Research Progress in Mechanical and Manufacturing Engineering Vol. 2 No. 2 (2021) 641-649

RPMME

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Design and Development of an Experimental Rig to Evaluate the Performance of Air-Conditioner

Isma Nur Hafizi Ismail[1], **Sulastri Sabudin**[2*]

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA.

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rpmme.2021.02.02.070
Received 02 Aug. 2021; Accepted 27 Nov. 2021; Available online 25 December 2021

Abstract: R-22 is a hydrochlorofluorocarbon (HCFC) refrigerant commonly used in air-conditioner system but it have to be phase out by year 2020 because of its ozone depletion potential (ODP). Hydrocarbon (HC) refrigerant can be an alternative as a replacement, since they natural, non-toxic and compatible with lubricating oil. HC has nearly identical properties to R-22, gives the advantages to retrofit without having to replace any refrigeration system components. The objectives of this study are to design and develop an experimental rig due to air-conditioning, and to evaluate the performance of both R-22 and HC-22 refrigerants in split unit air-conditioner. The design process starts from sketching until developing virtual prototype model using *Solidworks* 2019 software. The manufacturing process to develop the rig also been proposed, including the process of measuring, cutting, drilling, welding, assembly, connecting and finishing. During the process, some modification has been done by changing the position of the outdoor unit in the opposite direction to the indoor unit and installing air duct around the outdoor unit to prevent hot air from approaching the indoor unit component. Overall, it can be concluded that the main objectives of this study were achieved. It is hope that the proposed design can be used in future learning and research purposes.

Keywords: Experimental Rig, Air-Conditioning, Refrigerant, HC-22, R-22, Virtual Prototype Model, *Solidworks*

1. Introduction

Air-conditioning is a gadget comprising of mechanical parts which serves to ingest heat from the encased space, for example, a room and move warmth to the outside. Knowledge of thermodynamics and basic refrigeration cycle is a priority to better understand the principles and applications of air conditioning. The main components involved during energy transfer are four (4) namely compressor, condenser, metering device or expansion valve and evaporator [1]. Refrigerant is a substance or

Corresponding author: sulastri@uthm.edu.my

combination that is typically in the fluid stage utilized in heat pumps and air-conditioning system. In many cycles, it goes through a stage progress of fluid to gas stage and back once more [2] .

This study was focused on designing a suitable experimental rig to evaluate the performance and impact of the refrigerant in the air-conditioner on the environment. The focus is more on the refrigerant used which is hydrocarbon-22 (HC-22) compared to hydrochlorofluorocarbon-22 (HCFC-22). Before starting the experiment, this refrigerant must be certified through the Malaysian / ASHRAE standards that have been setup.

1.1 Examples of Air-conditioning Experimental Rig

D. V. Raghunatha Reddy et. al (Fig.1.1) proposes a new approach to predicting vapor compression refrigeration system (VCRS) performance with R-134a as the working refrigerant at various loads in the evaporator.

Figure 1.1 : Vapour Compression Refrigeration Test Rig [3]

D.J Prabha (2015) studied the comparison of refrigerants for the retrofitting process in a 1.5 ton room air conditioner. Fig. 1.2 shows the schematic diagram represents an experimental setup for air conditioning system. Many other arrangement was reported for various refrigerant study.

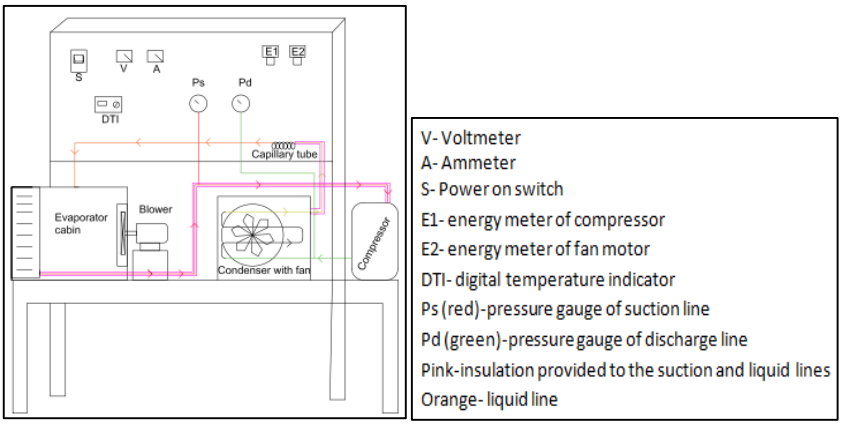


Figure 1.2 : Schematic diagram of air-conditioner test rig [4]

