CFD-Enhanced Design: Dual-Propeller Advanced Dry Garbage Cleaning Machine for Efficient Plastic Waste Management

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***Abstract*—This study discusses the plastic garbage problem in the environment, which is mostly caused by poor waste management habits. A lack of knowledge about disposal separation and recycling results in improper treatment methods such landfilling or incineration. The study aims to develop a dry plastic waste cleaning machine to reduce these problems. To maximize its efficiency, the machine has been developed as a plastic cleaning device and used Computational Fluid Dynamics (CFD) simulations. The machine's design focuses on two components: the beating rotor and the outer shell. While the propeller-equipped rotor assembly deliberately beats the garbage and produces axial flow velocity, the outer shell helps manage the garbage flow and avoid splashing. Using SolidWorks software, three models of the dry waste plastic cleaning machine: type of thread, number of propellers, and propeller pattern, were created and subjected to simulation and airflow analysis. The velocity and pressure distributions that resulted from varying the shaft speed parameters from 500 to 2,000 rpm were investigated. The results of the airflow simulation showed that varied propeller configurations resulted in diverse internal airflow behaviors. In particular, the propeller configuration models have affected the axial flow rotation speeds between 500 and 1,500 rpm. Furthermore, axial flow was found to diminish after 1,500 rpm, and there was no discernible variation in air pressure between the three models. This knowledge will contribute to improving the efficiency of the cleanup procedure that is a part of recycling plastic garbage.**

***Keywords*—cleaning machine, plastic garbage, propeller, mechanical cleaning, Computational Fluid Dynamics (CFD)**

I. Introduction

Plastics have become widespread in our daily lives due to their lightweight, durability, and high flexibility. Plastic film, commonly used for packaging and single use items, generates a substantial amount of waste that presents serious environmental challenges. The slow decomposition of plastic waste results in a long-lasting impact on the environment. Thailand's annual municipal waste generation is a significant environmental concern, with indicating an increase in waste production over the coming years. In 2023, Thailand produced about 73,840 tonnes/day of Municipal Solid Waste (MSW), equivalent to approximately 1.12 kg/person/day [1]. By 2030, the forecast suggests that municipal solid waste generation could reach 84,070–95,728 tons/day, translating to 1.23–1.40 kg/capita/day, representing a 10–25% increase compared to 2018 levels [2]. Additionally, the country's plastic waste management strategies aim to achieve a recycling rate of 100% for target plastic waste by 2027, with projections indicating that in 2030, annual municipal plastic waste generation could reach 2.19 million tons [3]. In order to address Thailand's increasing waste creation, these data indicate a critical need for sustainable waste management techniques and the introduction of efficient waste-to-energy technology [4, 5].

Refuse-Derived Fuel (RDF) processes, as highlighted in multiple research papers [6, 7], offer a sustainable solution for converting various waste materials, including high-calorific-value plastic waste, into renewable energy sources. Pyrolysis, a thermochemical decomposition process discussed in another study [8], is particularly effective in converting plastic waste into fuels like pyrolysis oil and hydrocarbons. Additionally, the utilization of waste materials to produce fuel briquettes, as explored in a different paper [9], showcases the potential of RDF in generating alternative fuels with high calorific values. Furthermore, the conversion of waste into RDF for energy production, as demonstrated in a separate study [10], emphasizes the versatility and applicability of RDF processes in managing various types of waste to create valuable energy sources, thereby offering a sustainable alternative to burning high-calorific-value plastic waste. Proper separation processes can lead to low-moisture-content plastic waste suitable for such energy conversion [11–14].

