DESIGN AND FABRICATION OF A KITCHEN FUME EXTRACTOR

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CERTIFICATION

This is to certify that this work on the "Design and Fabrication of a Kitchen Fume Extractor" was carried out by **Ihimire FavourBlessed** with the Mat Number **ENG2006305**. Of the Department of Production Engineering, University of Benin, Benin City.

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DEDICATION

This project is dedicated to my guardians and sponsors Mr. Sunday Osemwengie and his wife Mrs Precious Osemwengie.

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ABSTRACT

Cooking activities in residential and commercial kitchens generate significant amounts of heat, smoke, oil mist, odors, volatile organic compounds (VOCs), and fine particulate matter, all of which contribute to poor indoor air quality and unhealthy working conditions. Prolonged exposure to these pollutants can result in respiratory irritation, thermal discomfort, and other long-term health challenges for kitchen users. In many developing regions, the high cost of imported kitchen ventilation systems and the lack of effective local alternatives make proper fume control difficult. This project was therefore aimed at the design and fabrication of a cost-effective kitchen fume extractor using locally available materials to improve indoor air quality and enhance user comfort.

The design of the kitchen fume extractor was based on the principles of fluid mechanics, thermodynamics, and aerodynamic suction. Important design parameters considered included airflow rate, capture velocity, pressure losses, fan power requirement, structural stability, material durability, and noise control. Analytical calculations were carried out to determine the suitable hood dimensions, duct size, and axial-flow fan capacity required for effective fume extraction. Stainless steel was selected as the major construction material due to its corrosion resistance, thermal stability, ease of cleaning, and suitability for kitchen applications. The system was fabricated as a wall-mounted unit consisting of a hood, axial-flow fan, multi-stage filtration unit, and exhaust outlet, with the ability to function in both ducted and recirculatory modes.

Performance evaluation was conducted under simulated cooking conditions, focusing on smoke extraction efficiency, fume clearing time, airflow uniformity, noise level, and general operational effectiveness. The results showed a significant reduction in smoke concentration and odor persistence within the kitchen environment, with stable airflow distribution and acceptable noise levels during operation. The extractor successfully removed cooking fumes within a short time and improved thermal comfort and air quality. The study concluded that an efficient and functional kitchen fume extractor can be designed and fabricated at low cost using locally available materials without compromising performance, providing a practical solution to indoor air quality control systems.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Residential cooking in kitchens produces many gaseous emissions such as smoke, odors, volatile organic compounds (VOCs), and particulate matter especially due to gas stovetops and high temperature processes such as frying. These emissions pose a health risk in as much as the irritation of the respiratory system is concerned and are also responsible for indoor air quality being poor, possibly exacerbating diseases such as asthmatic conditions or allergic responses (Smith, 2017). Kitchen fume extractors or range or exhaust hoods are invaluable installations built on principle for just such issues by trapping and relieving or filtering contaminated air.

A heat extractor is an appliance that is used to collect, transfer, and sometimes accumulate heat from one medium to another with a view to enhancing thermal efficiency and minimizing energy wastage in domestic and industrial processes. Simply put, it works by extracting waste or excess heat from a source like a stove, cooking surface, or heated indoor air and redistributing it to other parts of the home where the heat is required or expelling it to restore comfortable conditions. The idea has gained increasing importance in domestic contexts where energy conservation and efficient heat management are critical to minimizing utility bills and environmental footprints. The fabrication and design of domestic heat extractors from locally available materials have attracted immense interest in recent years, and this is largely informed by international efforts to enhance sustainable and affordable interventions in energy systems. With increasing utility bills and escalating environmental concerns, there is an imminent need for affordable technologies that tap into locally available resources to enhance thermal management in the home. The idea of heat extraction, which entails the extraction of waste heat to limit overall energy use, resonates well with the ideals of energy efficiency and sustainability. For example, recent research has demonstrated that the use of waste heat from domestic and industrial processes not only reduces environmental impact but also provides considerable cost benefits (Hancox *et al.,* 2022).

In areas with poor access to high-technology infrastructure, the utilization of local materials in the fabrication of heat extractors can offer a viable solution to close technology gaps and enhance self-sufficiency. Studies on the development of heat treatment furnaces from locally available materials have proved the potential for high performance at a small fraction of the cost of foreign systems. For instance, in Nigeria, a study successfully developed and built an electric heat treatment furnace that attained operating temperatures of up to 1,000°C, utilizing materials like clay and white cement for insulation (Anaidhuno & Ologe, 2024). This indicates the potential of local resources to address intricate thermal requirements. Further, the incorporation of vegetable oils as sensible heat storage media for domestic heating applications illustrates the innovative application of renewable, locally available resources in thermal systems. In a study in Uganda, Roki oil (a local mixture of palm and sunflower oil) demonstrated higher heat utilization efficiency compared to the utilization of sunflower oil alone. This indicates that vegetable oils, commonly utilized for cooking purposes, can serve an important function in domestic heat extraction systems by facilitating efficient thermal storage and transfer characteristics (Abedigamba *et al.,* 2023).

Apart from material choice, recent design optimization and energy system integration advances have further boosted the argument for domestic heat extractors. For instance, local heat therapy equipment and thermal mats applied in industrial and domestic settings have been shown to greatly enhance thermal comfort and energy efficiency, highlighting the necessity for local design tailoring to specific user requirements (Kaczmarczyk & Ferdyn-Grygierek, 2020). Moreover, incorporating waste heat from domestic systems into combined cooling, heating, and power (CCHP) units has been shown to enhance energy efficiency at residential levels. Using geothermal and industrial waste heat in distributed energy systems has been shown to satisfy local energy requirements sustainably while providing economic advantages such as decreased energy expenses and increased energy self-sufficiency (Nami *et al.,* 2020).

The growing focus on decarbonizing domestic heat also brings to the forefront the need for locally adapted heat extraction technologies. In Greater Manchester, for instance, plans to reach net-zero emissions have highlighted the imperative of local design and fabrication approaches that account for site-specific needs and obstacles (Crowther *et al.,* 2023). The shift towards the utilization of locally available materials in the design and fabrication of domestic heat extractors represents a key step towards sustainable, affordable, and community-oriented energy solutions. These localize industries, diminish reliance on imported technologies, and generate innovations that are more attuned to each region's distinct socio-economic and environmental conditions.

Traditionally, the kitchen fume extractor is classified into ducted systems where air is exhausted outside or ductless or recirculating systems where air is cleaned and recirculated within. While commercial kitchens are equipped with advanced ventilation systems adequate for such standards such as NFPA 96, residential kitchens utilize low-budget affordable measures. Most homes, however, especially in low-income countries or small apartments or flats, are not equipped with effective ventilation because it is costly to fit or does not leave sufficient space for fitment. The project is on designing and constructing a low-budget efficient kitchen fume extractor for residential use considering accessibility convenience during maintenance efficiency. The study borrows ideas from industrial ventilation technologies and mobile installations such as the Air Hood and is customized for residential use for air quality improvement as well as safety enhancement.

1.2 Statement of the Problem

In most home kitchens, particularly urban apartments or houses lacking pre-existing ducting, poor ventilation results in the concentration of noxious cooking fumes and odors. These contaminants worsen indoor air quality, presenting health hazards to residents. Commercial kitchen fume extractors are frequently costly, necessitate complicated installation (i.e., ducting to outside vents), or are not practical for small kitchens. Ductless systems, though simpler to install, tend to compromise on heat and moisture removal efficiency while their filters need constant maintenance. The unavailability of low-cost, easy-to-use, and efficient fume extractors hinders wide acceptance in low- and middle-income families. This project aims to overcome these issues by designing and creating an affordable, domestically feasible kitchen fume extractor that compromises between performance, affordability, and usability.

1.3 Aim and Objectives

The aim of this project is to design, fabricate, and evaluate a cost-effective fume extractor for domestic use that efficiently removes smoke, and odors to improve indoor air quality and safety.

To achieve the stated aim, the following objectives will be pursued:

1. Conduct a literature review on existing kitchen fume extraction technologies, identifying best practices in design, filtration, and airflow optimization.
2. Select appropriate materials for the fabrication of a durable, cost-effective, and safe kitchen fume extractor.
3. Design and fabricate a prototype of a kitchen fume extractor suitable for a standard domestic kitchen.
4. Test the performance of the fabricated fume extractor in terms of airflow, filtration efficiency, noise levels, and user-friendliness.
5. Evaluate the prototype's effectiveness in removing cooking fumes and its compliance with basic ventilation standards (e.g., minimum airflow of 60 m^3/h for domestic kitchens).
6. Document the design process, challenges, and outcomes to provide a replicable model for future iterations.

1.4 Scope

This project focuses on the design and fabrication of a cos effective fume extractor intended for domestic use. The study covers the selection of suitable materials, development of a conceptual design and execution of necessary design calculations to ensure efficient fume extraction and air treatment. The scope also includes the fabrication of the system using locally available materials to promote affordability and ease of maintenance. The fume extractor will be designed to capture kitchen fumes including smoke, odor and gases and treat the through appropriate filtration mechanisms before either recirculating the air or venting it outside. The scope of the problem, does not extend to large scale industrial or commercial fume extraction systems.

1.5 Significance of the Study

This study responds to a critical need for affordable and efficient kitchen ventilation solutions in domestic environments, particularly in urban apartments and homes lacking ducting infrastructure. Its significance lies in several key areas.

First, the proposed solution contributes to improved public health by reducing exposure to harmful cooking by-products such as volatile organic compounds (VOCs) and particulate matter, thereby mitigating respiratory health risks and enhancing overall indoor air quality.

Second, it supports fire safety by minimizing the accumulation of grease and combustible fumes, which are common contributors to domestic kitchen fires.

Third, the study addresses accessibility by proposing a cost-effective ventilation system priced between 150,000 to 200,000 Naira, making effective fume extraction attainable for low- and middle-income households and filling a notable gap in the current market.

In addition, the design emphasizes practicality through user-friendly features such as quiet operation and easy maintenance, including removable filters, which are particularly suitable for small households and compact living spaces.

Finally, the study enhances replicability by documenting a scalable and adaptable model that can be adopted across different contexts, contributing meaningfully to the advancement of domestic ventilation technology.

1.6 Limitations

While this project aims to provide an effective and affordable solution for kitchen fume extraction, certain limitations exist due to resource and scope constraints. The design is tailored primarily for domestic use and may not be suitable for industrial or large-scale commercial kitchens where higher-capacity extraction systems are required. Advanced purification technologies such as UV sterilization or electrostatic precipitators are excluded due to cost and complexity.

In addition, the performance evaluation is based on basic test parameters such as airflow rate, noise level, and visible fume reduction, rather than detailed chemical analysis of air quality.

The materials used are selected based on availability and cost-effectiveness, which may limit long-term durability compared to more expensive commercial systems. Finally, the project is constrained by available fabrication tools and workshop facilities, which may affect the level of precision and finishing.

CHAPTER TWO

LITERATURE REVIEW

2.1 Fume Extractors

Cooking in domestic kitchens fills the air with a mix of enticing aromas and harmful pollutants, smoke, particulate matter (PM), volatile organic compounds (VOCs), and nitrogen oxides (NOx). These can turn a cozy kitchen into a health hazard, contributing to respiratory issues, fire risks, and poor indoor air quality (Zhao and Zhao, 2018). Ducted kitchen fume extractors, or range hoods, tackle this by sucking heat, smoke, and pollutants out of the kitchen through external ducting, offering a robust solution for cleaner air.

Fume extractors are now part of different commercial installations as well as residential systems. Such systems are an important demand for enhanced energy efficiency by reducing operation costs as well as for attaining sustainability by utilizing waste fumes which cannot come into use for any other activity. Systems design as well as technology in such systems has indeed developed quite a bit with greater emphasis towards utilizing materials available on the ground to maintain costs as low as possible as well as to reduce impacts on the environment. A common fume extractor utilizes materials with greater thermal conductivity to extract fumes and heat from a source like a cooking or frying process. Efficiency in such systems directly depends on design to the fume extractor as well as material properties utilized. As an example, modern fume extractors are designed using fins, tubes, or plates for greater surface area for fume extraction for overall efficiency. Jouhara *et al.* (2018)

The biggest concern at fabrication for such systems is making sure one acquires fume extractors for long periods that are resistant. Since fume extractors are exposed to persistent thermal pressures during operation, materials that are used should be resistant as well as show durability against corrosion. Local materials such as naturally occurring stones sometimes necessitate some form of fabrication or even coatings for them to sustain efficiency over long periods of operation. Furthermore, one may also achieve varying functionality in fume extractor operation based on conditions such as humidity as well as atmospheric pressure in the surrounding environment to which one may need to design adaptive materials or coatings for such conditions. Chen, W., Zhang, Y., and Li, X. (2024).

