DESIGN and Development of a Portable Air Conditioning System for Energy Efficiency

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ABSTRACT :

Portable air conditioners are a type of air conditioner that can operate independently in a specific area or space. The design of a portable AC is to be compact and mobile, making it easy to move from one place to another without having to worry about complicated installation or permanent fixtures. Small mobile devices that consist of the compressor, condenser, and evaporator in one case are usually used. In small spaces or compact areas, portable air conditioning units are small AC systems that provide reliable and convenient cooling. Thus, portable air conditioning is another type of portable conditioning systems, which are more convenient than traditional fixed air conditioning system, because the equipment can be easily transported from one place to another as well as from one building to another.. In relation to this abstract, kindly attempt to explain what portable air conditioning is, how it was developed, how it functions, and the advantages of portable AC. The components of a portable air conditioner, which can be transported, are a wheel, movable condenser, portable evaporator, and compressor. Portable ACs have the ability to operate in nearly any space due to their freedom of movement. Because they don't require permanent repairs, they are ideal for renting or anyone who has a house that changes frequently. Moreover, putting them up is a simple affair and will only need a window or vent on which the hot air is expelled out while the cooling process is going on. The popularity of these machines is due to their flexibility and ease of use in providing cooling comfort in almost any desired location.

Keywords: Portable, Energy Efficiency, Comfort, Lightweight.

1. INTRODUCTION

In today's fast-paced world, it's necessary to keep you cool and comfortable throughout the day. Portable air conditioners are the ultimate solution to high temperatures, whether you're at home, at the office, or moving around. It can be used to create an air-conditioned environment, whether it's at home or in an office, among other places. The purpose of these is to effectively cool and dehumidify, yet they are not too bulky and can be easily moved and set up. Moving these from one place to another or even carrying them with you when you're on a trip or away from home is a breeze. Easy installation is an advantage of flexible air conditioning systems. In comparison to conventional central air conditioning, portable systems don't require complicated installation or modifications to the rented premises on your property. They offer an exhaust hose that can be blown out through the window or a special kit that blows out hot air. Portable air conditioning systems are often chosen by renters, small spaces, or places that cannot accommodate permanent installations because of their flexibility. This device can be hauled around and its role is to cool and eliminate humidity from a particular region or a room. Designed to be mobile so it can be easily relocated from one location to another. The portable air conditioners are usually placed where central air conditioning services cannot reach, for instance in apartments, small offices or short-term accommodations. Be prepared to get acquainted with the portable air conditioners!

2. LITERATURE REVIEW

The air conditioning system has been the subject of many studies. “Design and development the Air Conditioner” Applying Design for manufactured (DFM) concept about product design. DFM is a valuable tool for lowering manufacturing costs and outlines a method for analyzing the proposed design.[1] The research was made in 2018 by kasuba Sainath and Chaitanya Kumar DFM tools facilitate conversation between the designer and the manufacturing engineer at the preliminary stage of product design thus assisting in the reduction of inventory, time as well as cost [2]. “Research on Air conditioning system” This is a deep structured learning about working principle and the science behind air conditioning [3] The Refrigerant discharged from the compressor expands at the expansion valve then it is evaporated and sucked in compressor, a gaseous refrigerant is injected in compressor thus improving the research was made on January 2018 by harsiman Singh Sodhi Chandigarh university[4]. It can be applied to enhance the efficiency of the air conditioner it is an effective method.

The novel technologies that are commonly referred to as ‘Portable air cooling and air conditioning technologies[5]. By employing the method of Evaporative Cooling. The consequence is it works on the basis of evaporation of water and it does not harm the ozone (HCFCS) which is damaged by other air conditioning systems[6]. IT was published on May 2022 by Author-Abhishek sarkar, co-author-Adarsh Singh, Mrs. Garima Singh. Its advantage is that it cools primary air while maintaining its humidity and it does not harm the ozone high frequency fluoride cool

surface. Aim designing and developing Air Conditioner: supported by aluminum rods, steel wire, pipes etc.[7]. And binding it around the drum I believe the aluminum drum is the most cost- efficient model currently existing. Basically, the component which uses to make the AC are pipes, wires, and sealing sheet. Design for manufacturer (DFM) for product design [8]. DFM helps to reduce manufacturing cost, it also provides systematic procedure for analyzing the proposed design[9]. The research was made in 2018 by kasuba Sainath and Chaitanya Kumar DFM tools encourage Dialogue between designer and manufacturing engineer during early stages of design which helps to save inventory as well as time and money [10]. "Research on Air conditioning system" Deep Structured Learning of working principle and science behind air conditioning The Refrigerant discharged from the compressor expands at expansion valve then it is evaporated and sucked in compressor a gaseous refrigerant is injected in compressor thus improving the research was made on January
2018 by harsiman singh sodhi Chandigarh university[11]. This method can be useful in improving the
performance of the air conditioner. Research on current electric vehicle thermal battery control systems focusing on the use of Peltier modules. Such as power consumption, temperature control or scalability12]. System concept design module. This includes selecting the appropriate power supply, modular installation and heating system [13]. This project aims to improve the quality control system of electric vehicle (EV) batteries using Peltier modules.

