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Design and Prototype Fabrication of an Ash Cleaning Device for Grill Application

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Abstract

Cleaning ash from grills is often messy, time-consuming, and poses safety risks due to airborne particles. This study presents the design and development of a Multi-Sprayer Ash Vacuum Cleaner a device that integrates vacuum suction with a water-spraying mechanism to simplify grill cleaning while improving hygiene and safety. The project began by identifying user needs through surveys, which highlighted the demand for a tool that is easy to use, heat-resistant, and effective at managing ash without spreading dust.

Using SolidWorks 2024 and ANSYS 2024 R2, multiple design iterations were simulated and optimized. The final prototype features a DC motor-driven suction system and a water pump-fed sprayer nozzle, designed to work in tandem. Fabricated through 3D printing and manual assembly, the prototype was tested under realistic conditions. Results showed the sprayer successfully dampened hot ash, while the suction system efficiently removed the residue.

With added features such as an ergonomic handle, detachable ash container, and heat-resistant housing, the device meets practical user demands. This study demonstrates how engineering design, simulation, and user feedback can be combined to develop a functional, user-friendly solution for a common household problem.

1. Introduction

Grills have long been cherished as versatile cooking appliances that bring people together, whether fuelled by gas, charcoal, or electricity. They transform everyday meals into delightful culinary experiences, infusing food with rich smoky flavours that evoke the joy of outdoor dining. From casual weeknight dinners to lively gatherings with family and friends, grills offer a unique space where both novice cooks and seasoned chefs can experiment from perfectly seared steaks to vibrant grilled vegetables and even homemade pizzas. Beyond the food itself, grilling creates memorable moments filled with good conversation and shared happiness.

However, the pleasure of grilling often comes with the challenge of dealing with ash, especially when using charcoal or wood. Traditional cleaning methods using shovels, brooms, and dustpans are time-consuming and messy. The fine ash particles easily become airborne, creating dust clouds that not only make cleaning harder but also pose health risks, particularly for people with respiratory sensitivities. To address these issues, ash vacuum cleaners have been developed. Unlike regular vacuums, these specialized devices are designed to safely and efficiently handle the unique demands of ash cleanup, making the post-grill experience cleaner and healthier for everyone.

2. Methodology

The development of the multi-sprayer ash vacuum cleaning device for grills followed a systematic engineering design process, combining creative brainstorming, digital modeling, and hands-on fabrication to ensure both innovation and practicality.

2.1 Concept Design

Designing a multifunctional ash vacuum cleaner for grill use starts with understanding the real needs of users. Through a targeted survey, the team gathered insights into common cleaning struggles like ash buildup, hard-to-reach spots, and the time it takes to clean. This user feedback shaped the direction of the design from the very beginning.

Next, existing ash vacuum models on the market were reviewed to spot gaps and limitations. Key considerations like heat resistance, safety, ease of use, and overall efficiency helped guide improvements. Practical aspects like preferred size and price range were also factored in.

At the heart of the new design are two main systems: a powerful vacuum suction unit to collect ash, and a precision nozzle to clean tight grill spaces effectively. To make the device even more useful, a water pump system was added, allowing users to spray down greasy or dusty surfaces before vacuuming making the cleaning process easier and more efficient.

Figure 1 visually organizes this development process, mapping out the core features and enhancements inspired by both user feedback and technical research.