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II. Literature Review

Mechanical recycling, initiated in the 1970s, involves repurposing Plastic Solid Waste (PSW) through mechanical methods, mainly applicable to single-polymer plastics like PE, PP, and PS [15–17]. Challenges include the complexity and contamination levels of the waste, necessitating separation, washing, and PSW preparation for high-quality end products [18–20]. The degradation and heterogeneity of PSW pose significant challenges, but mechanical recycling remains economically feasible, particularly for foams and rigid plastics. Various everyday items, including grocery bags and profiles, result from mechanical recycling processes, but concerns about product quality persist. The industrial PSW generated during plastic product manufacturing proves suitable for mechanical recycling due to clear resin separation, low impurity levels, and abundant availability [21–22]. In the realm of research and development, there is a significant focus on the mechanical recycling of PSW, with a growing interest in utilizing polyolefins [23, 24]. The process includes various methods and necessary steps, aimed to reduce costs and energy consumption. The procedures include size reduction, separation, milling, cleaning, drying, infection, extrusion, and quenching. The issue of Municipal Solid Waste (MSW) in Thailand presents a pressing challenge, with significant annual increases in waste generation projected up to 2030 [25]. The mismanagement of MSW, including the mixing of infectious, hazardous, and general waste, poses environmental and health risks, necessitating effective waste management strategies [26]. Food waste comprises a substantial portion of MSW in Thailand, emphasizing the need for prioritizing food waste reduction through the waste management hierarchy [27]. While RDF offers a viable solution for waste crisis management, challenges such as high moisture content and chloride levels in mixed waste recycle and waste-to-energy managements [28]. To address these issues, promoting source reduction, waste segregation, and collaboration between stakeholders are crucial for sustainable MSW management in Thailand.

Plastic recycling indeed benefits from innovative approaches like the development of advanced plastic cleaning machines. These machines play a crucial role in the recycling process by effectively cleaning plastic materials for reuse. Various inventions highlight the significance of such machines, including a plastic mold cleaning device with specialized cleaning mechanisms [29], a breaking and cleaning machine for plastic recycling ensuring uniformity in material processing [30], a plastic recycling and cleaning device with stirring and clearing mechanisms for enhanced cleaning efficiency [31], a cleaning and air-drying integrated machine preventing recontamination of plastic particles [32], and a plastic product recycling, crushing, and cleaning integrated machine combining crushing, cleaning, and drying functions to improve work efficiency [33]. There is much research for gas-liquid separation. The four primary methods of gas-liquid separation technology [34]: gravity, inertial, filtration, and centrifugal, are widely employed in industry applications. Furthermore, the centrifugal technique is the most appropriate for both solid-solid and gas-liquid separation. Using rotary drum separator, the segregation effect in the rotary drum [35] has been studied. The size and density of particles, filling degree and rotational speed have been observed on both Computational Fluid Dynamics (CFD) simulation and experiment. The results show that the denser particles act as the smaller particles. For example, the less dense particles travel around the drum wall, while the denser particles gather in the center of the drum. Furthermore, the in the effects of inlet velocity, rotational speed, droplet diameter [36] have been investigated on separation efficiency of the rotary drum separator. The results indicate that a decrease inlet velocity or an increase rotational speed can improve the separation efficiency and reduce the cut-off diameter of rotary drum. Not only the inlet velocity and rotational speed can affect the separation efficiency, the impacts of inflow angular velocity, rotational drum speed and structural drum parameters [37] on the separation efficiency were also examined. The results revealed that separation efficiency and rational speed had influences on separation efficiency.

Amidst these challenges, plastic recycling has emerged as a salient and viable solution. Recognizing the potential for effective development, a research team is dedicated to designing and implementing a plastic cleaning machine geared towards reuse. The infusion of technological advancements to augment the efficiency of garbage cleaning processes becomes paramount in this context. The introduction of a dry waste beater, incorporating principles of beating, swinging, and air-blowing, seeks to facilitate the expulsion of dirt particles from garbage, consequently reducing cleaning time and overall waste generation. This innovative approach aligns with the imperatives of sustainable waste management, contributing substantively to a cleaner and more resilient environment.

On the literatures, there are still lack applications for solid-solid separation in plastic waste cleaning separation machine applications. In the many advantages in centrifugal technique, however, it still reveals a research gap regarding the integration of different separation methods and the optimization of their combined effects on efficiency. The propeller attached to the rotor will be induced to enhance the centrifugal force applied for plastic waste cleaning separation machine. These innovations show cases the importance of technological advancements in plastic cleaning to promote sustainable recycling practices. Technological advancements, like the introduction of a dry waste beater, aim to enhance garbage cleaning efficiency, contributing to sustainable waste management and a cleaner environment.