2. Materials and Method

2.1 Methodology

There are some of development model that can be used for this project. For example, Virtual Prototype model, Computer Simulation model and Engineering Design Process model. After making a comparison between several models, the Virtual Prototype [5] model as shown in Fig. 2.1 was selected based on phases suitability. Each phase above has a different work step and each development phase in this model is appropriate to the function of design.

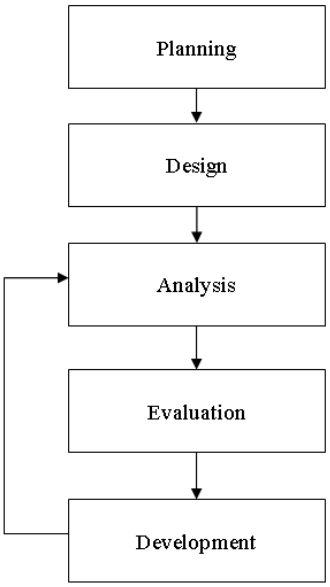


Figure 2.1: Virtual prototype model [5]

2.2 Experimental Setup

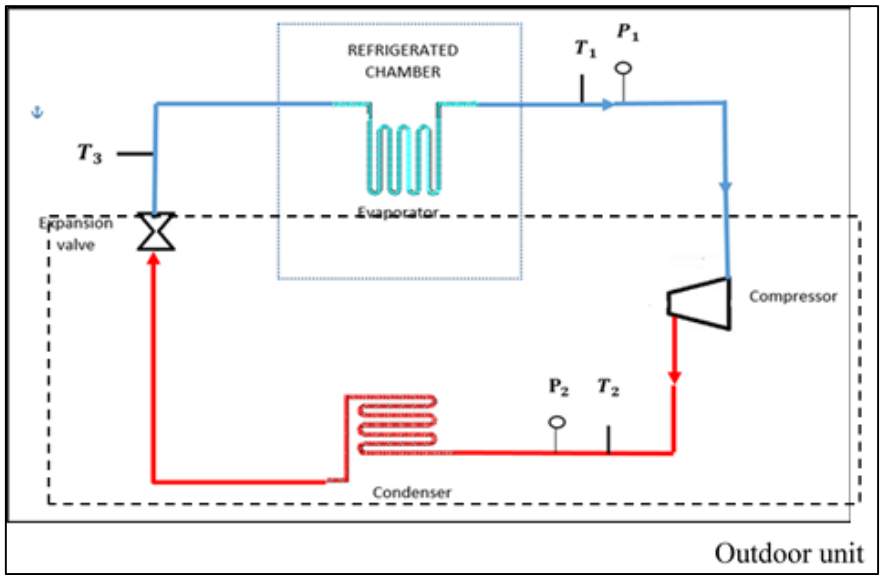


Figure 2.2 : Schematic layout for the air-conditioning system

The parameters involved during the process are pressure and temperature. Few locations was identified to collect data during experiment and named as T1, T2, T3 and P1 and P2 for pressure gauge. During experimental study, K-type thermocouples will be used to measure temperatures. The thermocouples are spot welded and inserted at four different locations in the test rig. T2s are installed inside the condenser tubes. T1 and T3 are installed at the inlet and outlet of the evaporator. Pressure gauges are used to measure the refrigerant pressure. P1 is mounted at the evaporator outlet, and P2 mounted at the condenser inlet.

2.3 Design Specifications

The ACU used in the present study consists of four main components namely compressor, condenser, capillary tube and evaporator for which can be shown in Fig. 2.3 (a). They are four

components involved during energy transfer namely compressors, condensers, expansion valves and evaporators. The compressor and condenser are usually called as outdoor unit while evaporator and expansion valve as indoor unit. The outdoor unit, fitted outside the room, houses components like the compressor, condenser and expansion valve. The indoor unit comprises the evaporator or cooling coil and the cooling fan. An arrangement of typical split unit air conditioner can be shown at Fig. 2.3 (b).