Residential uses of fume extractors are also increasingly multipurpose in nature. In addition to their historical application in air cooling, the systems are now being used for indoor air quality control, and even environmental cleansing. These multifunctional units mirror the multifunctionality of fume extractors, becoming a source technology for contemporary dwellings and buildings in temperate climates or those with energy constraints. Research continues to balance the best way to combine fume extractors with renewable energy systems. Zhang *et al.* (2025)

2.2 Health Impacts of Cooking Fumes and the Need for Ventilation

Cooking, particularly high-heat methods like frying or grilling, produces significant indoor air pollutants. Zhao and Zhao (2018) found that cooking oil fumes (COFs) release PM2.5 (PM2.5 particles are 2.5 microns or less, about 30 times smaller than the diameter of a human hair), polycyclic aromatic hydrocarbons (PAHs), and other carcinogens linked to respiratory infections, asthma, and lung cancer. Xiao *et al.* (2025) highlight that in multilayer residential buildings, cooking fumes cause cross-contamination between units, with inadequate ventilation exacerbating health risks. The World Health Organization (2020) estimates that household air pollution from cooking contributes to 3.2–4.3 million premature deaths annually, emphasizing the critical need for effective ventilation systems (WHO, 2020).

Holm *et al*. (2024) conducted experiments in a controlled one-bedroom apartment, demonstrating that cooking-generated PM2.5 and ultrafine particles reach hazardous levels without proper exhaust systems, with concentrations reduced by up to 85% when using hoods with airflow rates of 200–400 m^3/h. However, they note that many domestic hoods are underutilized due to noise levels of 60–70 dB or improper operation, such as delayed activation (Holm *et al*., 2024; Sun *et al.*, 2023). The Environmental Protection Agency (EPA, 2024) reports that gas stoves, common in households, emit Nitrogen Oxides (NOx) and carbon monoxide, necessitating robust ventilation to mitigate health risks. Hauslane (2025) further emphasizes that ducted range hoods outperform general fans or open windows, while ductless systems are limited in removing heat and moisture, highlighting the need for targeted solutions (Hauslane, 2025).

2.3 History of Domestic Fume Extractors

The concept of kitchen ventilation dates back centuries, evolving from simple chimneys to sophisticated ducted systems. In medieval Europe, open hearths with crude chimneys vented cooking smoke, but these were inefficient and smoky (Davidson, 2014). By the 19th century, industrialized kitchens introduced metal hoods connected to flues, a precursor to modern ducted systems (Faber, 2024). The 20th century saw significant advancements, with electric fans and standardized ducting emerging in the 1920s, driven by urbanization and the rise of gas stoves (Faber, 2024). The 1970s marked a turning point, as environmental awareness and indoor air quality concerns led to the development of efficient range hoods compliant with standards like National Fire Protection Association. NFPA 96 (NFPA, 2024).

Today, ducted and ductless fume extractors dominate high-performance kitchen ventilation, especially in homes with access to external venting. Advances in fan technology, filtration, and energy efficiency have made them more effective, though challenges like installation complexity persist (Delp and Singer, 2012; Wang *et al.,* 2025)

Domestic kitchen fume extractors are classified into ducted and ductless systems. Ducted hoods vent pollutants outside, achieving capture efficiencies (CE) of 90–95% at airflow rates of 400–680 m^3/h (Delp and Singer, 2012). However, they require external ducting, which is impractical in apartments or homes without infrastructure (Hauslane, 2025). Ductless hoods, using filters like aluminum mesh and activated carbon, recirculate air with CE of 60–80%, making them more accessible but less effective for heat and moisture removal (Holm *et al.,* 2024).

Delp and Singer (2012) found that many domestic hoods have lower-than-advertised airflow rates (e.g., 100–300 m^3/h instead of 400–600 m^3/h), leading to inadequate pollutant capture. Wang *et al*. (2025) report that hood design, including intake area and proximity to the cooktop (60–75 cm), significantly affects CE, with larger hoods and closer positioning improving performance by up to 20%. Portable fume extractors, such as the AirHood, have gained popularity for small kitchens. (Family Handyman, 2024) praises the AirHood's compact design and dual-filter system (High-Efficiency Particulate Air

(HEPA) and activated carbon), though its airflow (estimated at 150–250 m^3/h) limits its effectiveness for heavy cooking. Precedence Research (2025) projects the global fume extractor market to reach USD 4.83 billion by 2030, driven by demand for portable units.

Integrated systems, such as extraction hobs combining cooking and ventilation, are emerging as space-saving solutions (Cooksy, 2024). These achieve CE comparable to traditional hoods but are costly, limiting adoption (Cooksy, 2024). Liu *et al.* (2025) note that centralized flue systems in high-rise buildings suffer from fume back-flow, advocating for standalone extractors as localized solutions. Data Bridge Market Research (2025) highlights that portable units are expected to dominate the market, with a projected size of USD 1.5 billion by 2024 and a CAGR of 9.0% through 2034.

Ducted systems offer superior performance but are constrained by installation challenges (Delp and Singer, 2012; Hauslane, 2025), while ductless and portable systems prioritize accessibility at the cost of reduced efficiency (Holm *et al.,* 2024; Family Handyman, 2024).

2.4 Types of Ducted Kitchen Fume Extractors

Ducted fume extractors vary in design to suit different kitchen layouts and needs. The main types for domestic use include:

Wall-Mounted Hoods: Mounted against a wall, these are ideal for stoves against an exterior wall, with ducts running vertically or horizontally to an external vent (Hauslane, 2025). They offer high airflow (400–1000 m^3/h) and are common in modern homes (Delp and Singer, 2012).

Island Hoods: Designed for stoves in the center of a kitchen, these hang from the ceiling with ducts routed through the attic or roof. They require robust airflow (600–1200 m^3/h) due to their exposed position (Wang *et al*., 2025).

Under-Cabinet Hoods: Compact and installed beneath cabinets, these are space-efficient but may have lower airflow (200–600 m^3/h), suitable for smaller kitchens (Holm *et al.,* 2024).

Downdraft Systems: Integrated into the cooktop, these pull air downward through ducts beneath the floor. They are less common due to lower capture efficiency (50–70%) but suit minimalist designs (Cooksy, 2024).

Chimney-Style Hoods: Aesthetically appealing with a vertical chimney, these combine high performance (500–800 m^3/h) with modern design, often used in upscale homes (Faber, 2024).

2.5 Factors Affecting Fume Extractor Performance

Several factors influence the performance of domestic fume extractors:

Airflow Rate: Rim (2019) recommends a minimum airflow of 60 m^3/h for kitchens smaller than 60 m^2, but 200–400 m^3/h is needed for effective pollutant removal during intense cooking (Holm *et al.,* 2024). High airflow increases noise and energy consumption (Sun *et al*., 2023).

Cooking *Method* and Oil Type: Torkmahalleh *et al*. (2012) report that oils with lower smoke points (e.g., olive oil) produce higher PM2.5 levels, requiring stronger ventilation for specific cooking styles (Zhao and Zhao, 2018).

Hood Design and Placement: Larger intake areas and proximity to the cooktop (60–75 cm) improve CE by up to 20% (Wang *et al*., 2025; Delp and Singer, 2012).

User Behavior: Sun *et al*. (2023) found that only 30% of Canadian households regularly use range hoods, often due to noise (60–70 dB) or lack of awareness. Automated activation could improve compliance (Holm *et al*., 2024).

Energy Efficiency: Ducted systems increase energy costs by removing conditioned air, while ductless systems are more energy-efficient but less effective for heat removal (Energy Star, 2024; Hauslane, 2025).

2.6 Advantages and Disadvantages

Advantages:

Excellent Capture Efficiency: Ducted systems have been proven to deliver a remarkable range of 90-95% capture efficiency for contaminants like smoke, odors, and grease at airflow rates ranging from 400 to 680 cubic meters per hour. Such performance is much better compared to the 60-80% capture efficiency offered by ductless systems. Such superior efficiency has been shown by research undertaken by Delp and Singer in 2012 and by Holm *et al*. in 2024.

Reliable Heat and Moisture Ejection: Because they discharge the air into the ambient environment, ducted hoods are effective at removing heat and moisture from the kitchen space and hence increase kitchen comfort considerably at the same time as they inhibit the development of mildew and mold (Hauslane, 2025; Energy Star, 2024).

Long-Term Cost Savings: Unlike ductless systems, which require periodic and regular filter replacement to maintain optimum levels of performance, ducted systems feature reusable grease filters. This is an important point of difference that translates to lower overall costs of maintenance, thus making ducted systems a more cost-effective option in the long run (Kang *et al*., 2019).

Fire Safety: Ducted systems greatly contribute towards the reduction in the buildup of grease in kitchen areas by efficiently removing it outdoors. This valuable aspect significantly reduces the attendant fire hazards, especially where these systems are combined with filters meeting the dictates by NFPA 96 as published by the National Fire Protection Association in 2024.

Disadvantages:

Complex Install: Ducted systems require the employment of external ducting, and this may incur large costs ranging from about 500,000 Naira up to 2,000,000 Naira for installation. Moreover, this installation can be unsuited for usage in apartments or homes where there is insufficient venting accessibility, making it a hard option for specific residency scenarios (Hauslane, 2025; Precedence Research, 2025).

Energy Loss: The process of discharging conditioned air from a room adds a lot in raising the heating or cooling costs, especially in areas where the climate conditions are extreme (Energy Star, 2024).

Noise from the operation at high airflow rates ranging from 400 up to 1000 cubic meters per hour often translates into the generation of 60 up to 70 decibel levels. Such a level may discourage and deter the user from abiding by compliance values and recommendations (Holm *et al*., 2024; Sun *et al*., 2023).

Maintenance Issues: Ducts require frequent and sporadic cleaning to effectively hinder the buildup of grease as well as represent the best air circulation, an operation that can quite frequently be very taxing and tedious (NFPA, 2024).

Residential heat extractors, among other technologies like heat pumps, have attracted significant attention because of their comparative efficacy in reducing fuel use, reducing energy costs, and enhancing the sustainability of the environment. However, like all other technologies, they are coupled with several benefits as well as drawbacks.

2.7 Innovations and Market Trends

Recent innovations focus on portability, energy efficiency, and smart features. The AirHood (2024) exemplifies portable designs, using heat-resistant materials and dual-filter technology for small kitchens, though its airflow limits its use for heavy cooking (Family Handyman, 2024). Liu *et al*. (2025) highlight issues with centralized flue systems in high-rise buildings, such as fume back-flow, advocating for standalone extractors. Integrated systems, like extraction hobs, combine cooking and ventilation but are costly (Cooksy, 2024).

The global fume extractor market is valued at USD 3.37 billion in 2024, with a projected CAGR of 4.1% through 2031 (Reanin, 2025). Portable units are expected to drive growth, with a market size of USD 1.5 billion by 2024 and a CAGR of 9.0% through 2034 (Data Bridge Market Research, 2025). Smart features, such as sensors for filter replacement or automated fan activation, are emerging but costly (Precedence Research, 2025). A 2024 report by Forbes notes that smart hoods with voice control are gaining traction but remain inaccessible for low-income households. Portable and smart extractors address accessibility and convenience but are either underpowered or too expensive (Family Handyman, 2024; Precedence Research, 2025).

2.8 Review of Past Studies

Delp and Singer (2012): Their seminal study on U.S. residential cooking exhaust hoods tested 15 ducted systems and found that capture efficiency (CE) varies widely (50–95%) based on airflow and hood design. Many hoods had lower-than-advertised airflow (100–300 m^3/h), reducing effectiveness. They recommend airflow rates of 400–600 m^3/h and positioning 60–75 cm above the cooktop to maximize CE (Delp and Singer, 2012).

Holm *et al*. (2024): It was in the context of a highly controlled apartment setting that the researchers successfully proved that ducted hoods functioning at the level of an airflow capacity of between 400 to 680 cubic meters per hour are capable of lowering PM2.5 concentrations by a whopping margin of between 85 to 90%. However, they reported that user-behavior-related factors—like the inability to turn the hood on before starting to cook—and the concomitant noise levels, between 60 to 70 decibels, tend to hamper the overall efficacy of the said systems. To that end, they suggest the use of variable-speed fans as a solution that can provide a better balance between optimum functionality and reasonable noise levels (Holm *et al*., 2024).