This study focuses on developing a dry garbage (plastics) cleaning machine using Computer Fluid Dynamics (CFD) simulation with SolidWorks 2020 software. The machine's design emphasizes the rotor's propeller positioning to improve centrifugal force and axial velocity. The study analyzes how the rotor structure, rotation speed, and tangential velocity affect the machine's performance through numerical calculations. The research aims to design and improve waste cleaning machines to make waste management more efficient and cost-effective.

III. Materials and Methods

This section presents a description of the conceptual design, geometric parameters, boundary conditions, rotor assembly, mesh independence analysis, governing equations, and numerical methodology employed to elucidate the operational principles of the machine.

A. Conceptual Design

Plastic bags and food waste possess distinct densities; plastic wastes are assumed as less density particles and thin sheets with a considerable surface area, while food scraps comprise of small organic fragments, water, and oil are assumed as denser particles. In addition, this study is assumed in isothermal case as there is no effect from heat transfer. To address plastic wastes contaminated with food scraps, a centrifugal process is employed at an appropriate speed, effectively separating the food scraps. A machine designed for this purpose features a structure with a blower and several fans connected in series, all mounted on the same shaft. The machine's bottom is equipped with drilled holes to facilitate the separation of food scraps.

Upon feeding plastic wastes containing food scraps into the machine's rear, the garbage undergoes centrifugation by rotor with propellers. The smaller, denser food particles are expelled through the holes in the bottom grating. Once an adequate amount of food, water, or oil particles have been removed from the plastic wastes, the lightweight wastes are transferred away by the airflow through the blower in the axial velocity of rotor as depicted in Fig. 1.

In operation, the machine utilizes centrifugal force to separate food scraps from plastic wastes. The rotor must rotate at a speed sufficient to dislodge food particles from the plastic wastes and provide ample airspeed for transporting the plastic wastes. Additionally, the machine must possess sufficient moment of inertia to accommodate variable loads resulting from the inconsistent rate of waste addition. Furthermore, it must exhibit adequate strength to withstand stress induced by centrifugal forces and air resistance. The propellers are required to be durable to withstand potential impacts from dirt, stones, or glass fragments that may be present due to incomplete separation in previous waste separation processes.

The plastics waste is fed into an opening at the top of the machine. The waste is then moved by the propeller to loosen the dirt particles, making the waste lighter and allowing it to be blown along the axis and ejected on the other side. Simultaneously, any debris or dirt is directed towards the shell, ultimately gravitational force to the floor beneath the apparatus as illustrated in Fig. 1. Moreover, Fig. 2 showed the rotor components in different models to improve separation performance.

The rotor with propellers is depicted in greater detail in Figs. 2–4. Dry garbage cleaners demonstrate remarkable effectiveness in achieving thorough and rapid cleaning. As a result, a comprehensive understanding of the airflow dynamics within these machines is imperative for their optimal design and development.

The key components of the apparatus include an outer shell and a rotor specially engineered to dislodge plastic waste. The rotor is designed with strategically positioned propellers intended to impact the garbage and generate both centrifugal force and axial and tangential velocity. Consequently, incoming waste experiences an impact, propelling it to the opposite end of the machine.

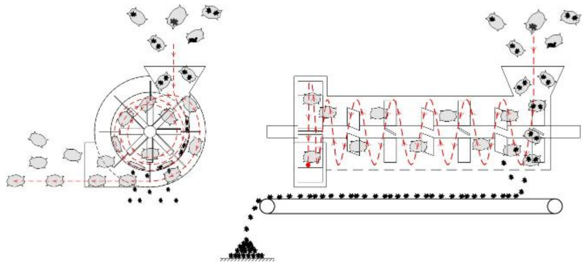


Fig. 1. Dry garbage cleaner design concept.

B. Geometry and Boundary Conditions

A prototype of a dry plastic waste cleaning machine has dimensions of $1.9 \times 2.6 \times 1.5$ m^3. An experimental methodology, although yielding validated data and analysis, frequently necessitates costly arrangements. Furthermore, assessing process variables in specific components of the waste cleaning machine presents and safety issues are considerable. To deal with these issues, numerical techniques are presented as a useful attractive tool. Simulations can be executed and reproduced at a comparatively low expense and within a short time, in contrast to numerous physical research. Numerous simulation models have been created for different scenarios, with Computational Fluid Dynamics (CFD) being increasingly favoured for addressing fluid flow issues [38]. A variety of proficient tools, including MATLAB, ANSYS, CFX, and SolidWorks [39], are accessible for developing simulation models. SolidWorks 2020 software, for example, simulates design parameters, fluid characteristic analysis and heat transfer problem [40].