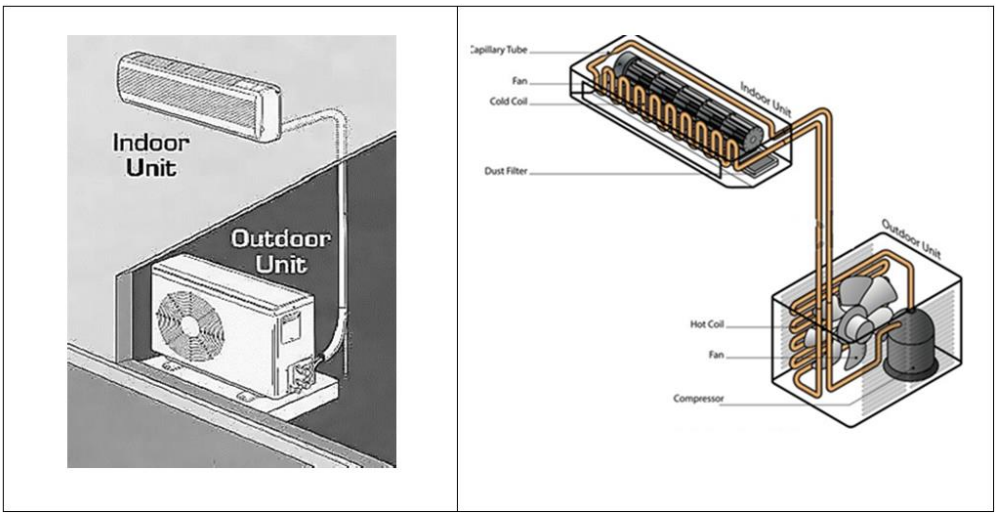


Figure: 2.3: (a) Indoor and outdoor unit (b) Components in indoor and outdoor unit

On the evaluation of these specifications, the determination of the design of the product to be produced. The morphological chart method was used in the idea generation process for the design of air-conditioning experimental rig. Table 2.1 shows the morphological chart for the production of the design concept. The initial idea for the product design of an experimental rig is to use a split unit air-conditioning divided into four(4) main parts namely:

i. Types of air-conditioning

ii. Refrigerants

iii. Test rig base

iv. Air duct

Table 2.1 : Morphological chart of characteristics and materials selection in the design of air-conditioning experimental rig

Design	Types of air-conditioning	Refrigerants	Test rig base	Air duct
1	 Split unit	R-22 and HC-22	 Roller/Wheel	Install
2	 Window unit	R-22 and HC-22	 Leg	Not install

