the box, the designs were developed by paying attention to the ability to direct the air and the effective air conditioning of this directed fresh air. In addition, a fresh air intake module, which is the final project output, was made by designing in accordance with the parameters that the end user would consider, such as aesthetics, acoustics and compactness of the whole system that makes up the fresh air intake split air conditioner.

The effective air routing capability of the fresh air intake module and the ability to fully absorb the fresh air it directs by the split air conditioner suction zone were examined with the PIV experiment system. It has been observed that the fresh air intake performed by the split air conditioner in the fresh air intake module positioned on the side of the split air conditioner, which is the first design, is insufficient and it has been observed that an additional air direction apparatus is needed for the fresh air intake module. The second fresh air intake module, which is an improved design, is designed to be positioned on the top of the split air conditioner and to direct all the

fresh air with the air outlet towards the split air conditioner suction area, and it is designed not to need any air-guiding apparatus. This new design second module was then tested in performance test rooms and examined in terms of air conditioning efficiency, and it was calculated that the air conditioning of the whole fresh air split air conditioning system was at an appropriate level.

The final output of this study, the split air conditioner with fresh air intake, provides the fresh air intake function with an extra fresh air intake module. In future studies, depending on the industry requirements and end-user demands, a new design that is fully integrated into the split air conditioner without causing the product dimensions to grow too much can be considered, and the fresh air flow rate and the sound levels it will create can be adjusted in line with the user needs. In today's world, the importance of health in human life has been understood once again with the last major pandemic, COVID-19. In our world, whose air quality is decreasing day by day due to pollution, the need for clean air has ceased to be a choice and has become a necessity over time. It is expected that this need will be met thanks to the products and similar products developed as a result of the study.

Although there are split air conditioners that can take fresh air in the industrial sense, it has been observed that most of the academic studies on this subject are on the HVAC sector and VRF systems. In the case of split air conditioners, there is no detailed study that includes a fresh air intake module like the project output. Therefore, this study can be considered as a pioneering study academically and can be used as a guide for further studies.

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