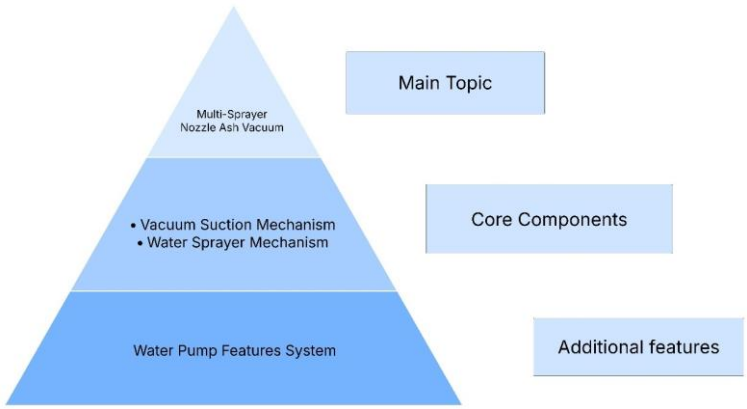


Fig 1: *Multi-Sprayer Ash Vacuum Mind Map [1]*

2.2 Embodiment Design

The embodiment design of the Multi-Sprayer Ash Vacuum Cleaner brings together all the key components in a well-organized, practical layout aimed at making grill cleaning easier and more efficient for users. At this stage, the focus is on how everything fits and works together from the suction and spray systems to the smaller supporting parts. To guide this, a schematic diagram was created, showing how the motor, water pump, spray nozzle, and ash container are connected. Each part has a clear role, and the diagram helps visualize how ash is collected and how water is sprayed during cleaning. A basic geometric layout was also drafted to give an early look at the size and arrangement of components inside the cleaner's body. This helped ensure that everything fits neatly, works efficiently, and feels comfortable to use. Altogether, this design approach balances function with user-friendliness ensuring the final product isn't just effective but also safe, compact, and convenient for everyday grill maintenance [2].

Figure 2 illustrates how the Multi-Sprayer Ash Vacuum Cleaner works, breaking down each component and showing how they come together in one smooth system. The design revolves around two main features: a water-spray system and a vacuum suction system working in sync to make grill cleaning quicker, safer, and more effective. On the left side of the schematic, the process begins with the water tank. When the user activates the pump switch, water is drawn from the tank and flows through the tubing to the spray nozzle. This allows the

user to moisten the grill surface, softening hardened ash and greasy build-up. On the right side, the vacuum system kicks in. With the motor switch on, the DC motor generates suction, pulling in the loosened debris through the vacuum nozzle. The design ensures that dust and ash are removed efficiently with minimal mess. What makes this system unique is how the sprayer and vacuum work together. The sprayer prepares the surface, and the vacuum handles the cleanup making it especially effective for stubborn residues that regular vacuums might struggle with [3].

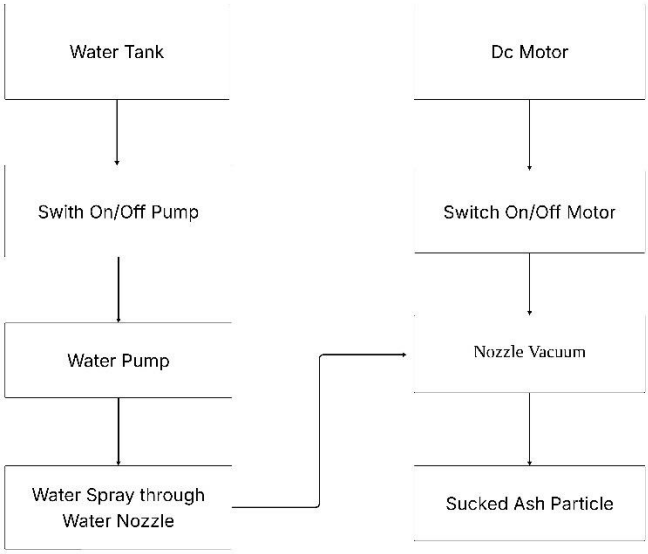


Fig 2: Schematic Diagram of Multi-Sprayer Ash Vacuum

Figure 3 show that all the objects of the schematic diagram be grouped together. In general, a cluster is one or more different parts that are substantially adjacent or near to each other. The shape diagram is a non-linear graphic organizer that shares parallels a mind map, and starts with a single entry to branch out into multiple cause and effect relationship's compartments. Below is a sketch of the Multi-Sprayer Ash Vacuum Cleaner.