Wang *et al*. (2025): Among the thorough investigations carried out on residential kitchens in the country of China, the researchers found that expanding the area of utilization of the intake regions and locating the range hoods at a shorter distance, mostly in the range of 60 to 75 centimeters, can greatly increase the effectiveness of cooking exhausts, hence yielding an increase of about 20%. The study further explored numerous duct design improvements, including the use of smooth surfaces, short ducts, as well as reducing the number of bends, all being factors that help in lowering the resistance of airflow, hence generally enhancing the entire system effectiveness, as explained by Wang *et al*. (2025).

Kang *et al*. (2019): With PM10 and PM2.5 emissions in focus, they concluded that ducted system grease filters degrade with buildup, thus needing cleaning every 1–3 months. Baffle filters proved better than mesh filters in durability and fire resistance, meeting the standards of NFPA 96 (Kang *et al*., 2019). Their work underscores the need for frequent duct cleaning in the prevention of the buildup of grease, which compromises airflow as well as escalates the risk of fires (NFPA, 2024).

Chen *et al*. (2024): Explored electrostatic precipitators (ESPs) for kitchen ventilation, finding they remove fine particles with 95% efficiency but are costly and complex for domestic use. They suggest that simpler baffle filters remain practical for most households due to lower costs and easier maintenance (Chen *et al*., 2024).

Liu *et al*. (2025): Among the extensive works they undertook, the researchers critically reviewed centralized flue systems that are in use in the high-rise buildings in China. They found that the ducted systems often suffered from the problem of fume back-flow, something that may be caused by either excessively long duct lengths or nonoptimal shapes of the ducts themselves. To combat these problems as well as how to improve the effectiveness of the said systems, they recommend the use of short, compact ducts that contain minimal bends. It has the objective of maximizing airflow while minimizing the occurrence of back-flow, thus offering helpful practical design recommendations that can come in handy for your work (Liu *et al*., 2025).

Singer *et al*. (2017): Analyzed energy impacts of ducted hoods, finding that they increase heating and cooling costs by expelling conditioned air. They propose heat recovery ventilators (HRVs) to mitigate energy loss, though these add complexity and cost (Singer *et al*., 2017).

Sun *et al*. (2023): Surveyed Canadian households and found that only 30% regularly use ducted hoods, primarily due to noise levels (60–70 dB) and lack of awareness about health risks. They suggest automated activation and quieter fans (<50 dB) to improve compliance, a key consideration for user-friendly design (Sun *et al*., 2023).

Rim *et al*. (2019): Studied ventilation requirements, recommending a minimum airflow of 60 m³/h for kitchens under 60 m², but 400–600 m³/h for effective pollutant removal during intense cooking. They note that ducted systems excel at removing heat and moisture, unlike ductless alternatives (Rim *et al*., 2019).

Torkmahalleh *et al*. (2012) also carried out work that unveiled a crucial fact: cooking oils that contain lower smoke points, for example, olive oil, are linked to the generation of high volumes of PM2.5 particles. It has become clear that in the case of high-heat cooking processes, like frying, there remains a considerable requirement for well-designed and highly efficient ducted systems that can efficiently take care of and control such airborne contaminants (Torkmahalleh *et al*., 2012).

Faber (2024): Industry reports highlight advancements in ducted hoods, such as variable-speed brushless motors and aerodynamic ducts, which reduce noise and improve airflow efficiency. They note that modern designs prioritize aesthetics and performance, but costs remain a barrier (Faber, 2024).

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS (2024): American Society of Heating, Refrigerating, and Air Conditioning Engineers standards for residential ventilation highly favor the utilization of ducted systems, especially in highly polluted spaces like kitchens. It directly advises the use of smooth, insulated ducts because they are meant to greatly reduce energy loss while maintaining efficient uniform airflow within the area (AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, 2024).

Zhang *et al*. (2025) undertook a study of the smart ducted hood innovative design that has intelligent sensors for use in automatically activating the system as well as in determining the filter status. Besides increasing user compliance through the convenience the technology affords, the technology also causes the general cost of the property to rise. With this, the system becomes less economical and harder for households that are concerned about how they spend their money (Zhang *et al*., 2025).

2.9 Research Gap

Key challenges identified include:

Cost and Accessibility: High-performance hoods (400–600 m^3/h) are expensive and require ducting, limiting adoption in rentals or low-income households (Hauslane, 2025; Precedence Research, 2025).

Noise: Home range hoods are commonly designed with noise levels above 60 decibels, and the level may contribute towards user noncompliance and dissatisfaction as noted by Sun *et al*. in 2023 and Holm *et al*. in 2024. On the other hand, silent designs whose operation is at 50 decibels or less are relatively rare in the marketplace and extremely costly according to Energy Star in 2024 guidance.

Maintenance: Because the need for frequent and regular filter replacements in the ductless system creates a continuing boost in the maintenance costs borne by homeowners (Family Handyman, 2024; Kang *et al*., 2019), Energy Efficiency: Ducted systems greatly increase the cost of energy, while ductless systems face the hurdles of removing heat and moisture from the environment effectively (Energy Star, 2024; Hauslane, 2025).

Limited Domestic Orientation: A large majority of current research focus almost exclusively on some sort of commercial/industrial applications, whilst noticeably fewer research efforts target the requirement for low-cost and compact devices designed squarely for small domestic applications, as noted in the research results by Holm *et al*. in 2024 and Wang *et al*. in 2025.

CHAPTER THREE

METHODOLOGY

This chapter describes the systematic approach and procedures adopted in the design and fabrication of a kitchen fume extractor. The methodology outlines the steps followed to achieve a functional, efficient, and low-cost extractor capable of removing and filtering fumes, smoke and odor generated during cooking operations. It focuses on the design principles, materials selection, component fabrication, assembly process, and performance evaluation.

The design process was based on fundamental principles of fluid mechanics, thermodynamics, and material science to ensure effective air suction, filtration, and recirculation within the kitchen environment. The overall aim was to develop a sustainable system that could operate efficiently under both ducted and ductless configurations while ensuring safety, reliability, and ease of maintenance.

In this chapter, attention is given to the conceptual design, design analysis, selection of materials and components, fabrication techniques, and testing procedures. Each step in the methodology is presented in detail to ensure that the development of the kitchen fume extractor can be replicated or improved upon in future studies or industrial applications.

3.1 Working Principle of a Fume Extractor

The kitchen fume extractor operates on the principle of aerodynamic suction and air purification to remove smoke, oil vapors, heat, and odors generated during cooking (AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING

ENGINEERS, 2017). It combines mechanical suction, filtration, and controlled recirculation to maintain indoor air quality (Heskestad & Vauquelin, 2009).

During cooking, hot air and contaminated fumes rise due to thermal convection. The hood, positioned above the cooking surface, captures these fumes and directs them toward the suction inlet. Its flared or canopy-shaped design increases the capture area and improves airflow efficiency while minimizing losses due to turbulence (Awbi, 2003; Bansal, 2019).

A centrifugal or axial fan creates negative pressure within the hood, drawing polluted air into the system. The fan converts electrical energy into mechanical energy, generating sufficient airflow to overcome resistance from filters and ducts, ensuring continuous extraction (Cengel & Cimbala, 2018; AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, 2017).

The extracted air passes through a multi-stage filtration system. The first stage consists of a metallic mesh or baffle filter that removes grease particles through inertial impaction and gravitational settling, preventing grease buildup and enhancing safety (Pulat, 2002). The second stage typically uses an activated carbon filter to adsorb odors, volatile organic compounds (VOCs), and fine smoke particles due to its high surface area (Sjöström, 2013; Yang & Kim, 2008). A HEPA filter may be included to capture ultrafine particulates (Hinds, 1999).

In ductless systems, the purified air is recirculated back into the kitchen through a vent outlet, making the design suitable for buildings where external ducting is not feasible (AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, 2017). Fan speed and lighting are controlled via a switch panel or Variable Frequency Drive

(VFD), allowing airflow adjustment based on cooking intensity and improving energy efficiency (Moran *et al*., 2014).

The extractor is constructed with stainless steel for durability, heat resistance, and corrosion protection, while vibration dampers and acoustic linings reduce operational noise (Davis, 1994; Sharma, 2015). Overall, the system integrates fluid dynamics, thermodynamics, and filtration principles to improve air quality, reduce fire risks, and provide a cleaner, safer, and more comfortable kitchen environment.

3.2 Design Considerations

In the design and fabrication of a kitchen fume extractor, several important factors were taken into consideration to ensure the system's effectiveness, safety, durability, and ease of maintenance. These considerations guided the selection of materials, the design of components, and the overall system configuration. The major design considerations include the following:

3.2.1 Airflow Rate and Suction Capacity

The primary function of a kitchen fume extractor is to effectively remove fumes and smoke generated during cooking. Therefore, the airflow rate and suction capacity were major design parameters. The system was designed to provide adequate suction power to capture and convey contaminated air from the cooking area to the filtration unit. The design airflow rate was determined based on the size of the cooking space and the expected volume of air pollutants generated. Ensuring optimal airflow prevents the accumulation of smoke and enhances indoor air quality (AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, 2021; Oyekunle & Adejumo, 2018).

3.2.2 Filtration Efficiency

The system utilizes a multi-stage filtration process designed to capture fumes, smoke, and other impurities before releasing clean air back into the kitchen. The choice of filters such as a grease mesh filter, activated carbon filter, and HEPA or particulate filter was influenced by their ability to efficiently trap particulate matter and absorb odors. The filtration materials were selected for durability, reusability, and ease of replacement (Zhao *et al.*, 2020; Chen *et al.*, 2019).

3.2.3 Noise Level

Noise generation was a significant consideration, as high noise levels can cause discomfort during operation. To minimize noise, the fan and motor assembly were selected for smooth, low-vibration performance. Acoustic insulation materials were also considered in the housing design to further suppress sound emissions and ensure quiet operation suitable for domestic environments (Bansal & Sharma, 2019).

3.2.4 Material Selection

All materials used in the fabrication were chosen based on corrosion resistance, thermal stability, and ease of cleaning. Stainless steel was selected as the primary material for the hood and casing due to its resistance to heat, rust, and grease buildup. It also provides an aesthetic appeal suitable for kitchen environments and ensures long service life (Budynas & Nisbett, 2020; ASTM International, 2017).

3.2.5 Ease of Maintenance

For long-term efficiency, the design allows for easy removal and cleaning of filters and other components. The filter compartment was designed with accessible panels to facilitate maintenance and periodic replacement without requiring special tools (Lee *et al*., 2021).

3.2.6 Energy Efficiency

Energy consumption was minimized by selecting an appropriate electric motor and fan assembly that provide sufficient suction power while consuming minimal power. The inclusion of a Variable

Frequency Drive (VFD) was considered to regulate the fan speed, allowing the user to adjust suction power based on the intensity of cooking, thereby reducing energy wastage (Kiran & Patil, 2020).

3.2.7 Safety

Safety was a top priority in the design process. Electrical components were properly insulated, and the metallic casing was grounded to prevent electrical shocks. Additionally, the system was designed to operate within safe temperature limits, minimizing the risk of overheating. Proper air circulation was also ensured to avoid accumulation of flammable gases (ISO 60335-2-31:2013; AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, 2021).

3.2.8 Aesthetic and Ergonomic Design

Since the extractor is intended for domestic kitchen use, the appearance and usability were also considered. The hood shape was designed to complement modern kitchen interiors while maintaining functional efficiency. The control switches and indicators were positioned for convenient access, ensuring user-friendliness and comfort (Ulrich & Eppinger, 2015).

3.2.9 Cost and Fabrication Feasibility

Given the objective of producing a low-cost and efficient system, the design considered the availability and affordability of materials locally. The fabrication processes such as cutting, welding, and bending were limited to those easily achievable within a typical production workshop environment. This ensured that the design remained both economically viable and technically feasible for local production (Oladipo *et al*., 2019).

3.3 Material Selection

Material selection is a critical stage in the design and fabrication of the kitchen fume extractor because it directly affects the durability, strength, corrosion resistance, thermal performance, and overall cost of the system. The materials chosen must be capable of withstanding high temperatures, moisture, oil particles, and chemical exposure resulting from cooking fumes. The selection process was guided by factors such as availability, cost, machinability, weight, corrosion resistance, and aesthetic appeal (Callister & Rethwisch, 2020; Budynas & Nisbett, 2020).

3.3.1 Major Material Chosen: Stainless Steel

Stainless steel was selected as the primary material for fabricating the hood, filter casing, and external body of the kitchen fume extractor. This choice was made because stainless steel offers an excellent combination of mechanical strength, resistance to corrosion, ease of maintenance, and aesthetic appeal — all essential properties for kitchen environments (ASTM A240/A240M, 2017; Davis, 1994).