2.4 Idea Development

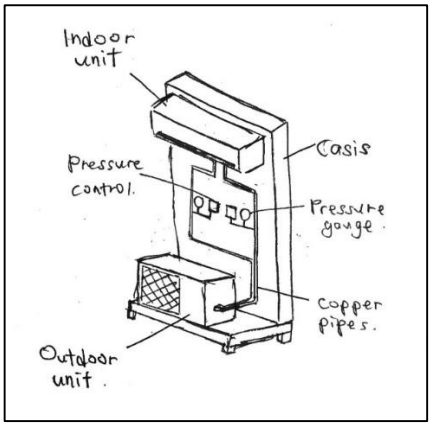


Figure 2.4: Basic arrangement 1

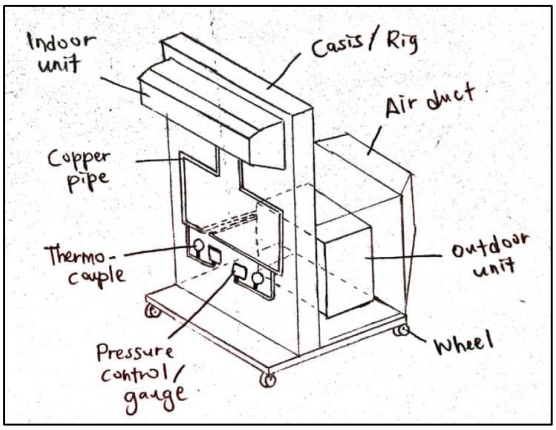


Figure 2.5: Basic arrangement 2

The idea is to mount the indoor unit and put the outdoor unit at lower condition. Fig. 2.4 shows the most common arrangement in refrigeration trainer. The body of the rig must be strong enough to support the whole system. The second idea (Fig. 2.5) was proposed after few considerations. The position of outdoor unit is placed at the back of the rig. To make the unit portable, the rig was equipped with wheels. Other than that, an air duct has been added to prevent hot air from the outdoor unit from entering the indoor unit. The air duct will be connected to a host and remove the heat to surroundings.

3. Result and Discussion

3.1 Design Drawing

Fig. 3.1 shows the full isometric drawing sketch using *Solidworks* 2019 software. Like the orthographic drawing sketch below, this software is required to draw the sketch required for the final sketch of the project. The different of an orthographic drawing sketch and a full isometric drawing sketch is their finishing. The full isometric drawing sketch shows the final sketch of the project in more detail and is given colour without putting measurements for the sketch.

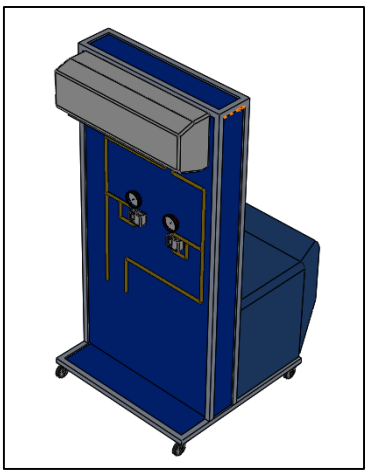
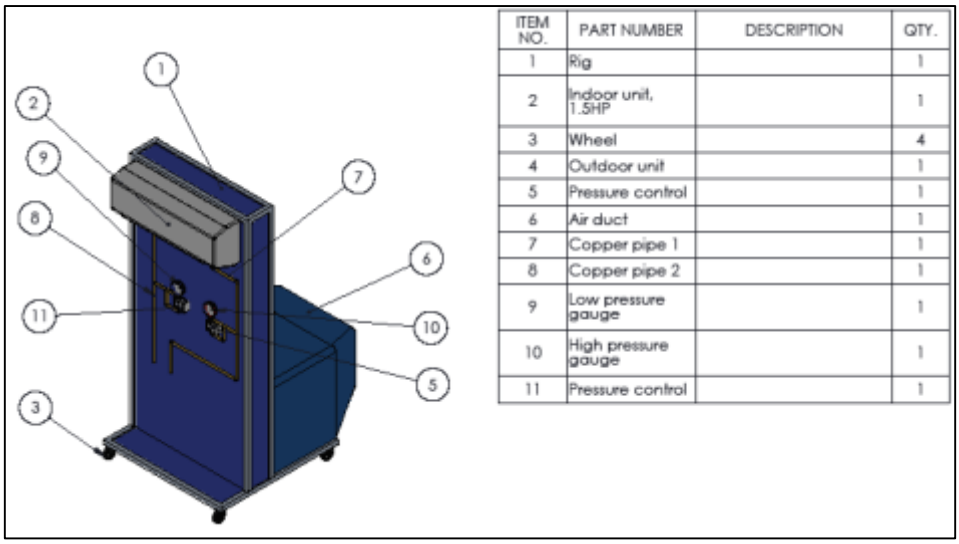


Figure 3.1: The full isometric drawing sketch

3.2 Bill of Materials (BOM)

A bill of materials (BOM) is a diagram that lists all of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts, and quantities required to produce one unit of a finished product or end part, and it is also generally displayed as a structure made up of hierarchical relationships between different components and materials [6]. To explain the condition of each component in this system, BOM has been developed to include particular product data in the BOM record. Fig. 3.2 below shows the bill of materials for air-conditioning experimental rig.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Rig		1
2	Indoor unit, 1.5HP		1
3	Wheel		4
4	Outdoor unit		1
5	Pressure control		1
6	Air duct		1
7	Copper pipe 1		1
8	Copper pipe 2		1
9	Low pressure gauge		1
10	High pressure gauge		1
11	Pressure control		1

Figure 3.2: Bill of materials for air-conditioning experimental rig

3.3 Manufacturing Process

The best method of such a situation is to produce a prototype through engineering drawings that suitable to the project. The next method is the model assembly process which is only in planning form because of the difficulty of using the workshop for real model assembly purposes. Table 3.2 shows the manufacturing process in planning form.