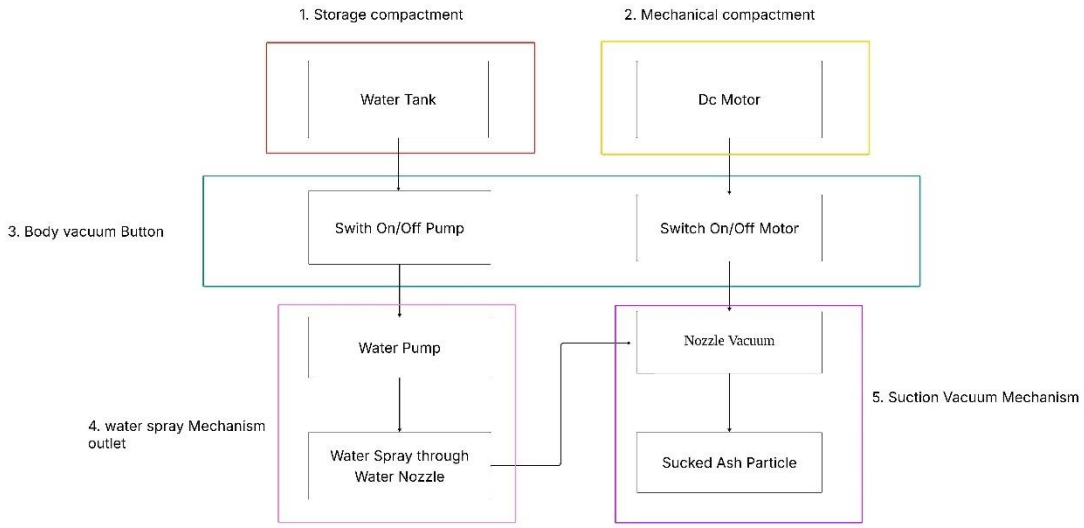


Fig 3: The Element Schematic of Multi-Sprayer Ash Vacuum [4]

This section will showcase an initial sketch of this product (Figure 4), demonstrating its innovative features and versatile designs to simplify the Multi- Sprayer Nozzle Ash Vacuum.

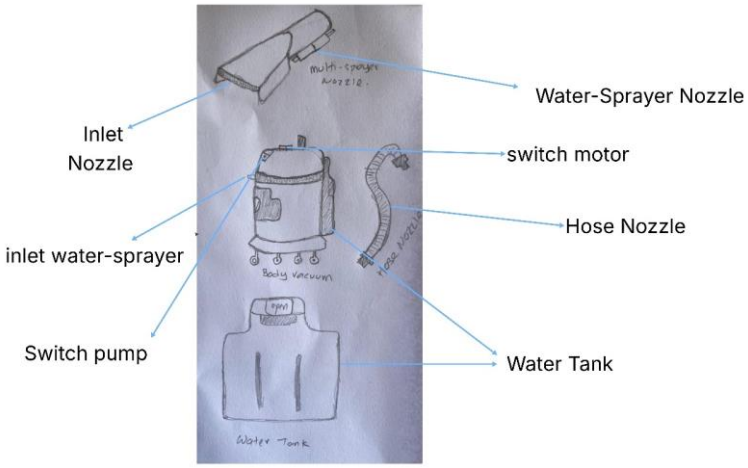


Fig 4: Initial Drawing of Multi-Sprayer Ash Vacuum

3. Result and Discussion

The final design of the Multi-Sprayer Ash Vacuum Cleaner brings together all the key features developed during the project ensuring the prototype delivers both strong ash suction and precise water spraying as intended. This completed design not only meets the technical goals but also aligns with user expectations for ease of use and reliability.

Two main visuals help communicate the design clearly: the assembly view, showing the device fully built with all components motor, pump, housing, nozzle, and container in place; and the exploded view**,** which breaks it all down, part by part. The exploded view is especially helpful for understanding how everything fits together, making it a valuable guide for building, servicing, or upgrading the vacuum in the future. Together, these views form a solid reference for both fabrication and future innovation.

3.1 Design Outcome

The solid modelling image offers a clear, complete view of the Multi-Sprayer Ash Vacuum Cleaner in its fully assembled form. It highlights how all the main parts like the DC motor housing, ash container, sprayer nozzle, water tank, tubing, and pump come together to create a functional, user-friendly device.

This visual not only demonstrates the integration of suction and spraying functions but also shows how the design has been carefully optimized for performance and ease of use. Figure 5, which presents the assembly view, serves as a practical reference for understanding how each part connects and interacts making it helpful for building, maintaining, or upgrading the prototype in the future.