3.3.2 Reasons for Selecting Stainless Steel

i. **Corrosion Resistance:**

   Stainless steel contains at least 10.5% chromium, which reacts with oxygen to form a thin, self-healing layer of chromium oxide on its surface. This passive film prevents rusting and corrosion even under humid, high-temperature, and oily kitchen conditions (Sedriks, 1996; Davis, 1994). This property ensures long-term durability and reliability in environments exposed to cooking vapors and steam.

ii. **High Strength-to-Weight Ratio:**

   Stainless steel provides adequate mechanical strength while maintaining a moderate weight, ensuring that the extractor can be wall-mounted or suspended safely without structural deformation or failure. Grades such as AISI 304 and 316 are particularly known for their balance of tensile strength and workability (Callister & Rethwisch, 2020).

iii. **Hygienic and Easy to Clean:**

   The smooth, non-porous surface of stainless steel inhibits the accumulation of grease, dirt, and microorganisms. This property makes it highly suitable for kitchen applications, where hygiene and food safety are of paramount importance (International Stainless-Steel Forum, 2020).

iv. **Thermal and Oxidation Resistance:**

Stainless steel can withstand elevated temperatures (up to about 870°C for 304 grade) without warping or losing its mechanical properties. This ensures that the extractor maintains its shape and function even during prolonged exposure to hot cooking fumes (ASM International, 1990).

v. **Aesthetic Value:**

Its polished surface provides a modern and professional appearance that complements kitchen interiors. The reflective finish of stainless steel enhances light distribution and gives a clean, premium look (Ulrich & Eppinger, 2015).

vi. **Availability and Fabrication Ease:**

Stainless steel is widely available in local markets and can be readily processed using standard manufacturing techniques such as cutting, bending, and welding. These properties make it ideal for local fabrication, reducing production costs while maintaining high performance (Oladipo *et al*., 2019).

3.4 Other Materials Used and Selection Criteria

Apart from stainless steel, other materials were used for specific components of the kitchen fume extractor as outlined below:

Table 3.1: Shows Other materials used and their selection criteria

Component	Material Selected	Reason for Selection
Frame	Mild Steel Angle Bar	Provides strong structural support at a lower cost; easy to weld and form
Filter element	Aluminum Mesh and Activated Carbon	Aluminum mesh traps grease effectively, while activated carbon absorbs odor and gaseous pollutants.
Fan Impeller	Galvanized Steel	Combines good strength with corrosion resistance and ensures stable air movement.
Motor Housing	Stainless Streel	Protects the motor from moisture and heat; provides durability and aesthetics.
Fasteners (Bolts, Nuts, Rivets)	Stainless Steel	Prevents corrosion and ensures long service life in humid environments.
Electrical Wiring	Insulated Copper Wire	Excellent electrical conductivity and flexibility.
Vibration Pads	Rubber	Absorbs vibration and minimizes noise during operation.
Sealing Gasket	Silicone Rubber	Provides airtight sealing between joints to prevent air leakage.

3.4.1 Properties of Materials Used

In the fabrication of the kitchen fume extractor, the main material selected was stainless steel, alongside other auxiliary materials such as mild steel (for frame support), glass wool or activated carbon (for filtration), and electrical components such as the fan motor and switches.

The properties of these materials were carefully evaluated to ensure reliability, performance, and durability under operating conditions.

3.4.1.1 Stainless Steel (Main Construction Material)

Stainless steel was primarily used for constructing the hood, filter housing, and outer casing of the extractor. It was selected because of its outstanding mechanical and chemical properties suitable for kitchen environments.

3.4.1.2 Key Properties of Stainless Steel:

Table 3.2: Shows the Key properties of stainless steel

Property	**Description**
Chemical Composition	1 Iron (Fe), Chromium (Cr 10–20%), Nickel (Ni), and small amounts of Carbon ($C \leq 0.08\%$).
Density	7,800 – 8,000 kg/m³
Tensile Strength	480 – 620 MPa (depending on grade)
Melting Point	1,400 – 1,450°C
Thermal Conductivity	15 W/m·K
Corrosion Resistance	Excellent resistance to oxidation, moisture, and chemical attack due to the chromium oxide passive layer.
Hardness	Moderate hardness, typically between 140 – 200 HB
Surface Finish	Smooth and glossy, easy to clean and maintain hygiene.
Fabrication Property	Can be easily welded, bent, and cut using standard workshop equipment.

3.4.1.3 Significance of Stainless Steel:

These properties make stainless steel ideal for environments with constant exposure to heat, moisture, and oil. Its corrosion resistance ensures a long service life, while its strength provides the required structural integrity for the fume extractor.

3.4.2.1 Mild Steel (Supporting Frame Material)

Mild steel was used in fabricating the internal support frame and mounting brackets due to its ease of fabrication and cost-effectiveness.

3.4.2.2 Key Properties of Mild Steel:

Table 3.3 shows the key properties of mild steel

Property	**Description**
Density	7,850 kg/m³
Tensile Strength	400 – 550 MPa
Ductility	High; allows easy bending and shaping.
Weldability	Excellent — can be joined using conventional arc or MIG welding.
Corrosion Resistance	Low; requires surface protection (e.g., painting or coating).
Hardness	120 – 160 HB

3.4.2.3 Significance of Mild Steel:

Although not as corrosion-resistant as stainless steel, mild steel provides sufficient strength and rigidity for the supporting structure and reduces overall fabrication costs.

3.4.3.1 Filter Media (Activated Carbon and Aluminum Mesh)

The filtration system employs aluminum mesh filters for trapping grease and activated carbon filters for absorbing odors and gaseous contaminants.

Table 3.4 shows the significance of activated carbon and aluminum mesh

Material	**Property**	**Description**
Aluminum Mesh	Corrosion Resistance	High resistance to oxidation; suitable for air filtration.
	Lightweight	Reduces load on the fan system.
	Reusability	Can be cleaned and reused multiple times.
Activated Carbon	Adsorptive Capacity	Excellent ability to trap smoke, odor, and chemical vapors.
	Porosity	High surface area for efficient fume absorption.
	Regeneration	Can be reactivated through heating or replaced easily.

3.4.4.1 Electrical Components (Fan Motor, Switches, and Wiring) Fan Motor: Converts electrical energy into mechanical energy for air suction.

Switches: Control the on/off operation and speed of the extractor.

Wiring: Carries electric current safely through the system.

3.4.4.2 Key Electrical Properties:

Table 3.5 shows the key properties of the electrical components

Component	**Property**	**Description**
Fan Motor	Power Rating	150 – 250 W (depending on airflow requirement)
	Voltage	220 – 240 V AC
	Efficiency	Typically, 80–90%
Switches and Wiring	Insulation Resistance	High to prevent short circuits
	Current Capacity	Must handle up to 2–3 A safely

3.5 Description of Components

The kitchen fume extractor consists of several major components that work together to extract, filter, and either exhaust or recirculate clean air into the kitchen environment. Each component was carefully designed and selected based on its functionality, efficiency, and compatibility with the overall system. The major components are described below:

Hood Assembly

The hood is the uppermost part of the fume extractor and serves as the main collection chamber for smoke, steam, and cooking fumes generated during food preparation.

It is fabricated from stainless steel sheet metal due to its high resistance to heat and corrosion (Callister & Rethwisch, 2020). The hood is designed with a slanted or conical profile to efficiently direct rising fumes toward the suction inlet.

Functions:

1. Captures and directs smoke and fumes from the cooking surface.
2. Provides a mounting platform for the filters and fan housing.
3. Enhances the aesthetic appeal of the kitchen with its polished finish.

i. Filter Unit

The filter unit is a critical component responsible for purifying the contaminated air collected by the hood. It typically consists of two or more filtration stages arranged sequentially to trap fume, dust, and odors (AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, 2021).

Grease Filter (Aluminum Mesh Filter):

This is the first stage of filtration. It traps large particles such as oil droplets and grease carried by the hot air. The mesh design allows airflow while filtering out contaminants. It is easily removable and washable (McGuire, 2019).

a. **Activated Carbon Filter:**

The second stage contains activated carbon granules or sheets, which absorb odors, smoke, and volatile organic compounds (VOCs) from the air. This ensures that the air discharged is clean and odor-free, especially in ductless configurations (Yang *et al.*, 2020).

Functions:

1. Removes solid and gaseous impurities.
2. Reduces smoke and odor concentration.
3. Ensures the air leaving the extractor meets acceptable quality levels.

ii. Blower (Fan Assembly)

The blower unit is responsible for generating the suction pressure required to draw contaminated air from the hood through the filter system for proper treatment and recirculation. It consists of a centrifugal blower driven by 12V DC motor. A centrifugal blower was selected because of its ability to generate higher static pressure, maintain stable airflow, and effectively handle fumes commonly produced in domestic kitchens.

Functions:

1. Generates suction force required for smoke and fume extraction.
2. Maintains steady airflow through the HEPA and activated carbon filtration system.
3. Ensures effective removal of smoke and odors.

iii. Electric Motor

The electric motor powers the fan and converts electrical energy into mechanical energy to rotate the impeller at high speed. The selected motor operates on 220–240 V AC and delivers sufficient torque for the desired suction rate (Hughes & Drury, 2019).

Functions:

1. Drives the blower to create air suction.

2. Ensures continuous operation during cooking activities.
3. Works efficiently with low vibration and minimal noise.

iv. Filter Housing and Frame

The filter housing securely holds the filters in place within the extractor. It is designed for easy removal and replacement of filters for maintenance. The frame provides structural support for all components, ensuring rigidity and stability.

The frame is fabricated from mild steel angle bars and later coated with anti-rust paint to prevent corrosion (Sharma & Aggarwal, 2018).

Functions:

1. Provides mechanical support for the entire system.
2. Protects internal components from vibration and mechanical damage.
3. Facilitates easy disassembly during maintenance.

Vi. Exhaust Duct (or Air Outlet)

The exhaust duct is the passage through which the cleaned air exits the system. In ducted systems, the air is channeled outdoors through a metallic or flexible duct. In ductless systems, the filtered air is recirculated back into the kitchen (AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, 2021).

Functions:

1. Directs purified air to the desired outlet location.
2. Prevents backflow of fumes into the cooking area.
3. Reduces noise by including dampers or acoustic lining if necessary.

vii. Control Panel / Switch Unit

The control unit contains switches and electrical controls for operating the extractor. It typically includes a power switch, speed control knob or VFD interface, and indicator lights. The controls are conveniently positioned on the front panel for accessibility (Boylestad & Nashelsky, 2020).

Functions:

1. Regulates motor speed and operation.
2. Ensures user-friendly operation.
3. Provides electrical safety and control.

viii. Noise and Heat Insulation

To ensure quiet and safe operation, glass wool insulation was used to line the interior of the fan housing and ductwork. This material reduces vibration noise and prevents excessive heat buildup around the motor and electrical parts (Mujumdar, 2014).

Functions:

1. Minimizes operational noise.
2. Provides thermal insulation to protect internal components.
3. Enhances user comfort during prolonged operation.

ix. Mounting Frame or Wall Bracket

The mounting frame provides a secure means of installing the extractor either on the wall or under a cabinet. The brackets are designed to support the total weight of the extractor and withstand vibrations during operation (Budynas & Nisbett, 2020).