The project will start with a comprehensive review of existing thermal management technologies and identify the limitations of traditional systems[14]. The cooling system will be expanded by integrating Peltier modules, electronic components and necessary electronic devices (such as heat sinks or fans). The manufacturer will also investigate the use of renewable energy to power the Peltier modules to increase energy efficiency[15]. Since the invention of portable air conditioners, they have gone through a lot of development from being bulky and huge to compact and light systems. The early PACs were mainly functional but very non-energy efficient and portable. Modern compressors and smart technologies are integrated with the latest lightweight materials to enhance usability and performance[16]. This paper discusses the thermodynamic cycles employed in PACs, focusing specifically on vapor compression cycles. The use of advanced refrigerants such as R-410A and R-290 increases the efficiency of cooling[17]. Furthermore, inverter technology applied in compressors has reduced energy consumption with consistent cooling. The paper highlights the use of composite materials, such as reinforced polymers and lightweight aluminum alloys, to reduce the weight of PACs. Also, these materials contribute to improved durability and thermal insulation properties, making the systems more efficient and user- friendly[18]. IoT integration has provided smart control systems in PACs. Users can monitor temperature settings and adjust them using mobile applications from remote locations. Machine learning algorithms are also now being used to optimize cooling patterns based on user behavior and room occupancy[19]. The high global warming potential (GWP) of traditional refrigerants, such as R-134a, has led researchers to focus on the use of low-GWP refrigerants like R-290 (propane) and hydrofluoroolefins (HFOs), which are more environmentally friendly. However, challenges such as flammability and cost concerns make such a transition difficult[20]. The biggest noise contribution in PACs is often from compressors and fans. There have been significant efforts to look into acoustic insulation techniques, noise-dampening enclosures, and brushless DC motors that reduce operational noise without a performance penalty[21]. This paper reviews energy-efficient PAC designs with variable-speed compressors and advanced heat exchangers. It has been proven that energy Star-certified PACs consume up to 25% less electricity than the ones that are not certified. With the increased focus on renewable energy, solar-powered PACs have come to the forefront as a viable green option. Photovoltaic panels integrated with PAC systems offer an off-grid cooling solution for remote areas. The drawbacks include initial cost and dependency on sunlight availability.

3. PROPOSED WORK

Conventional Vapor Compression Air Conditioning Cycle

The vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. The main heat transfer part is done via convection method between evaporator coil and environment. Figure depicts a typical, single- stage vapor- compression system. All such systems have four components: a compressor, a condenser, a Thermal expansion valve (also called a throttle valve or Tx Valve), and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapor and is compressed to a higher pressure, resulting in a higher temperature as well. [9]

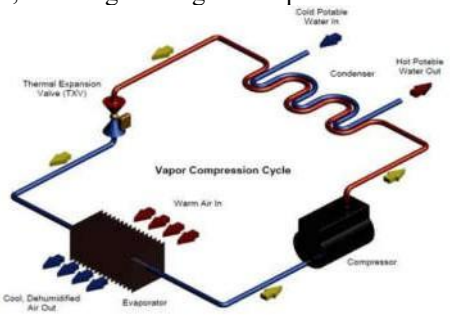

Fig 1: Conventional Vapor compression Air Conditioning System

4. METHODOLOGY

Insufficient cooling is the most common AC problem that people face. If your AC isn't cooling properly, it could be due to a number of reasons. It could either be due to clogged air filters, low refrigerant, a faulty motor, dirty outdoor unit, or even incorrect mode selection. A portable air conditioner is designed to cool the air in a specific space, providing relief from high temperatures during hot weather. It works by drawing in warm air, passing it through cooling coils, and then releasing the cooled air back into the room. Component selection for a portable air conditioner involves selecting the hardware needed to accurately measure and analyze various parameters during testing. Selecting proper cooling capacity of the

condenser, and evaporator then energy consumption for the compressor and specifies the refrigerant. When selecting these components, it is important to consider the compatibility of the selected Evaporator, compressor and condenser systems with the specific requirements of the specific size. Creating a prototype model for a portable air conditioner involves a simplified representation of the final product to test and validate the design. Materials Needed: Cardboard or Foam Board, small fan, cooling elements, power source. Steps to Create the Prototype, Design the casing, internal components, cooling element, and adjustment of the elements and testing it.