In the subsequent steps, meshes are generated within the geometry. The CFD model is then solved using the Flow Simulation function of SolidWorks, employing an unstructured mesh. Accurate specification of initial and boundary conditions is necessary in numerical simulations; poorly defined boundaries can result in inaccurate outcomes. To accurately simulate the airflow and garbage movement within the cleaning machine, the simulation utilizes the following parameters and atmospheric pressure boundary conditions have been set at the inlet and outlet. In the study, the rotational rotor speeds vary from 500, 750, 1,000, 1,250, 1,500, 1,750 and 2,000 rpm.

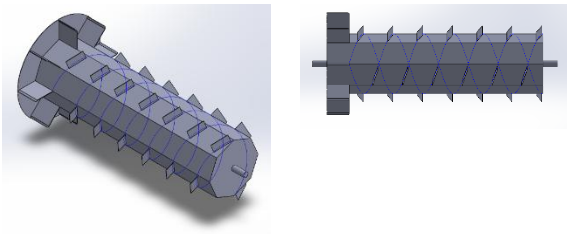
C. Rotor Assembly and Mesh Independence Test

The rotor assembly is a critical component of the dry garbage cleaning machine, significantly influencing its efficiency and effectiveness in separating plastic waste. Different rotor designs can impact the airflow patterns and separation performance within the machine. To ensure the accuracy and reliability of the Computational Fluid

Dynamics (CFD) simulations, a mesh independence test was conducted. This test aims to verify that the simulation results are not affected by the mesh resolution, ensuring that the chosen mesh provides a balance between computational cost and accuracy.

1) Rotor assembly

Fig. 2 shows the characteristics of the rotor assembly study. All three models have different propeller pattern as follows:



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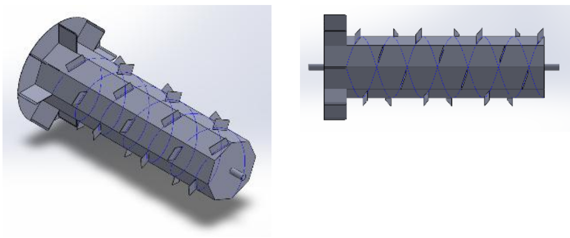

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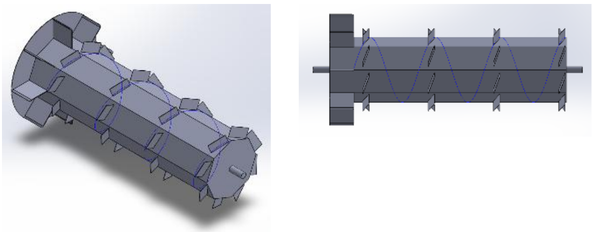

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Fig. 2. The rotor of (a) Model 1; (b) Model 2; (c) Model 3.

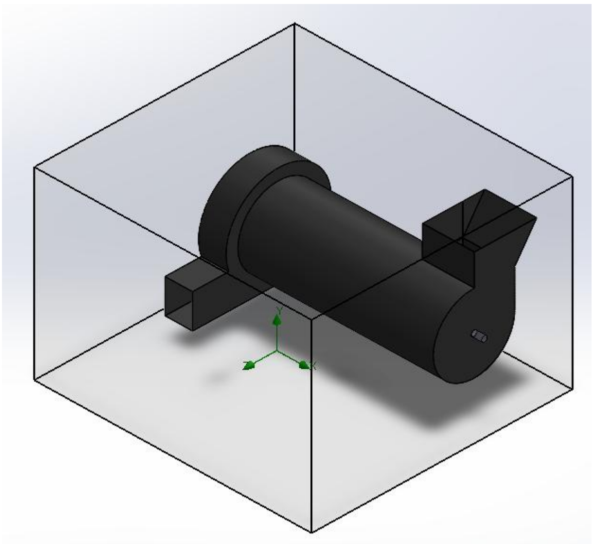


Fig. 3. Assembly of shell and rotor parts with computational domain.