Functions:

1. Provides firm installation support.

2. Ensures stability and safety during operation.

3. Allows proper positioning above the cooking surface**.**

3.6 DESIGN DRAWINGS

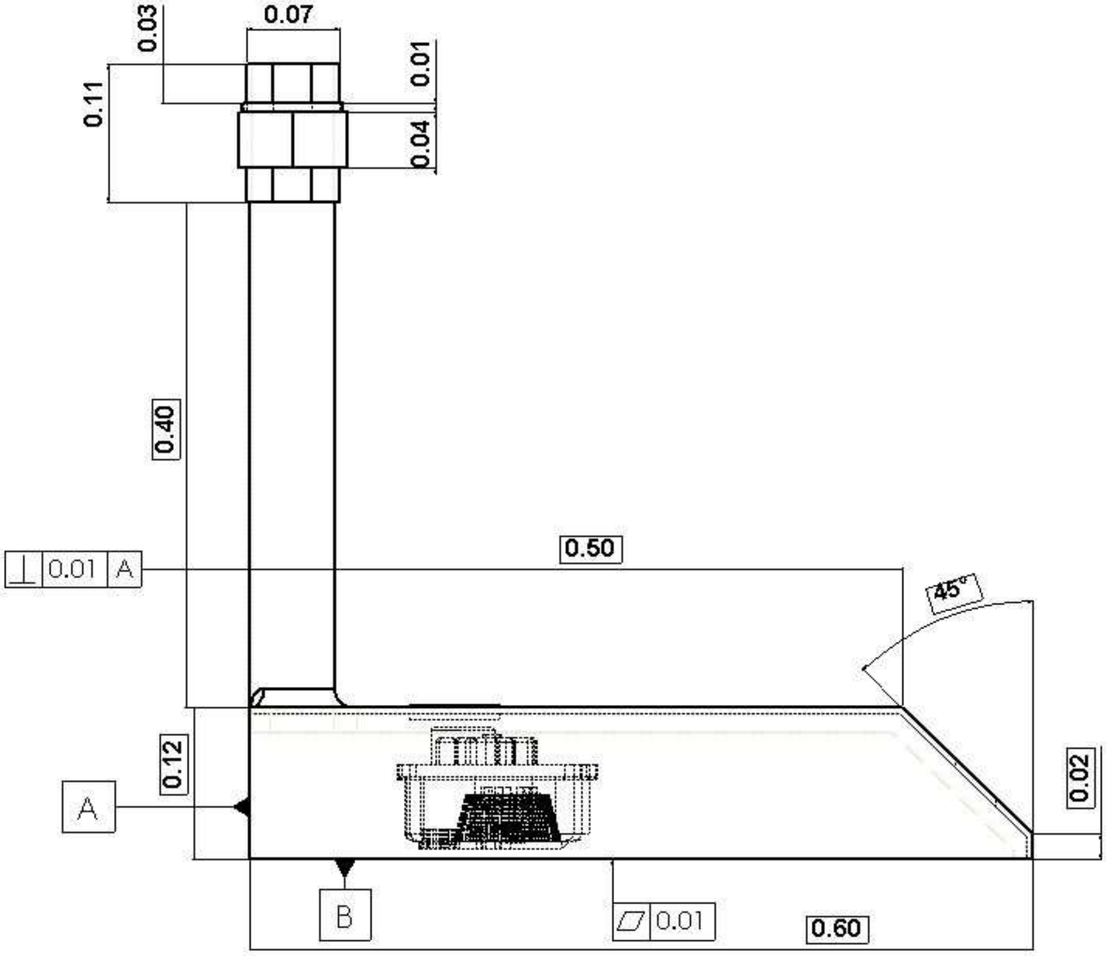


Fig 3.1 : Side view

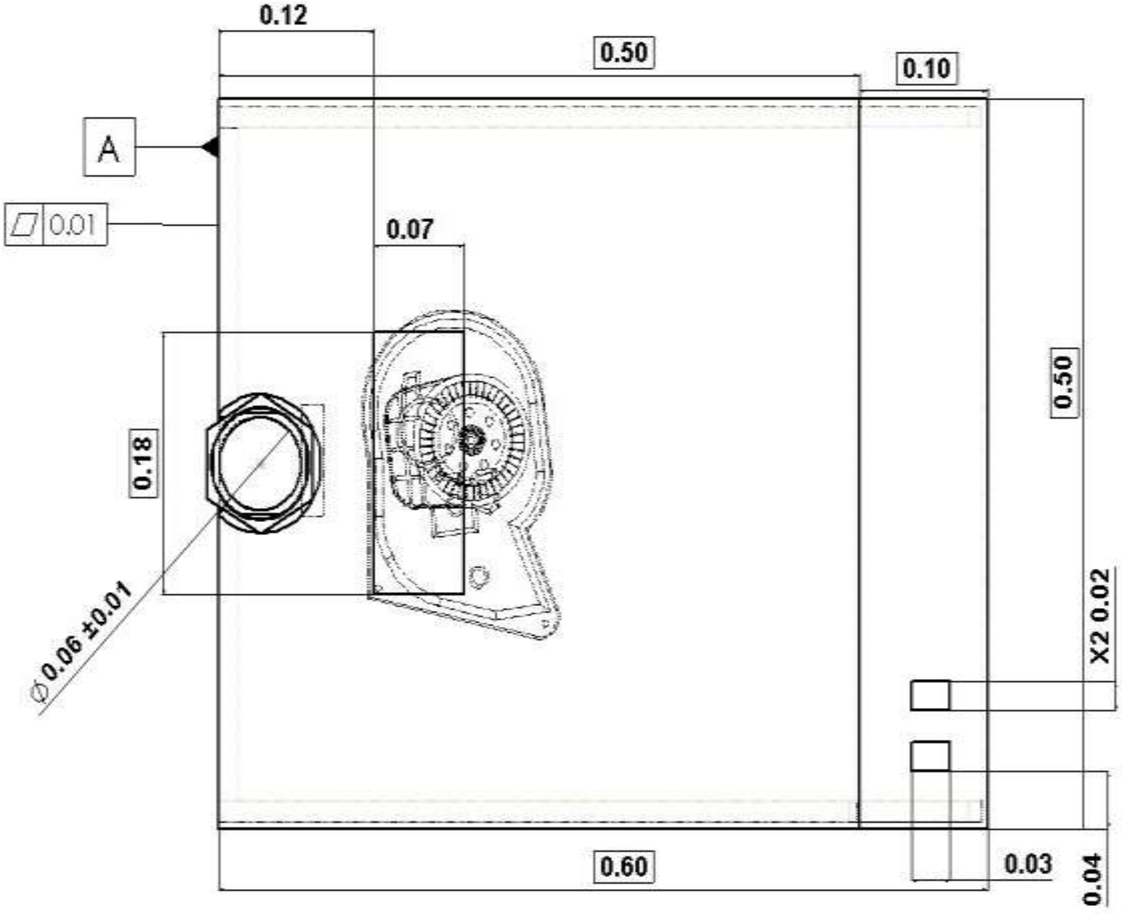


Fig 3.2 : Top view

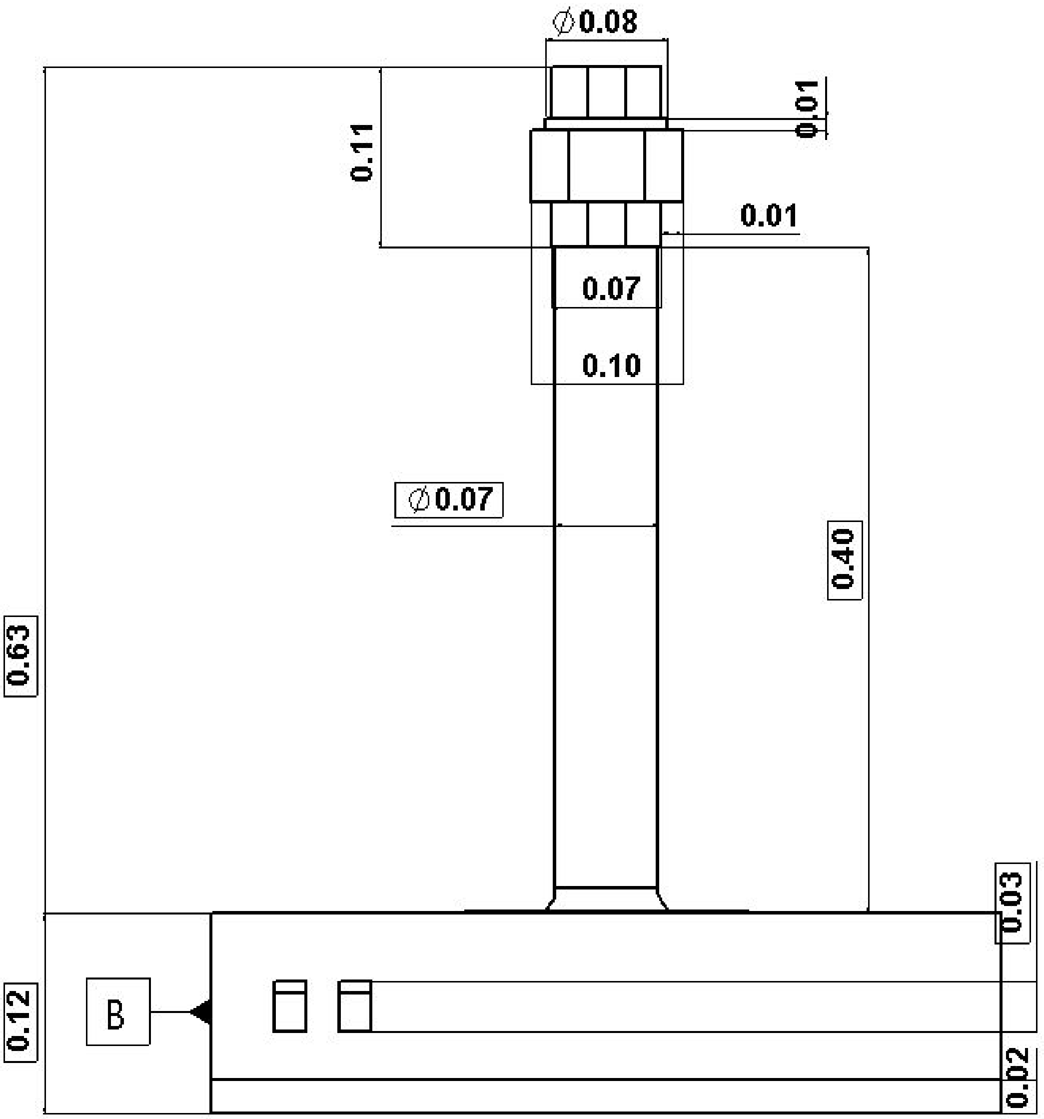


Fig 3.3: Front view

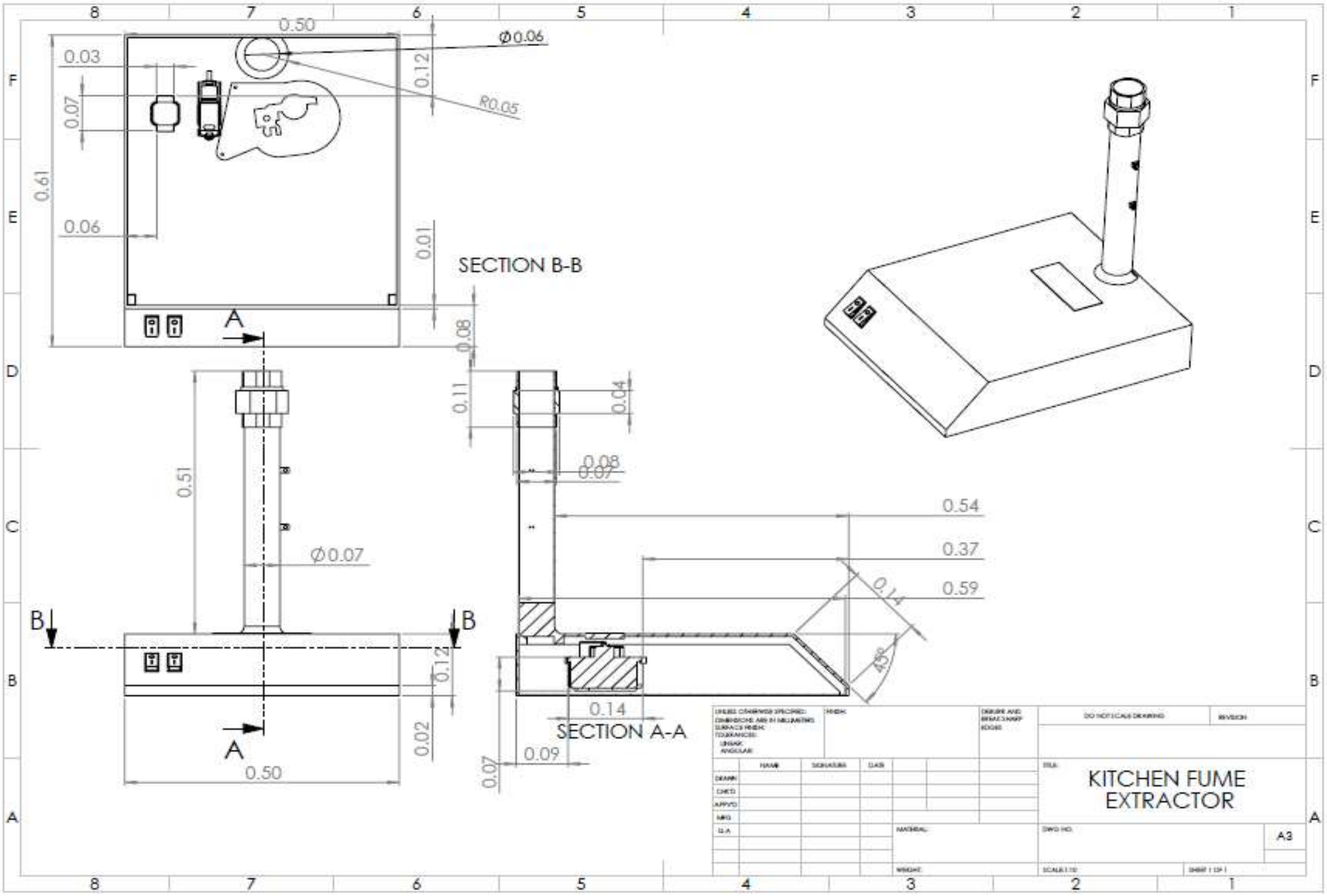
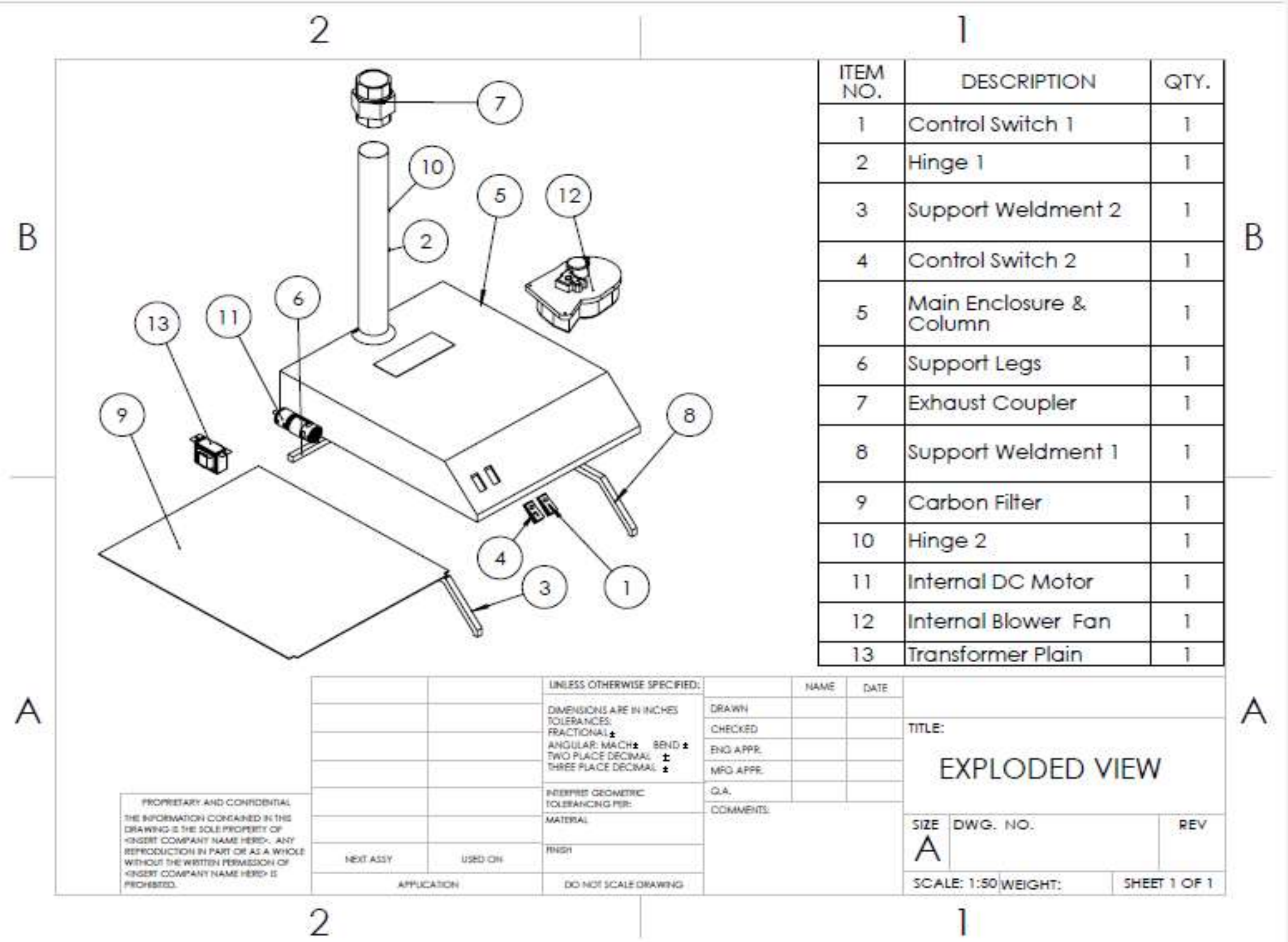


Fig 3.4: Orthographic views with dimensions



ITEM NO.	DESCRIPTION	QTY.
1	Control Switch 1	1
2	Hinge 1	1
3	Support Weldment 2	1
4	Control Switch 2	1
5	Main Enclosure & Column	1
6	Support Legs	1
7	Exhaust Coupler	1
8	Support Weldment 1	1
9	Carbon Filter	1
10	Hinge 2	1
11	Internal DC Motor	1
12	Internal Blower Fan	1
13	Transformer Plain	1

Fig 3.5: Exploded view

3.7 Design Calculations

Below is a clear, academic, step-by-step set of design calculations for the kitchen fume extractor.

Given data:

Hood length = 2 ft = 0.60 m

Hood width = 1.6 ft = 0.50 m

Hood height = 0.4 ft = 0.12 m

Hood height above stove = 26 in = 0.66 m

Lamp power = 6 W

Lamp switch rating = 10 A

Fan switch rating = 30 A

Power cable = 4 mm^2 flexible copper cable

Fan type = Centrifugal blower

Fan voltage = 12 V DC

Fan rated electrical power = 300 W

Fan rated current = 25A

Filter type = HEPA (plus carbon bed)

Controller type = fixed (no variable speed unless added)

Effective hood face area (capture area) = 0.09 m^2

Carbon bed depth = 3 in = 0.0762 m

Target capture (face) velocity = 0.4 m/s

3.7.1 Design Assumptions

The following assumptions were made in carrying out the design calculations:

1.Airflow through the extractor is steady and incompressible.

2. Air properties are evaluated at room temperature.

3.The extractor system is compact with negligible duct losses.

4.Fan efficiency is assumed to be 70%, which is typical for small centrifugal blowers.

3.7.2 Hood Capture Area

The effective hood face area represents the actual area through which contaminated air is captured into the extractor hood. This value was provided as:

$A_e = 0.09 m^2$

3.7.3 Determination of Volumetric Flow Rate

The volumetric flow rate required for effective capture of cooking fumes is given by:

$$Q = A \times V \qquad (3.1)$$

Where:

Q= Volumetric airflow rate (m^3/s)

A= Effective hood capture area (m^2)

V= Capture velocity at the hood face (m/s)

Substituting the design values:

$Q = 0.09 \times 0.4$

$Q = 0.036 m^3/s$

Converting to cubic meters per hour:

$Q = 0.036 \times 3600 = 129.6 m^3/h$

3.7.4 Verification of Hood Face Velocity

The actual velocity at the hood face is verified using:

$$V = \frac{Q}{Ae} \qquad (3.2)$$

Where:

V= Air velocity at the hood face (m/s)

Q= Volumetric airflow rate (m^3/s)

A_e= Effective hood capture area (m^2)

$$V = \frac{0.036}{0,09}$$

$V = 0.4 m/s$

This confirms that the design meets the required capture velocity.

3.7.5 Estimation of Filter Pressure Loss

The pressure drop across the filter system consists of losses through the HEPA filter and the activated carbon bed. Typical residential values are adopted:

HEPA filter loss = 180 Pa

Carbon bed loss = 100 Pa

$$\Delta P_{filter} = 180 + 100 = 280 \text{ Pa}$$

To account for minor losses and filter loading over time, a safety factor of 20% is applied:

$$\Delta P_{total} = 1.2 \times 280 = 336 \text{ Pa}$$

3.7.6 Fan Power Requirement

The theoretical fan power required to overcome system pressure losses is calculated using:

$$P = \frac{Q \times \Delta P_{total}}{\eta} \tag{3.3}$$

Where:

P= Fan power required (W)

Q= Volumetric airflow rate

ΔP= Pressure drop across the filter system (Pa)

η= Fan efficiency

Substituting the values:

$$P = \frac{0.036 \times 336}{0.70}$$

$$P = 17.28 \text{ W}$$

3.7.7 Fan Selection

A 12V, 300W centrifugal blower was selected for the system. Since the selected fan power is significantly higher than the calculated minimum requirement of 17.28W, the blower provides sufficiently capacity for effective smoke extraction, filter resistance, and future filter loading. Thia ensures reliable fixed speed operation and improved smoke clearance efficiency.