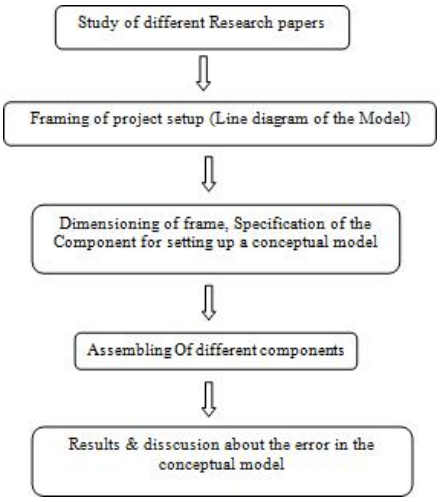

Fig.2 Flow Chart For Working Process

4.1 SYSTEM DESIGN & ANALYSIS

In our attempt to design a special purpose machine we have adopted a very a very careful approach, the total design work has been divided into two parts mainly;

- **System design**
- **Mechanical design**

System design mainly concerns with the various physical constraints and ergonomics, space requirements, arrangement of various components on the main frame of machine no of controls position of these controls ease of maintenance scope of further improvement; height of m/c from ground etc.

In Mechanical design the components are categorized in two parts.

- **Design parts**
- **Parts to be purchased.**

The research about portable air conditioners involves the systematic approach to design, performance, and the environment. The study starts by creating clear objectives, such as those on energy efficiency, cooling performance, refrigerants, and material usage. This approach involves a comprehensive literature review by gathering insights from existing research papers, technical reports, and case studies, which will provide the base for a solid theoretical basis. This stage consists of selecting a range of portable air conditioners with diversified specifications, such as differences in cooling capacities, mechanisms, and refrigerants. Then these systems are tested in a controlled environment that mimics real-world conditions and monitors parameters like cooling efficiency, energy consumption, noise levels, and improvement in air quality. Data is collected using accurate measuring devices such as temperature sensors, power meters, and sound level meters. Surveys and user feedback are used to give qualitative information. Computational modeling tools such as MATLAB and ANSYS are used to simulate airflow, heat transfer, and energy consumption to provide a detailed thermodynamic analysis. A comparative analysis is then conducted to compare the performance of single-hose versus dual-hose systems and to benchmark the findings against industry standards like Energy Star. Furthermore, an LCA is performed to study the environmental impacts using processes for manufacturing, in-service energy consumption, and ultimate disposal practices. Statistical analysis that involves regression analysis is also implemented to find important factors affecting the performance. Lastly, detailed findings are compiled in a recommendation report suggesting areas for design improvement, introduction of environment-friendly refrigerants, and further potential for energy efficiency improvement, and, if applicable, implementation in the development of the prototype. This is a holistic approach to understanding portable air conditioners and their optimization potential.

4.2 EXPERIMENTAL WORKING :

Vapour Compression Air Conditioning Cycle

A vapour compression Air Conditioning system is an improved type of air Air Conditioning system in which a suitable working substance, termed as refrigerant is used. It condenses and evaporates at temperatures and pressures close to the atmospheric conditions. The refrigerant used does not leave the system but is circulated throughout the system alternately condensing and evaporating. The vapour compression Air Conditioning system is now days used for all-purpose Air Conditioning. It is used for all industrial purpose from a small domestic refrigerator to a big Air Conditioning plant. The vapour compression Air Conditioning cycle is based on the following factor:

- Refrigerant flow rate.
- Type of refrigerant used.
- Kind of application via air-conditioning, Air Conditioning, dehumidification.
- The operation design parameters.
- The system equipment's / components proposed to be used in the system.

The vapour compression Air Conditioning cycle is based on a circulating fluid media, via, a refrigerant having special properties of vaporizing at temperatures lower than the ambient and condensing back to the liquid form, at slightly higher than ambient conditions by controlling the saturation temperature and pressure. Thus, when the refrigerant evaporates or boils at temperatures lower than ambient, it extracts or removes heat from the load and lower the temperature consequently providing cooling. The super-heated vapour pressure is increased to a level by the compressor to reach a saturation pressure so that heat added to vapour is dissipated/ rejected

into the atmosphere, using operational ambient conditions, with cooling Medias the liquid from and recycled again to form the Air Conditioning cycle.