TABLE I. STRUCTURAL MODEL

Model	Propeller number	Thread	Pitch (mm)	Propeller pattern
1	26	double	800	Continuous screw
2	26	double	800	Zigzag screw
3	32	single	800	Circle on pitch

Table I. presents the structural model for all three models, each with a consistent pitch distance of 800 mm. Models 1 and 2 incorporate with the propeller number of 26 and double-threaded type, while Model 3 distinguishes itself with 32 single-threaded type. Despite the numerical difference in propellers, the primary distinction among the models lies in their propeller pattern. Model 1 features a continuous rotational propeller pattern around the central axis, whereas Model 2 adopts a zigzag configuration. In contrast, Model 3 utilizes a circular propeller pattern on the pitch. All rotor models are assembled with the shell as depicted in Fig. 3. Then, the CFD models of the garbage cleaning machine are simulated and analyzed using SolidWorks simulation.

2) Mesh independence test

After defining the computational domain and boundary conditions, the mesh model was specified. The total meshes of level 3, 5, 6, and 7 were 5,967, 31,408, 59,811, and 77,822 cells, respectively. A resolution mesh level of 7 was shown in Fig. 4. A comparison between level 6, and 7 showed no difference in tangential velocity. Therefore, the mesh level 7 was selected in the numerical and it supports in ensuring both accuracy and computational efficiency as shown in Fig. 5.

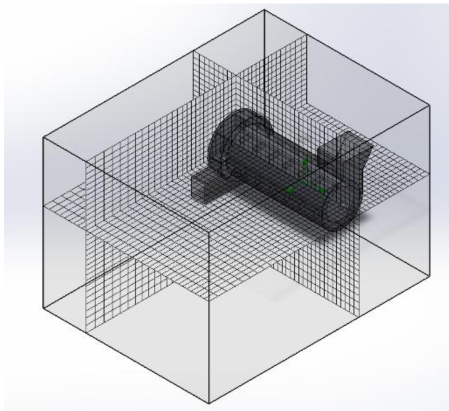


Fig. 4. A sample of global mesh level at 7.

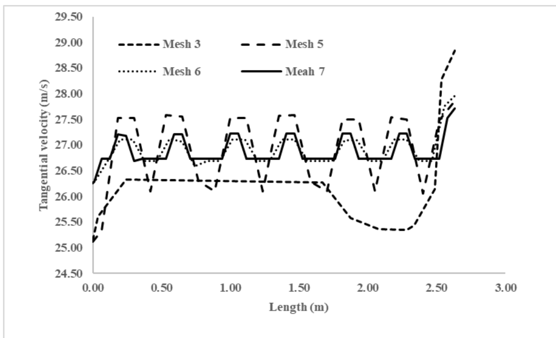


Fig. 5. Tangential velocity of the Y axis on drum separator.

D. Governing Equations

The CFD approach is employed to compute the velocity and pressure of fluid in the garbage cleaning machine model. The characteristics of fluid flow are elucidated by the conservation form, combining the continuity equation and momentum equation which can be expressed in the general form as follows [41].

Continuity equation:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{u}) = 0 \qquad (1)$$

Momentum equation:

$$\frac{\partial (\rho \vec{u})}{\partial t} + \nabla \cdot (\rho \vec{u} \vec{u}) = -\nabla p + \nabla \cdot \tau \qquad (2)$$

where ρ is the density, $\vec{u}$ is the vector of velocity, p is the pressure, and τ represents the stress tensor.

E. Numerical Method

The study utilizes the finite-volume method, which involves applying the integral form of the transport equations to a discretized equation. The geometric domain is divided into a finite number of subdomains. The variables within the domain are computed through approximating methods, and it is essential to specify the necessary initial and boundary conditions. Subsequently, the transport equation in its general form is iteratively solved for all cells in the domain.

The hexahedral mesh approach in SolidWork simulation facilitates the execution of integrated multiphysics simulations. This is achieved using a singular numerical mesh that includes fluid cells, solid cells, and partial cells with multiple control volumes (multi-CV). Additionally, the tool allows the independent treatment of fluid flow and thermal conduction. Throughout these simulations, the basis CAD geometry remains the primary source of initial geometric information. In the fluid regions, SolidWorks simulation addresses the Navier-Stokes equations. These equations represent formulations of the conservation laws for mass, momentum, and energy, declaring a comprehensive understanding of the fluid behavior within the simulated domain. The simulation procedure and operating conditions are shown in Fig. 6 and Table II.