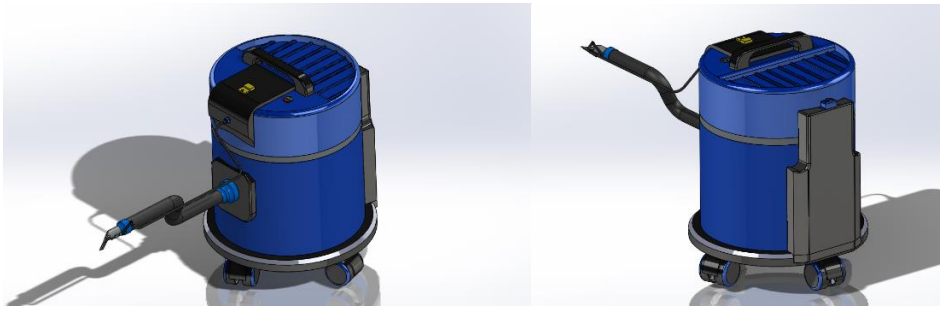


Fig 5: Assembly View of Multi-Sprayer Ash Vacuum

The vacuum suction mechanism in the Multi-Sprayer Ash Vacuum Cleaner works by creating negative pressure to pull in ash and debris from grill surfaces. As shown in Figure 6, suction begins at the nozzle, where air and ash are drawn in by a DC motor-powered impeller. The nozzle's design helps ensure even suction, reaching into narrow gaps and corners [5].

Research Progress in Mechanical and Manufacturing Engineering Vol. 7 No. 1 (2026) p. 385-395

The ash-laden air then travels through a flexible hose into the main vacuum body. Inside, it passes through a pleated filter that traps fine dust, protecting both the motor and the environment from particles. Clean air is then released through the ventilation system, while the collected ash settles into the lower container making the cleaning process both efficient and mess-free [6].

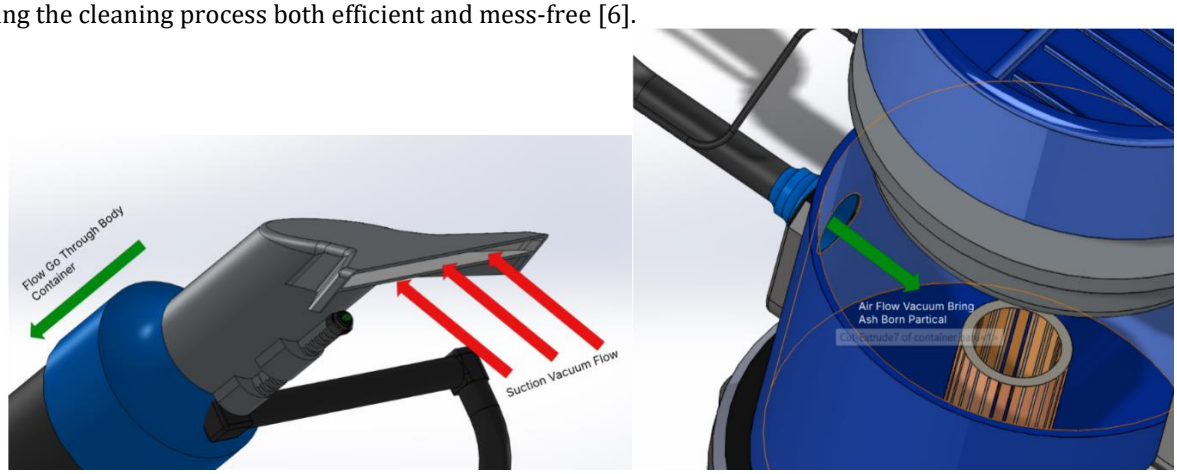


Fig 6: Vacuum Suction of Multi-sprayer Ash Vacuum

The nozzle sprayer system in the Multi-Sprayer Ash Vacuum Cleaner is designed to make grill cleaning easier by delivering a focused, pressurized spray of water before vacuuming begins. As shown in Figure 7, the process starts in the water tank, which holds clean water or a mild cleaner. Once the pump is switched on, water is drawn up and directed through a sealed connector and tubing system.
The water then travels along the vacuum body through flexible tubes until it reaches the multi-sprayer nozzle at the front. There, it's sprayed outward in multiple directions, covering the grill surface and helping to loosen ash and grease. This pre-spray softens stubborn debris, making the vacuuming that follows more effective and reducing the need for manual scrubbing [7].