The components used are:
1. Evaporator
2. Compressor
3. Condenser and receiver
4. Throttling device

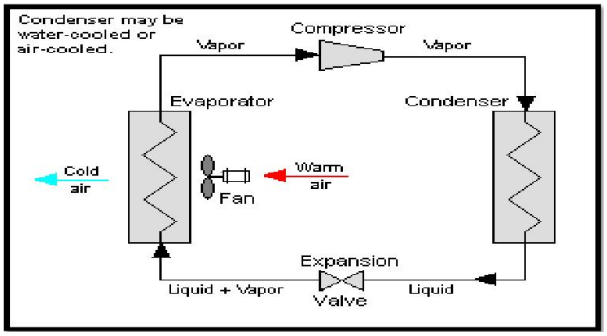

Fig.3 Single Stage Vapour Compression Cycle

CAD MODEL

Fig.4 CAD Model

The CAD model for the portable air conditioner presents a compact and functional design tailored to modern cooling needs. The model has an ergonomic structure, optimized for portability and ease of use. It consists of a primary housing unit designed to fit key components like the compressor, evaporator coil, condenser coil, and a fan system. The housing is streamlined with smooth edges, making it aesthetically pleasing and safe to handle. Air intake and exhaust vents are provided with strategic positioning for better airflow management. Intake vent will allow warm air in while the exhaust vent ensures smooth exhaustion of the processed air that ensures the proper performance of the cooling operation. Another feature is a double hose system that enables effective circulation of air through a fresh hose that takes air inside the cooling unit and a second one that allows exhaust heat. It enhances energy efficiency.

An intuitive front panel for digital controls will be on the front that includes the temperature settings, fan speed settings, and mode of operation. These modes are cooling, dehumidification, and ventilation. Below this control panel is an easily removable filter slot designed for convenient maintenance and higher indoor air quality. The bottom side of this model will have caster wheels for easier movement, and both sides are provided with side handles. Internally, the model shows the placement of components to an accurate scale, with an emphasis on space optimization. Compact heat exchangers and energy-efficient components like variable-speed compressors are also integrated to reflect modern developments in portable air conditioner technology. The design also comes with a reservoir or condensate management system, which collects excess moisture without leaking and ensures easy handling. Overall, the CAD model represents a blend of aesthetics, functionality, and technological innovation, making it an ideal solution for flexible and energy-efficient cooling.

HARDWARE AND SOFTWARE REQUIREMENTS

Structural Parts

Main Housing: ABS plastic or aluminium, a lightweight and tough material for easy portability and to sustain wear and tear.
Vents and Grills: The air intake and exhaust vents are properly designed to maintain airflow using corrosion - resistant materials.
Caster Wheels: Smooth, durable wheels, usually polyurethane material, to move easily around. Handles: Side or top handle for easier portability.

CORE COOLING COMPONENTS

Compressor: Hermetically sealed rotary or scroll compressor for compact and efficient cooling. Evaporator Coil: High-efficiency copper or aluminium coils for optimum heat absorption. Condenser Coil: Copper or aluminium fins to dissipate heat efficiently.

Refrigerant: Environmentally friendly refrigerants like R-410A or R-290 with low GWP and ozone-friendly.

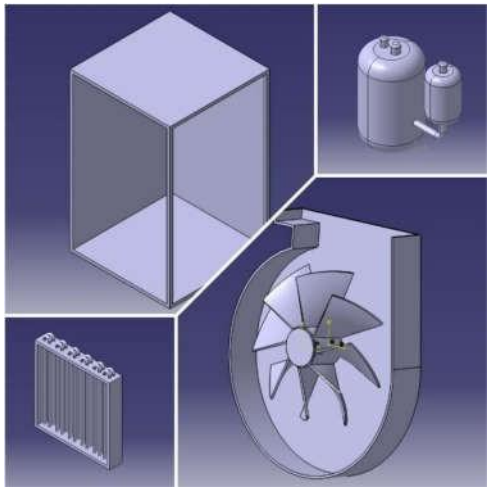

Fig.5

3D CATIA MODELING

CATIA provides advanced tools for creating detailed and accurate 3D models of your portable air conditioner, including housing, internal components (compressor, coils, fans), and airflow paths.
Part and Assembly Design: It allows the individual components to be integrated into a full assembly to visualize how the parts interact within the system.

Parametric Design: CATIA facilitates easy changes to dimensions and features, allowing iterative design to be executed more rapidly and efficiently.

DIGITAL TEMP SENSOR :

The LCD Electronic Fish Tank Water Detector Thermometer can make sure you know exactly what is the ambient temperature of your fish tank.