Table 3.2: Proposed material and manufacturing process of air-conditioning experimental rig.

No.	Items	Material	Manufacturing Process
1	Casis / Rig	Low carbon steel	• **Measuring** Measure the length of steel to get the exact size by using measuring tape. • **Cutting** Cut the steel into the pieces after measuring process. • **Drilling** Do drilling work on pieces of metal to produce holes. • **Welding** With welding, the pieces of steels could be combined into the design required. • **Finishing** Apply the coating to the rig.
2	Wheel	Stainless steel	• **Screwing** Assemble the wheels and the rig by screw on the hole that has been made.
3	Pipe (for piping system)	Copper	• **Measuring** Measure the length of copper pipe that wanted to use. • **Cutting** Cut the pipe after measuring process. • **Welding** Weld to make path. • **Assembly** Assemble the pipes with indoor unit and outdoor unit.
4	Indoor and Outdoor unit	-	• **Installing** Install the units with the rig at the position which has been set.

			• **Connecting**
5	Air duct	Aluminium	Connect the air duct with the outdoor unit without weld it to easy the process of servicing the outdoor unit.

4. Conclusion and Recommendation

In conclusion, the main objectives of the implementation of this project are to design and develop of a experimental rig, and to evaluate the performance of different refrigerant in a split unit air-conditioning has been achieved. The type of air conditioner used is the split unit type. The refrigerants used were R-22 and HC-22. Rollers are used to be contributors to the experimental rig base. Air ducts are also installed in this design.. Developing a 3D model is very useful to realize the idea. It is hope that the design project can be recognized and have a positive impact in the future.

Recommendation for this project in the future is to improve the piping system. This is because the piping system in the design of this experimental rig is not systematic, especially at the entrance and exit of the indoor unit and outdoor unit. In the pipe connection and reading devices such as pressure gauge and pressure control also need to be improved so that it is easy to take pressure readings. The pipe should also be covered with pipe insulation (thick and not easy to rust). This is to prevent the individual who performing the experiment if they touches the pipe. During the experiment, the pipe filled with fluid from the outdoor unit to the indoor unit was at a very low temperature and extremely cold. On the other hand, the pipes that are filled with fluid from the indoor unit to the outdoor unit have a high temperature and can burn human skin. Safety precaution must be considered during experimental process. Another recommendation that could be applied for this project is to increase the length of the air duct and direct the duct in a different direction to the indoor unit. With this action, the hot air will not affect the ambient air during the experiment and the indoor unit can function more efficiently.

Acknowledgement

The authors would like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for the support in conducting the research.

References

[1] Adel Alshamrani, A. B. (2015). A Comparison Between Three SDLC Models Waterfall Model, Spiral Model, and Incremental/Iterative Model . IJCSI International Journal of Computer Science Issues, Volume 12, Issue 1, No 1, 106.

[2] Cinelli, M. F. (2017). A network perspective on the visualization and analysis of bill of materials. International Journal of Engineering Business Management Volume 9, 1-11.

[3] D. V. Raghunatha Reddy, P. B. (2017). Performance Prediction of Vapor Compression Refrigeration System using Artificial Neural Network. International Journal of Refrigeration 82, 436-446.

[4] Haaf, S., & Henrici, H. (2003). Refrigeration Technology. Ullmann's Encyclopedia of Industrial Chemistry, vol. 31., 411-448.

[5] Nasrul, H. Z. (2012). Blog Penyejukan & Penyaman Udara. Retrieved from Laman web Blog Penyejukan & Penyaman Udara: https://cikgunas.net/nota-penyaman-udara/pengenalan/

[6] T.D.J Prabha, V. R. (2015). Experimental investigation on the performance of air conditioner using R32 Refrigerant. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 139-144.