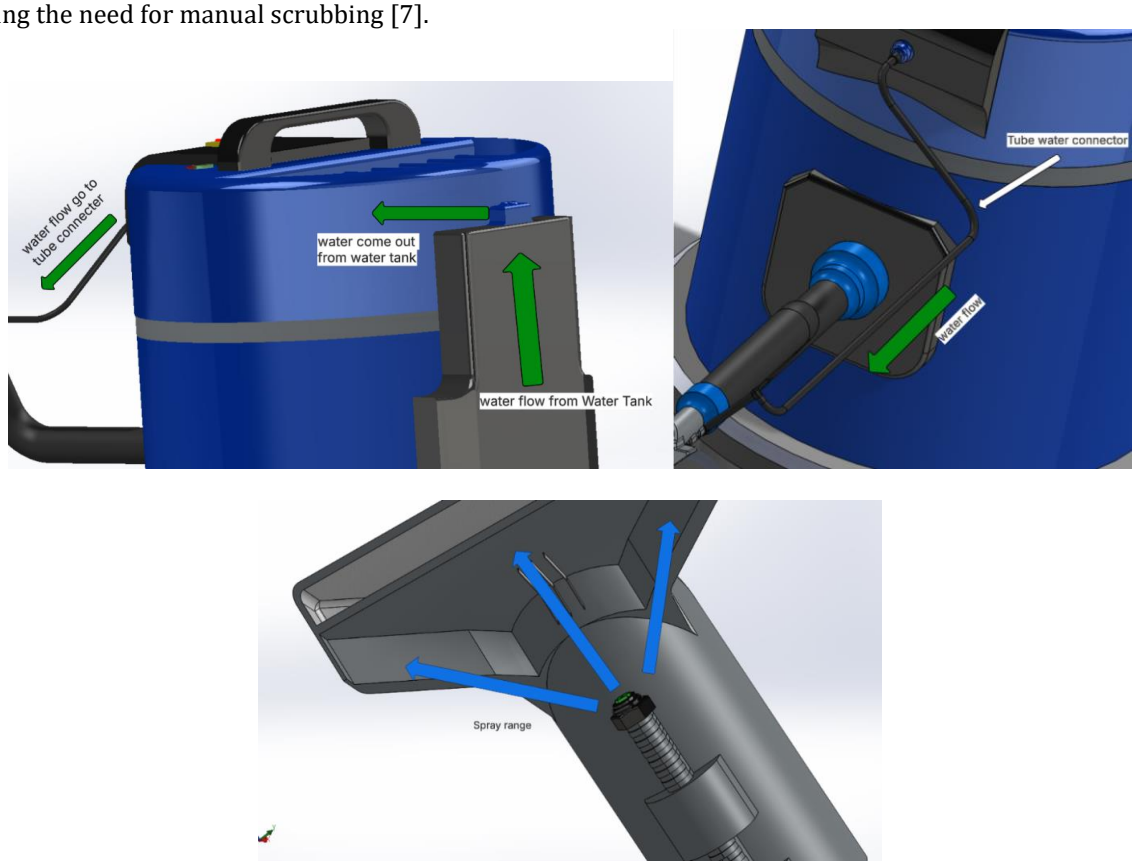


Fig 7: Nozzle Sprayer Mechanism Multi-Sprayer Ash Vacuum

3.2 Explode View

Figure 8 presents the exploded view of the Multi-Sprayer Ash Vacuum Cleaner. This illustration provides a detailed breakdown of the vacuum cleaner's individual components, showcasing how each part fits together to form a complete and functional system. Key components such as the vacuum head, motor housing, filter element, water tank, main body, sprayer nozzle, hose connection, and mobility wheels are displayed separately to highlight their specific design and placement within the unit.

This exploded view is essential for understanding the assembly sequence and the interconnections between components, ensuring smooth assembly, maintenance, and repair procedures. It offers a clear visualization of how air and water systems are integrated while emphasizing the modular design of the prototype.

The modular nature of the design allows for individual part replacement or servicing without requiring complete disassembly of the unit, making the vacuum more user-friendly, serviceable, and adaptable for long-term use. This attention to detail supports both the functional performance and practical usability of the Multi-Sprayer Ash Vacuum Cleaner in post-grill cleaning applications [8].