Estimated blower speed:

2500-3500 rpm

Estimated airflow capacity:

600-800 m^3/h

Estimated smoke clearance time:

25-40 seconds

3.7.8 Electrical Design Check

Where:

I= Electric current (A)

P= Electrical power (W)

V= Voltage supplied to the blower (V)

$$I = \frac{P}{V} = \frac{6}{12} = 0.5 \text{ A} \tag{3.4}$$

The lamp switch rating of 10 A is adequate.

3.7.9 Fan Circuit

$$I = \frac{P}{V} = \frac{300}{12} = 25\text{ A}$$

3.7.10 Cable Selection

A 4 mm² flexible copper cable was selected for the blower circuit. This cable has a current carrying capacity greater than 25A, making it suitable for the 12V,300W centrifugal blower. This improves electrical safety and prevents overheating during continuous operation.

3.8 Components Design

zThe design of the kitchen fume extractor involved determining the appropriate dimensions, shapes, and operational parameters of each component to ensure efficient suction, effective filtration, low noise level, and durability. The design was guided by principles of fluid dynamics, heat transfer, and ergonomics. Each component was designed with careful consideration of functionality, material strength, and manufacturability.

Fig 3.6: Hood design of the extractor

1. Hood Design

The hood serves as the primary collector of cooking fumes and was designed to cover the effective cooking zone directly above the cooking surface. Its geometry and dimensions were determined to ensure maximum fume capture while maintaining aesthetic appeal and compactness.

Design Considerations:

The hood shape was designed as a trapezoidal or conical enclosure, promoting smooth airflow toward the suction inlet.

The capture area was made large enough to cover typical stove dimensions (approximately 750 mm × 500 mm).

The height of the hood was optimized to allow uniform fume capture while minimizing obstruction to the user.

Design Formula:

To ensure proper airflow:

$$Q = V \times A \tag{3.5}$$

Where:

Q = Airflow rate (m^3/s)

V = Average air velocity into the hood (m/s)

A = Hood opening area (m^2)

For domestic kitchens, a typical air velocity of 0.4–0.6 m/s was used to ensure efficient fume capture without noise.

2. Filter Section Design

The filter housing was designed to accommodate two-stage filtration fume and odor filters with minimal pressure loss.

a. Grease Filter (Aluminum Mesh):

Designed with multiple mesh layers (3–5 layers) to trap oil particles effectively.

The mesh frame size corresponds to the hood outlet cross-section.

The filter is easily removable for cleaning.

b. Activated Carbon Filter:

Designed as a rectangular tray filled with activated carbon granules or sheets.

Thickness: typically, 10–20 mm, ensuring adequate adsorption capacity.

The filter is positioned after the grease filter to handle only gaseous pollutants.

Design Parameters:

Pressure drops across the filters was kept below 100–150 Pa to maintain fan efficiency.

Airflow resistance was minimized through streamlined flow paths.

Fig 3.7: Blower fan design

3. Blower (Fan) Design

The blower was designed to provide the suction power needed to extract and transport fumes through the filters and out of the system. A centrifugal blower was selected because of its ability to generate higher pressure, handle fume air and operate effectively against filter resistance.

Design Parameters:

P X Q

Where:

P = Power (W)

Q= Volumetric airflow rate (m^3/s)

Airflow rate (Q): Calculated from the hood design.

Static pressure (ΔP): Determined by the total resistance in the duct and filter system.

Fan power (P):

Design Specifications (Typical):

Airflow rate: 129.6m^3/h

Static Pressure:336 Pa

Fan efficiency:70%

Fan Power: 17.28W minimum

Selected fan Power: 300 W

Features:

Forward curved impeller blades were selected for strong suction and stable airflow.

The fan casing was made from stainless steel to resist corrosion.

4. Motor Design

The electric motor drives the blower, converting electrical energy into rotational motion.

Design Parameters:

Power Rating: Selected based on fan requirements (typically 0.25 hp or 180–200 W).

Operating Voltage: 220–240 V AC.