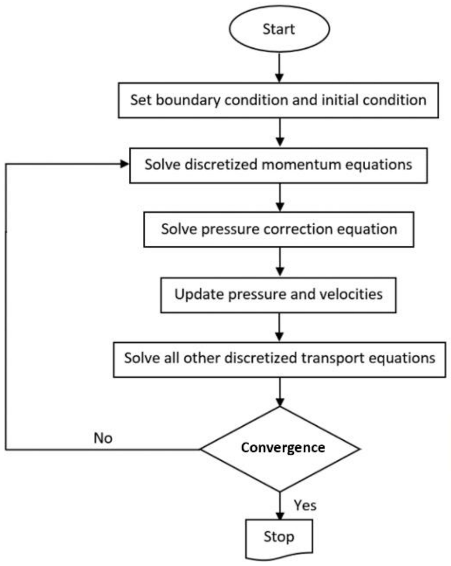


Fig. 6. The CFD model solution flowchart.

TABLE II. THE SIMULATION CONDITIONS

Descriptions	Setting	Boundary Conditions of the Drum chamber	Boundary values
Fluid flow behavior	Steady-State	Velocity Inlet	Velocity Magnitude = 0 m/s Turbulence Intensity
Gravity Gravitational Acceleration Operating Pressure Turbulence Model	−9.81 m/s^2 Axis Y 101,325 Pascal	Rotating region	647 rpm
Fluid type: Air	Density = 1.225 kg/m^3 Viscosity = 1.78994×10^{-5} kg/m-s	Pressure Outlet	Static Pressure: 101325 Pa
		Temperature	293.20 K
		Wall	Adiabatic

IV. RESULT AND DISCUSSION

The airflow models within the waste cleaning machine were designed and simulated for three different models, controlling various parameters to be consistent across all three models. The main difference among the three models lies in the propeller patterns on the rotor, which rotates to beat and propel the waste towards the other side.

From the rotor rotation simulations at various speeds, it was found that this had a significant impact on the velocity along each axis of all three models. Details are as follows:

A. Airflow Velocity Analysis

The x-axis indicates the axial velocity and y-axis and z-axis represent the centrifugal force that generates the tangential velocity at the wall. Consequently, when the plastic waste introduces to centrifugal force, the denser particles, including food scraps composed of small organic fragments, water, and oil, will be gathered into the drum center, while the less dense particles, especially plastic garbage, will be moved around the drum wall [35]. In addition, the x-axis produces the axial velocity, and it influences the plastic cleaning capacity of machine.

Along the y-axis, there was only a slight difference in airflow velocity among the three models, with velocity increasing as the rotor rotation speed increased. Along the z-axis, Models 1 and 2 exhibited similar airflow velocity values, while Model 3 consistently showed lower airflow velocity values compared to the other two models as the rotor rotation speed increased. This indicates that the propeller pattern on the rotor indicates a crucial role to induce the airflow behavior within the waste cleaning machine.

Fig. 7 shows the results from simulating the airflow behavior inside the garbage cleaning machine at a rotor rotational speed of 500 rpm for Models 1, 2, and 3, respectively. The airflow patterns of all three models are relatively similar. The clockwise rotation of the rotor with propellers installed induces airflow to enter from the top and exit from the bottom. However, the maximum velocity value for Model 2 is highest, reaching up to 62 m/s because of the propeller pattern.

When selecting a model with suitable airflow for waste cleaning, the importance lies in the velocity along the x-axis. This is because the velocity along this axis ensures efficient movement of waste within the cleaning machine without congestion. Fig. 8(a) compares the effect of the axial velocity along the x-axis of all three models. It is observed that at rotor rotation speeds ranging from 500 to 1,500 rpm, Model 1 provides the highest velocity along the rotor axis while Model 3 exhibits the lowest airflow velocity along the axis. Specifically, the axial velocity along the axis in Model 3 is only 48% of that in Model 1. Comparing the details of Model 1, which uses 26 propellers, and Model 3, which uses up to 32 propellers, this study indicates that the arrangement and number of propellers on the rotor significantly influences the airflow behavior within the waste cleaning machine. The axial velocity has been dropped when the rotational speed is more than 1,500 rpm because of back pressure. Clarifying, the rotor consists of two parts: the impeller and the blower. If the flow velocity of the impeller section is greater than the airflow, it will cause back pressure, resulting in a decrease in the axial velocity of the impeller zone.