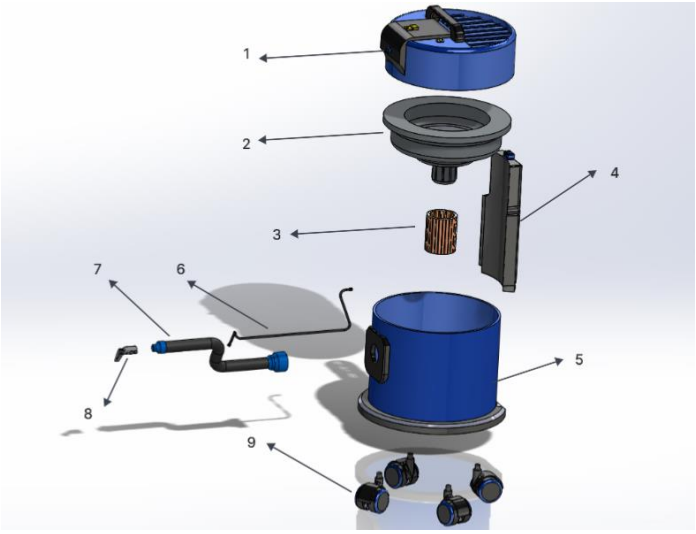


Fig 8: Exploded View of Multi-Sprayer Ash Vacuum

The parts contained in the exploded view are:
1. Head Vacuum
2. Motor Housing
3. HEPA Filter
4. Water Tank
5. Body Container
6. Water Tube Connecter
7. Hose Tube Vacuum
8. Multi-Sprayer Nozzle
9. Castor

3.3 Simulation Analysis Result

For Figure 9(a) The colour gradient illustrates pressure variation ranging from approximately –39,890 Pa (blue, indicating suction zones) to +55,590 Pa (red, indicating spray build-up areas). The simulation shows that the highest pressure occurs near the water inlet, while pressure drops toward the nozzle tip due to velocity increase confirming the nozzle's effective design for dispersing water without backpressure or turbulence. Then, for Figure 9(b) the velocity range spans from 0 m/s (deep blue) to 294 m/s (red), showing a smooth acceleration of flow toward the nozzle outlet. Swirling flow patterns and gradual velocity increase confirm that the nozzle's geometry promotes stable, high-speed spray dispersion. This ensures efficient conversion of pressure into kinetic energy, resulting in a consistent spray pattern ideal for cooling and cleaning ash deposits on grill surfaces. Lastly, Figure 9(c) the vector plot shows how fluid velocity behaves along the nozzle's inner surfaces under 60 m/s flow conditions. Blue zones near the walls indicate lower velocity, while green shades in the central path represent steady, high-speed flow. The results confirm that the nozzle's geometry enables smooth ,

Research Progress in Mechanical and Manufacturing Engineering Vol. 7 No. 1 (2026) p. 385-395

directed spray without turbulence or backflow ensuring consistent fluid delivery and efficient ash removal performance [9].