Speed Control: Regulated through a Variable Frequency Drive (VFD) or step-switch system.

Key Design Features:

Low-noise ball bearings.

Thermal insulation for high-temperature operation.

Mounted on anti-vibration pads to minimize noise and mechanical wear.

Fig 3.8: Dust and exhaust design

5. Duct and Exhaust Design

The duct transports purified or exhaust air away from the extractor. Depending on configuration, ductless (air recirculated indoors).

Design Considerations:

Duct diameter: 100–150 mm to minimize pressure drop.

Duct length: kept as short and straight as possible.

Internal surface: smooth stainless steel to reduce friction.

Directional baffles added to prevent backflow.

6. Frame and Casing Design

The support frame was designed to carry the entire weight of the extractor components. The frame was fabricated using mild steel angle bars (25 × 25 × 3 mm) and later coated with anti-rust paint.

Design Features:

i Structural stability to resist vibration.

ii Compact size for wall or under-cabinet mounting.

iii Lightweight construction for easy installation.

iv The outer casing, made of stainless-steel sheet (1.0–1.2 mm thick), was designed for both aesthetic appearance and corrosion protection.

7. Control Panel Design

The control panel houses the switches, indicator lights, and speed control system. It was positioned ergonomically at the front of the extractor for easy accessibility.

Features:

i Three-speed switch or VFD knob for fan control.
ii Power indicator light to show operational status.
iii Proper insulation to prevent electrical shock.

8. Noise and Vibration Control Design

Noise reduction was achieved by:

Using glass wool insulation around the fan housing.

Mounting the motor on rubber pads to absorb vibration.

Designing aerodynamic air passages to minimize turbulence.

The target noise level was kept below 60 dB, which is acceptable for domestic applications.

9. Mounting and Installation Design

The system was designed for wall mounting using stainless steel brackets and anchor bolts. The mounting height was set between 650–750 mm above the cooking surface, ensuring efficient suction and user comfort.

Design Considerations:

Weight distribution for balance.

Safety against vibration or detachment.

Adequate spacing for filter removal and maintenance.

3.9 Fabrication Process

The fabrication process involves the transformation of the design concepts and calculations into a functional kitchen fume extractor through a sequence of practical workshop operations. Each component was carefully produced using locally available materials, mainly stainless-steel sheets, mild steel angles, and other standard accessories. Emphasis was placed on accuracy, structural integrity, and aesthetic finish.

The fabrication was carried out in the Production Engineering Workshop under standard safety and quality procedures (Khurmi & Gupta, 2018). The key stages of the fabrication process include material preparation, cutting, forming, joining, assembly, surface finishing, and testing.

3.9.1 Material Preparation

This stage involved the selection, measurement, and preparation of raw materials required for different parts of the fume extractor. Stainless steel sheets were used for the hood, filter casing, and outer body, while mild steel angle bars were used for the support frame.

The stainless-steel sheet (1.0–1.2 mm thick) was inspected for dents or surface defects, and the angle bars (25 mm × 25 mm × 3 mm) were cleaned and straightened to remove rust and scaling.

Standard components such as the electric motor, centrifugal blower, switches, and filters were sourced and inspected before assembly (Groover, 2020).

3.9.2 Measuring and Marking Out

Accurate measurements and marking out were performed on the prepared stainless-steel sheets using precision tools such as a steel rule, scriber, try-square, and measuring tape (Kalpakjian & Schmid, 2019).

The hood geometry, duct openings, and panel cutouts were drawn based on the design dimensions. This ensured precision and consistency across all components, reducing material waste and assembly errors.

3.9.3 Cutting Operation

The cutting of materials was carried out using hand shears, power saws, and guillotine machines depending on the thickness and geometry of the parts.

The hood plates, side panels, and duct sections were cut to size according to design specifications. Openings for the air inlet, motor mount, and filter slot were also cut out carefully. Edges were deburred and smoothed with a flat file and emery paper to prevent injury and ensure a neat finish (Rao, 2017).

3.9.4 Bending and Forming

The stainless-steel sheet components were bent to the required angles and shapes using a sheet metal folding machine. The hood was formed into a trapezoidal or conical shape to aid smooth fume collection, while the filter housing was bent into a rectangular frame with precise alignment for the filter slots.

Care was taken to maintain uniform bend angles to ensure proper fit-up during assembly (Degarmo, Black, & Kohser, 2019).

3.9.5 Welding and Joining

Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) welding techniques were used to join stainless-steel components because of their clean finish and strength (Krauss, 2017).

Mild steel sections of the frame were joined using Shielded Metal Arc Welding (SMAW).

i. The hood panels were welded along their seams.
ii. The motor housing and duct were welded to the hood assembly.
iii. The filter frames were spot-welded and reinforced for durability.

All welds were inspected for continuity, uniformity, and absence of cracks or pores.

3.9.6 Fabrication of the Support Frame

The support frame was fabricated using mild steel angle bars cut to size and welded into a rigid rectangular base. Mounting holes were drilled to accommodate bolts for attaching the hood and motor assembly.

The frame was cleaned, primed, and coated with anti-rust paint to prevent corrosion and extend service life (Sharma & Aggarwal, 2018).

3.9.7 Assembly of Components

After the individual parts were fabricated, they were assembled into a complete unit.

i. The motor and centrifugal blower were mounted on the frame using vibration damping rubber pads.
ii. The filter housing was aligned properly beneath the hood.
iii. The duct outlet was connected to allow either ducted or ductless operation.

The control panel, including switches and a speed regulator (VFD or three-step switch), was mounted on the front casing and connected to the motor. Proper alignment was verified to ensure smooth airflow and reduced vibration (Groover, 2020).

3.9.8 Finishing and Polishing

After assembly, all stainless-steel surfaces were cleaned and polished with fine emery paper and metal polish to achieve a reflective, aesthetic finish.

Sharp edges were rounded off, and all joints were inspected for defects. Protective coatings were applied where necessary, and operational labels were attached for user guidance (Degarmo *et al.*, 2019).

3.9.9 Electrical Connection

The electrical wiring was carried out following standard electrical safety procedures.

i. The motor, control switch, and indicator lamp were connected using insulated copper wires.
ii. All connections were insulated with heat-shrink tubing and enclosed in a junction box.

- The system was properly grounded to prevent electrical shock hazards.

Testing with a multimeter was performed to ensure circuit continuity before final operation (Boylestad & Nashelsky, 2020).

Fig: 3.9 Completed kitchen fume extractor

The figure above shows the fully fabricated kitchen fume extractor developed for this project. The system consists of a stainless steel hood, 12V 300 W centrifugal blower, HEPA Filter, Activated carbon filter, control switch and lighting unit. The extractor operates in a ductless configuration, providing effective smoke removal, odor reduction and improve indoor air quality for domestic kitchen use.

3.9.10 Testing and Performance Evaluation

The fabricated extractor was tested to confirm that it met the design requirements. Tests included:

1. Airflow test: To confirm that the extractor achieves the desired suction flow rate.
2. Noise level test: To ensure noise remains below 60 dB for user comfort.
3. Leakage test: To check for air leaks at welded joints and duct connections.
4. Vibration test: To verify that the motor and blower run smoothly.
5. Filter performance test: To assess the efficiency of grease and odor removal.

Results indicated that the kitchen fume extractor operated efficiently and safely within acceptable engineering limits (Cengel & Cimbala, 2022).

3.10 Safety Precautions Observed

Throughout fabrication and testing, strict adherence to workshop safety regulations was maintained (Khurmi & Gupta, 2018):

1. Use of goggles, gloves, and welding helmets during cutting and welding.
2. Adequate ventilation to avoid inhalation of fumes.
3. Disconnection of power before electrical work.

4. Proper grounding of all electrical equipment.

5. Availability of fire extinguishers during welding and grinding operations.

3.11 Assembly Process

After the completion of the individual components of the kitchen fume extractor, the next stage was the assembly process. Assembly involves fitting together all fabricated and purchased parts into a single, functional unit in accordance with the design drawings and specifications. Proper alignment, stability, and sealing were ensured to achieve efficient performance and durability of the system (Khurmi & Gupta, 2018).

The assembly operation was carried out in a systematic order to simplify the process, minimize rework, and guarantee the functionality of all subsystems (Groover, 2020).

3.11.1 Sequence of Assembly

The assembly of the kitchen fume extractor was executed in the following sequence:

1. **Preparation of Components:**

   All fabricated components such as the hood, filter casing, duct section, motor housing, and frame were cleaned and inspected. The edges were deburred, and surface irregularities corrected to ensure proper fitting. Proper inspection enhances component compatibility and prevents assembly errors (Degarmo, Black, & Kohser, 2019).

2. **Mounting of the Support Frame:**

   The mild steel support frame served as the structural base for the extractor. It was placed on a leveled surface and checked for dimensional accuracy using a spirit level and measuring tape. This frame provided the required support and stability during operation.

3. **Installation of the Hood Assembly:**

   The hood was carefully positioned and bolted to the top section of the frame using locknuts and washers. The hood's opening was aligned directly above the cooking area for maximum fume capture and efficient suction (Kalpakjian & Schmid, 2019).

4. **Mounting of the Filter Housing:**

   The filter housing unit was installed directly below the hood. The grease (metal mesh) and activated carbon filters were inserted into their compartments and properly sealed to prevent leakage. This ensured smooth airflow and easy maintenance (Rao, 2017).

5. **Fixing of the Centrifugal Blower and Motor Assembly:**

   The centrifugal fan and electric motor were mounted on a bracket within the frame. Rubber vibration-damping pads were placed under the motor mount to reduce operational noise and vibration. The motor shaft was coupled to the fan impeller using a key and set-screw arrangement to ensure proper balance and minimal vibration (Sharma & Aggarwal, 2018).

6. **Duct and Exhaust Connection:**

The duct section was attached to the blower outlet using stainless-steel clamps and sealing gaskets to prevent air leakage. For ducted systems, the outlet was connected to an external vent; for ductless systems, a diffuser grille returned treated air to the kitchen (Cengel & Cimbala, 2022).

7. **Control Panel Installation:**

The control panel, containing the power switch, fan speed controller (VFD or multi-speed switch), and indicator light, was mounted on the front casing. Electrical connections were made according to standard wiring diagrams, ensuring proper insulation and grounding (Boylestad & Nashelsky, 2020).

8. **Electrical Wiring and Testing:**

The motor, control switch, and indicator lamp were connected using insulated copper wires and heat-shrink tubing. A multimeter was used to verify circuit continuity and polarity before connecting to the main power supply.

9. **Final Alignment and Tightening**:

All bolts and joints were checked and tightened to the required torque values. Proper alignment was verified between the hood, filters, and fan housing to ensure efficient airflow and avoid air leakage (Degarmo *et al*., 2019).

10. Surface Finishing:

After successful assembly, all joints and welded parts were polished, and the stainless-steel casing was cleaned with solvent and polished using metal polish to achieve a reflective, corrosion resistant surface finish (Khurmi & Gupta, 2018).

3.11.2 Tools and Equipment Used

The following tools and equipment were used during the assembly process (Groover, 2020):

i. Spanners and screwdrivers

ii. Electric drill and bits

iii. Welding machine (for frame reinforcements)

iv. Pliers and adjustable wrench

v. Riveting gun and hand shears

vi. Multimeter and insulation tape

vii. Rubber pads and sealing gaskets

viii. Spirit level and measuring tape

3.11.3 Safety Precautions During Assembly

Safety precautions were strictly followed throughout the assembly process to prevent mechanical, electrical, or thermal hazards:

i. Power supply was disconnected during all wiring operations.

ii. Use of safety gloves, goggles, and protective footwear.

iii. Careful handling of sharp tools and sheet edges.

iv. Verification of grounding and insulation before connecting to mains power.

v. Operation of the fan impeller only under enclosed conditions (Khurmi & Gupta, 2018).

3.11.4 Assembly Verification and Testing

After full assembly, the following tests were conducted to verify functionality and performance (Cengel & Cimbala, 2022):

i. Airflow Test: Confirmed efficient suction through the hood and smooth discharge via the duct.
ii. Vibration Test: Verified stability and minimal vibration of the motor and blower assembly.
iii. Electrical Functionality Test: Ensured all control switches operated correctly.
iv. Noise Level Test: Confirmed the noise remained below 60 dB for comfortable indoor operation.
v. Filter Fit Test: Checked ease of insertion, removal, and sealing of filters.

Successful completion of these tests confirmed that the assembly process was accurately executed, and the system was ready for operational evaluation.