B. Performance Comparison of Models

When considering the tangential velocity within the waste cleaning machine along the y-axis and z-axis of all three models, it is found that there is only a slight difference, and the velocity increases with the increasing rotor rotation speed as depicted in Fig. 8(b). As for Fig. 8(c), it can be seen that the tangential velocity along the z-axis in Models 1 and 2 is similar, while Model 3 consistently provides lower airflow velocity values compared to the other two models as the rotor rotation speed increases due to thread type.

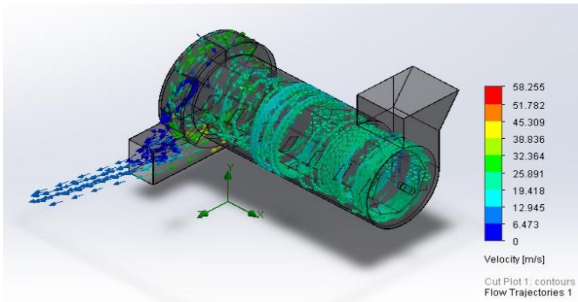
Figs. 9 to 11 depict contour plots of airflow velocity on the top view plane (xz-plane) within the waste cleaning machine for Models 1, 2, and 3, respectively. It can be observed that Model 1 exhibits the highest airflow velocity within the waste cleaning machine. This is attributed to the propeller pattern with an 800 mm of pitch diameter and a double thread configuration resulting in continuous and uninterrupted airflow.

C. Impact of Propeller Pattern on Efficiency

The propeller arrangement directly affects the airflow characteristics and the efficiency of the waste cleaning process. Model 1, with continuous double-thread propellers, demonstrates superior performance in generating higher airflow velocities, which is crucial for effective waste propulsion and cleaning. Model 2, with alternately arranged double-thread propellers, also performs well but to a slightly lesser extent. Model 3, with single-thread propellers, shows the lowest performance, indicating that a double-thread configuration is more effective in enhancing airflow dynamics.

D. Practical Considerations and Recommendations

While the simulations provide valuable insights, practical considerations must also be considered. The presence of debris and variations in waste composition can affect the actual performance of the cleaning machine. Therefore, additional simulations with real loads and varying waste types should be conducted to further validate and optimize the design. Furthermore, future work should use a two-phase cleaning process using water to enhance efficiency.



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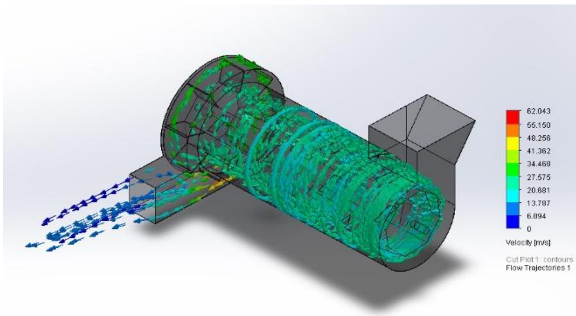

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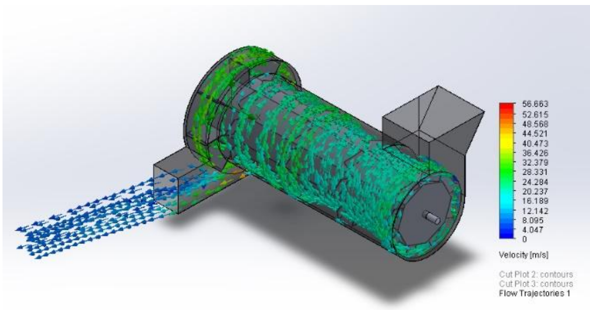