AIRFLOW MANAGEMENT

Fan System: Axial or centrifugal fans for circulating air through the evaporator and condenser. Blower Motor: Brushless DC motor with good efficiency and silent running.

CONTROL AND DISPLAY COMPONENTS

Control Panel: Digital or analog panel on temperature, fan speed, and modes. Thermostat: An embedded thermostat to control temperature efficiently.Sensors: These include temperature and humidity sensors for automatic adjustments.

SAFETY FEATURES

Overload Protection: Built-in fuse or circuit breaker to protect the system from electrical surges.
Insulation: Thermal and acoustic insulation to improve energy efficiency and noise levels. Power Components

ALL CALCULATIONS

1. **Cooling Capacity Verification(Q)** =2160 BTU / hr = 632.88Wattts,
2. **Refrigerant Mass Flow Rate =** 0.0126kg/s,
3. **Compressor Power =** 472.5W,
4. **Coefficient of Performance (COP)=** 1.67,
5. **Airflow Requirement =** 200 CFM,
6. **Condenser Fan Power** =16.17W,
7. **Heat Exchanger (Evaporator/Condenser) Area** =

1.27 ^{2}.

EXPECTED OUTCOMES

The portable air conditioner model is designed using CATIA that has successfully achieved its objective as it is compact, efficient, and user-friendly. Due to the ergonomic design, it is lightweight, incorporates caster wheels, and includes an integrated handle for ease in portability. The internal layout of main components such as compressor, evaporator, condenser, and fan is optimized for the utmost cooling efficiency while ensuring that the space usage is kept minimal. Strategically placed air intakes and exhaust vents in the device ensure effective heat dissipation, and the control panel area is designed to hold user-friendly temperature and mode settings.

Basic structural and thermal analysis validated the model's capabilities to withstand operational stresses and thus ensure efficient performance. It has maintenance considerations, for example, removable air filters, and a condensate management system, which enhance durability and usability. The CAD design incorporates technical drawings and a Bill of Materials, thus further confirming the model's readiness for manufacturing with easily sourced and assembled components. Photorealistic renderings produced in CATIA further demonstrate the product's aesthetics and practical functionality, and it can be used to present and market the product. Overall, the portable air conditioner design is a robust solution that fulfills functional, aesthetic, and manufacturing requirements and lays a good foundation for future enhancements, such as IoT integration or energy optimization. The portable air conditioner project designed meticulously in CATIA shows how modern cooling needs can be aptly served, combining functionality with aesthetics and portability. It has a compact size and weight, with the inclusion of caster wheels, which provides effortless mobility and user convenience through the ergonomically placed handles. Internal layout ensures the positioning of the critical components like compressor, evaporator coil, condenser coil, and fan so that it optimizes its cooling performance and reduces the footprint. The intake and exhaust vents are positioned in the most strategic way possible for enhanced airflow and thermal efficiency. Optional features include a dual-hose system that is designed to improve energy use. The design also takes into account user-friendliness by including a control panel that is suitable for digital or analog settings, thus allowing for precise adjustments of temperature, fan speed, and operational modes. Maintenance is simplified with easily removable filters and a condensate management system, which includes a reservoir or direct-drain option to prevent water overflow and leaks. Preliminary structural and thermal analyses using CATIA's simulation tools validate the robustness and efficiency of the design by confirming its ability to stand operational stresses while maintaining its optimal performance. In terms of manufacturability, the CAD model includes technical drawings in detail, dimensions, and a Bill of Materials that streamline the transition from design to production. Materials selected include ABS plastic for the housing and aluminum or copper for heat exchangers in order to ensure durability, thermal conductivity, and cost-effectiveness. The photorealistic renderings enhance the visualization of the final product, thus ideal for presentations, marketing, and client approval. The design can also be scaled up, opening up space for incorporating such advanced technologies as IoT-enabled controls, energy-efficient compressors, or air quality enhancement features. Thus, the portable air conditioner design strikes a perfect balance among functionality, modern cooling necessities and aesthetic appeal while maintaining energy-efficiency and user-centric elements to perfectly qualify for further development and to take into specific market needs thus becoming versatile and sustainable enough when it comes to cooling matters.

5. CONCLUSION

Use of water as air conditioning imposes a great impact on cop improvement at certain thermal loads. Using water as air conditioning and certain thermal load it is found that the 18-26% cop improvement has been achieved by the air conditioning in respect without air conditioning in conventional refrigerator. Experiment tests have been carried out to investigate the performance improvement of a household refrigerator using two different phase change materials of different quantities at different loads. Depending on the air conditioning and the thermal load around 18-26% cop improvement has been achieved by the air conditioning in respect to without air conditioning.

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