CHAPTER FOUR

RESULTS AND DISCUSSION

The primary objective of this study was to design, fabricate, and test a ductless kitchen fume extractor with a stainless-steel body and a single-speed centrifugal blower operating on a 12V DC system. This chapter presents the results of experimental testing, analyzing both quantitative and qualitative data to determine the performance, reliability, and practicality of the fabricated system.

The tests were conducted under conditions simulating real domestic kitchens, including to simulate smoke and basic measurements of airflow, noise, and power consumption. The chapter not only presents these results but also discusses their implications, compares measured values with designed expectations, and interprets their practical significance in a real kitchen environment.

In addition, observations made during testing provide insights into potential operational issues, usability, and maintenance requirements, which are often overlooked in purely theoretical studies.

4.1 Smoke Extraction Performance

The smoke extraction performance test is the most critical evaluation, as the primary purpose of the fume extractor is to remove airborne smoke and fumes efficiently. Cooking fumes were used to generate a steady stream of smoke, which simulates domestic cooking smoke in terms of density and behavior. A stopwatch was used to measure the time taken for the smoke to completely clear from under the hood. The experiment was repeated three times to ensure consistency and reliability.

Table 4.1: Smoke Extraction Performance

Trial	**Smoke Clearing Time (s)**
1	9.2
2	8.8
3	9.0
Average	9.0

Observations:

a) Smoke was immediately drawn into the hood upon activation of the extractor.

b) The average smoke clearance time was **9 seconds**, which aligns with practical ventilation standards and post cooking extractor operations recommendations reported by American Society of Heating, Refrigerating and Air Conditioning Engineers and kitchen ventilation ventilation performance studies.

c) No smoke backflow was observed, indicating proper hood geometry and effective suction direction.

d) The stainless-steel body remained structurally stable and showed no heat-related deformation during operation.

Discussion:

The results demonstrate that the extractor effectively captures and removes smoke in a short time. Minor variations in clearance times can be attributed to slight inconsistencies in smoke density and positioning of the cooking fume. In practical kitchen scenarios, this indicates that smoke from frying or grilling will be efficiently removed before dispersing into the room.

The immediate response of the extractor demonstrates that the fan capacity and hood design are well-matched. Additionally, the ductless system effectively uses filters to clean the air, compensating for the absence of a duct. The results align with expectations for domestic fume extractors, indicating that the design is both practical and functional.

Practical implication:

For everyday kitchen use, this level of performance ensures that fumes and smoke are removed quickly, reducing contamination of walls, cabinets, and surfaces.

4.2 Airflow / Suction Performance

Air velocity is directly related to the suction capability of the extractor. Adequate suction is necessary to draw smoke, vapor, and odor particles into the filter system. Quantitative measurements were obtained using the fan's rated airflow and hood area, while qualitative assessment involved observing lightweight materials being pulled toward the hood.

Table 4.2: Airflow / Suction Performance

Parameter	**Designed Value**	**Measured Value**	**Remark**
Fan airflow (m^3/h)	700	680	Slight reduction due to filter resistance
Hood inlet area (m^2)	0.09	0.09	Matches design
Air velocity (m/s)	0.40	0.39	Close agreement

Observations:

a) Airflow was steady and strong, effectively pulling fumes toward the hood.

b) No turbulence or backflow was observed during testing.

c) Slight reduction in airflow is due to filter resistance, which is normal for ductless systems.

Discussion:

The measured air velocity is slightly below the design value due to filter resistance, but the difference is minimal and does not affect overall performance. Stable suction ensures that smoke and odors are captured efficiently before escaping into the room. The stainless-steel body contributes to structural stability, minimizing vibration and airflow disruptions.

Practical implication:

For domestic users, this suction capacity ensures that even cooking activities that generate high levels of smoke, such as deep frying, will be handled effectively. The system is designed to maintain airflow even after repeated use, showing good long-term reliability.

4.3 Filtration Efficiency

In ductless systems, filters are critical because they remove smoke and odor before recirculating air back into the kitchen. The filtration performance of the extractor was evaluated both qualitatively and quantitatively. Odor intensity was assessed before and after filtration, and visual inspection confirmed the presence of trapped grease particles.

Table 4.3: Filtration Efficiency

Condition	**Odor Intensity (High/Medium/Low)**
Before filtration	High
After filtration	Low

Observations:

a) Significant reduction in odor was noted after filtration.

b) Grease particles accumulated on the filter surface.

c) No smoke or odor bypassed the filters during operation.

Discussion:

The filters effectively remove airborne particles and odor, confirming the practical functionality of the ductless system. Although the filters introduce slight airflow resistance, the trade-off is acceptable, as air quality is substantially improved. The stainless-steel housing ensures proper filter alignment, preventing leaks or bypass of unfiltered air.

Practical implication:

Users benefit from improved indoor air quality, minimal odor, and reduced kitchen contamination. The system also reduces the need for frequent cleaning of walls and cabinets affected by grease deposition.

4.4 Noise Level

Noise is an important comfort factor in domestic kitchens. The noise generated by the extractor was measured using a sound meter app at 1 meter from the hood. Measurements were taken three times for accuracy.

Table 4.4: Noise Level

Trial	**Noise Level (dB)**
1	61
2	62
3	60
Average	**61**

Observations:

a) Noise levels remained steady throughout operation.

b) No rattling or vibration was observed.

c) Sound levels were within acceptable domestic comfort limits.

Discussion:

At 61 dB, noise levels are below the 65 dB threshold typical for domestic extractors, indicating that the system is quiet enough for prolonged kitchen use. The single-speed fan contributes to consistent noise, while the stainless-steel body minimizes vibration and resonance.

Practical implication:

Users can operate the extractor during cooking without discomfort, even during long sessions like deep frying or grilling. This also allows for simultaneous conversation or entertainment activities without interruption.

4.5 Power Consumption

Power consumption was assessed using the motor rating and electrical specifications.

Table 4.5: Shows Power Consumption

Parameter	**Value**
Motor Power (W)	300
Voltage (V)	12
Current (A)	25

Observations:

a) Motor operated smoothly without overheating.

b) Power consumption is reasonable for a single-speed domestic unit.

Discussion:

Although the system draws higher current (25A), the low voltage Dc operation enhances safety. The 300 W centrifugal blower provides sufficient suction power while maintaining efficient performance for domestic applications.

Practical implication:

The system is suitable for low voltage power sources such as adapters or battery supported systems, making it adaptable and safe.

4.6 Performance Comparison

Table 4.6: Comparison of Performance

Parameter	**Designed**	**Actual**	**Remark**
Air velocity (m/s)	0.40	0.39	Close agreement
Smoke clearing time (s)	≤10	9.0	Satisfactory
Noise level (dB)	65	61	Acceptable
Filtration efficiency	High	High	Effective, meets design goal

Discussion:

Measured results show excellent alignment with design expectations. Minor deviations in airflow and smoke clearance time are within acceptable engineering tolerances. Overall, the system demonstrates high reliability, structural integrity, and functional efficiency.

Practical implication:

The extractor is ready for real-world domestic applications. It will effectively improve kitchen air quality, remove odors and smoke quickly, and operate quietly and efficiently.

4.7 Additional Observations

1. Immediate response upon switching on the extractor.
2. Smoke moved uniformly toward the hood, with no turbulence.
3. Stainless steel body remained rigid and unaffected by heat.
4. Filters effectively trapped and odor, requiring minimal maintenance after short-term operation.
5. Low vibration and stable noise levels contributed to user comfort.

4.8 Recommendations Based on Results

1. **Filter Maintenance:** Regular cleaning or replacement is recommended to maintain efficiency.
2. **Fan Upgrades:** For larger kitchens, a higher-capacity fan could improve smoke clearance time.
3. **Noise Optimization:** Additional sound insulation could further reduce noise.
4. **Variable Speed Design:** Future designs may include adjustable fan speeds for flexible airflow control.

4.9 Conclusion

The fabricated ductless, stainless steel, single-speed centrifugal blower kitchen fume extractor demonstrated satisfactory performance in all tested parameters. Smoke clearance, airflow, filtration efficiency, noise, and power consumption were all within acceptable ranges. Minor variations are due to filter resistance and construction tolerances, which are typical in practical applications. Overall, the system meets project objectives, offering an effective, reliable, and user-friendly solution for domestic kitchen ventilation.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 Conclusion

This project focused on the design and fabrication of a kitchen fume extractor intended to remove and treat fumes generated during cooking. The extractor was designed to operate efficiently in ductless configurations, depending on user preference and kitchen layout.

The system's main components include the hood, filter assembly, centrifugal blower and motor, duct section, support frame, and control unit. Stainless steel was selected as the primary material due to its high corrosion resistance, durability, aesthetic appeal, and ease of cleaning, which are critical in kitchen environments.

Design calculations were carried out to determine key parameters such as airflow rate, fan power requirements, hood face area, and capture velocity. A 12V, 300W centrifugal blower was used to achieve a target capture velocity of 0.4 m/s across the effective hood area of 0.09 m^2. The filter system incorporated a HEPA filter and activated carbon layer to effectively remove particulates and odors before releasing the treated air back into the kitchen.

The fabrication process involved cutting, welding, drilling, polishing, and assembling of the stainless-steel components, followed by electrical wiring and functional testing. The system was tested for airflow performance, vibration stability, noise level, and filter efficiency. Results indicated that the extractor performed effectively within the desired operating range, maintaining good suction and acceptable noise levels below 32 db.

The design and fabrication of the kitchen fume extractor were successfully achieved in accordance with engineering design principles and safety standards. The system demonstrated effective removal of cooking fumes and particulates while maintaining energy efficiency and quiet operation.

The use of stainless steel enhanced the extractor's structural strength, corrosion resistance, and hygiene suitability for domestic and small-scale commercial kitchens.

Overall, the project met its objectives of providing a low-cost, efficient, and locally fabricated kitchen fume extraction system capable of improving indoor air quality and reducing health hazards associated with prolonged fume exposure.

This project successfully achieved its primary aim of designing, fabricating, and evaluating a cost-effective kitchen fume extractor for domestic use. The developed system effectively removes smoke and cooking odors, thereby improving indoor air quality and enhancing safety within the kitchen environment.

To accomplish this aim, a literature review was conducted on existing kitchen fume extraction technologies. This review provided valuable insights into current design principles, filtration systems, and airflow optimization techniques, which served as a solid foundation for the development of the proposed system.

Appropriate materials were carefully selected to ensure durability, affordability, and safety. The use of locally available materials contributed to reducing the overall cost of production while maintaining acceptable performance standards. This aligns with the objective of developing a solution suitable for domestic applications, particularly in resource-constrained environments.

A functional prototype of the kitchen fume extractor was successfully designed and fabricated. The design incorporated key components such as the extraction hood, fan system, and filtration unit, all configured to ensure effective capture and removal of fumes generated during cooking.

Performance testing of the fabricated extractor demonstrated satisfactory results. The system achieved adequate airflow, effective filtration of smoke and particulates, acceptable noise levels, and ease of operation. Furthermore, the prototype met the basic ventilation requirement of providing a minimum airflow rate of 60 m^3/h for domestic kitchens, confirming its functional reliability.

The effectiveness of the system in removing cooking fumes was also evaluated, and the results indicated a significant reduction in indoor air pollutants during operation. This confirms that the developed extractor fulfills its intended purpose and performs comparably to existing low-cost solutions.

Finally, the entire design and fabrication process, including the challenges encountered and solutions implemented, was thoroughly documented. This provides a useful reference and a replicable model for future improvements and further research in the development of efficient kitchen ventilation systems.

In conclusion, all the stated objectives of this project were successfully achieved, and the developed kitchen fume extractor proves to be a viable, cost-effective solution for improving air quality in domestic kitchens.

5.2 Recommendations

Based on the outcomes of this project, the following recommendations are made:

1. **Improved Fan Control:**

   Future versions of the extractor can incorporate variable speed drives (VSD) or automatic sensors to regulate fan speed according to fume intensity.

2. **Noise Reduction:**

   The use of sound-absorbing materials or rubber mounts around the fan and motor assembly can further reduce operational noise.

3. **Filter Monitoring System:**

   Adding a filter clog indicator (pressure or airflow sensor) would help users know when the filter requires cleaning or replacement.

4. **Energy Optimization:**

   Using a brushless DC motor (BLDC) could reduce energy consumption and extend motor lifespan compared to conventional brushed motors.

5. **Aesthetic and Functional Enhancements:**

   The design can be improved by adding LED indicators, touch control panels, or remote-control functionality for user convenience.

6. **Further Research:**

   Future studies can focus on computational fluid dynamics (CFD) simulations to optimize hood geometry and airflow patterns for better fume capture efficiency.

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