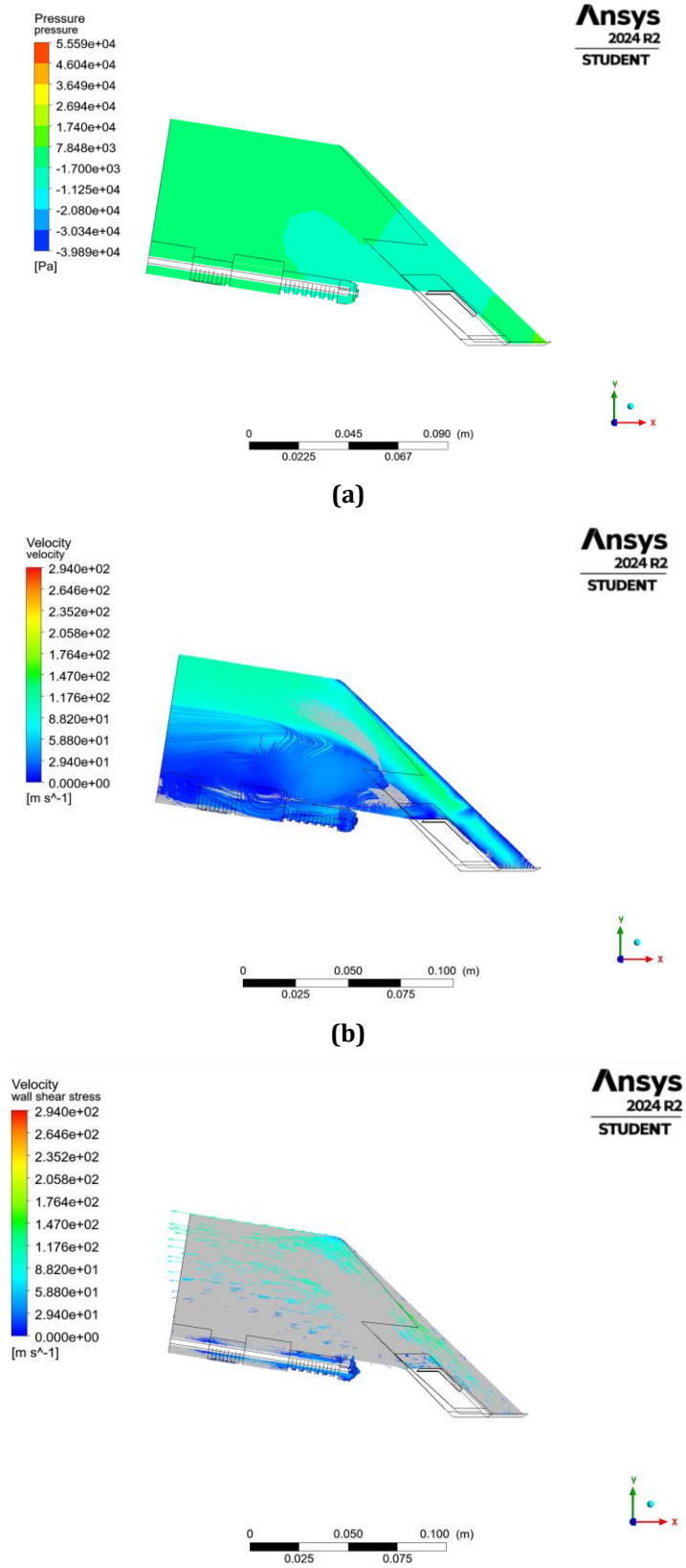
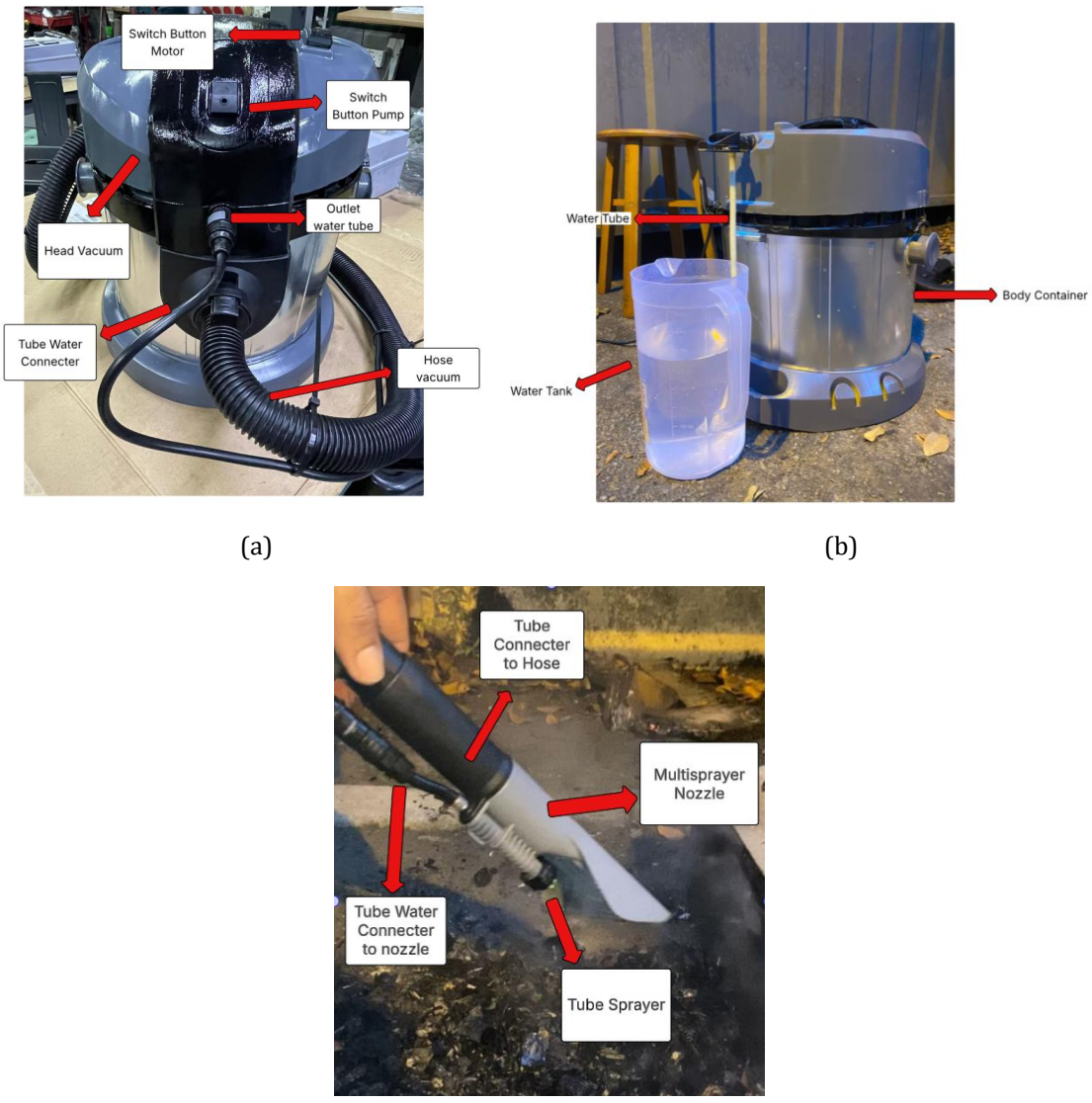


Fig 9: Simulation Result for Multi-Sprayer Nozzle(a) Pressure distribution (b) Velocity distribution (c) *Wall shear stress velocity distribution*

3.4 Prototype and Functional Testing Result

A prototype of the Multi-Sprayer Ash Vacuum Cleaner was fabricated and tested to evaluate its overall performance and functionality. The prototype underwent a series of tests to determine whether it met the intended objectives of ash suction and water spraying for grill cleaning applications. Each mechanism was assessed under simulated real-use conditions to measure its effectiveness, reliability, and to identify any areas for improvement. The completed and assembled prototype of the Multi-Sprayer Ash Vacuum Cleaner is shown in Figure 10.



(a) (b)

(c)

Fig 10: Prototype Multi-Sprayer Ash Vacuum (a) Front View Prototype (b) Back View Prototype (c) Nozzle Multisprayer

The water sprayer mechanism of the Multi-Sprayer Ash Vacuum Cleaner was tested to evaluate its ability to effectively moisten and suppress hot ash residue typically found in grill cleaning environments. The testing involved targeting a pile of burnt charcoal and ash, as shown in Figure 11, to simulate real post-grilling conditions [10].

Research Progress in Mechanical and Manufacturing Engineering Vol. 7 No. 1 (2026) p. 385-395

Fig 11: Testing Multi-Sprayer Nozzle On Ash Burn

The results showed that the water sprayer functioned reliably and fulfilled its purpose within the integrated system, contributing to the cleaner's dual-purpose operation.

The suction performance of the Multi-Sprayer Ash Vacuum Cleaner was tested in realistic grill-cleaning conditions specifically on a surface littered with burnt ash and charcoal remnants after grilling. As seen in Figure 12, the area was densely covered with debris, simulating a typical post-use scenario [11].

During operation, the vacuum nozzle effectively removed both fine ash and larger charred fragments. Thanks to its aerodynamic design and the strong suction from the DC motor, the nozzle maintained steady airflow and avoided clogging, demonstrating its reliability and efficiency in real-world use.

Fig 12 : Testing Suction Vacuum on Ash Burn Particle

The outcome is presented in Figure 13, which clearly shows a visibly cleaner surface with the majority of ash and residue successfully removed. This confirms that the vacuum suction mechanism is capable of delivering effective and reliable performance, fulfilling its intended function as part of the dual-action cleaning system The test validated that the device performs well in realistic usage scenarios, providing a convenient and hygienic solution for post-grilling cleanup tasks [12].

Fig 13: Before and After Use Prototype Multi-Sprayer Ash Vacuum Cleaner

4. Conclusion

This study set out to design, simulate, fabricate, and test a multifunctional ash vacuum cleaner tailored for grill cleaning and successfully achieved that goal. Guided by user input and validated through simulations and real-world testing, the final prototype effectively addressed the challenges of ash removal after grilling.

The combined spray and suction systems worked seamlessly to loosen and collect ash while minimizing dust and manual effort. Simulations using SolidWorks and ANSYS confirmed the design could handle operational pressure and deliver efficient fluid flow at a spray velocity of 60 m/s. Field tests reinforced these results, showing that the water spray cooled and settled hot ash, while the vacuum cleared both dry and damp residues with ease.

User-focused features like ergonomic handles, detachable parts, and heat-resistant materials further enhanced usability. Overall, the prototype performed reliably under realistic conditions, proving that the integration of spraying and vacuuming in one unit is a practical and hygienic solution for grill owners.

Acknowledgement

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

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Journal Article

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