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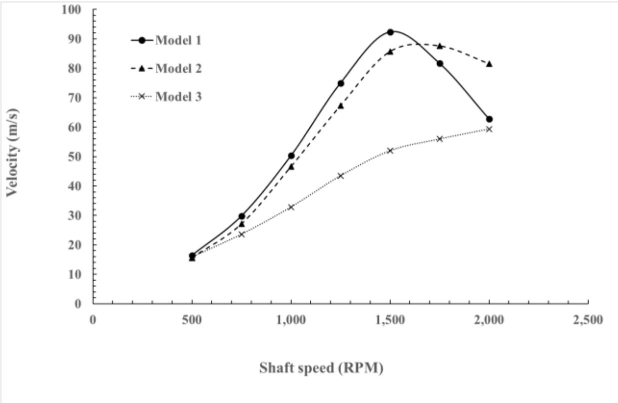
Fig. 7. Flow trajectory in garbage cleaning machine: (a) Model 1, (b) Model 2, (c) Model 3.



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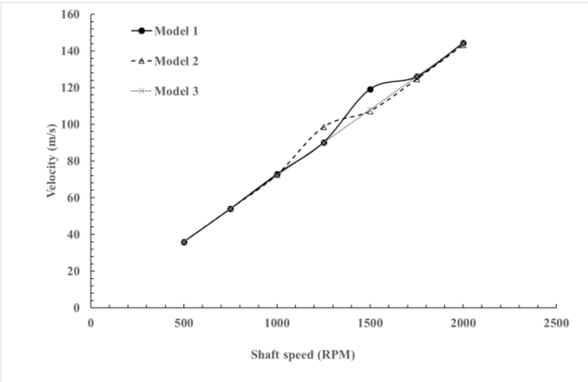

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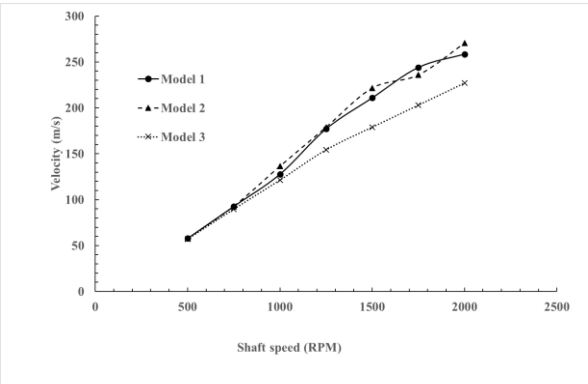

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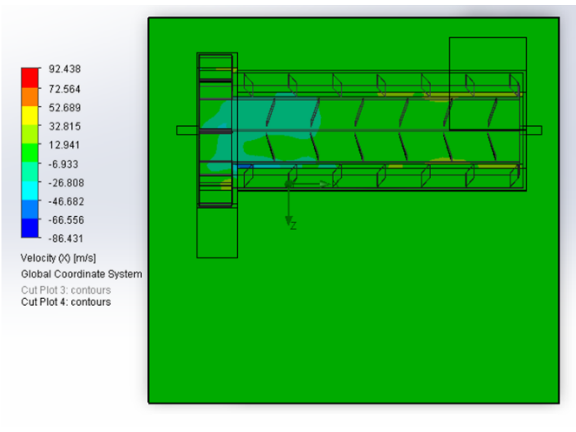
Fig. 8. Comparison of maximum velocity (a) x-axis; (b) y-axis; (c) z-axis.



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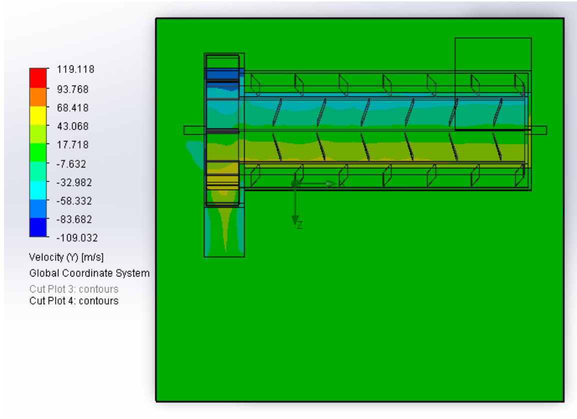

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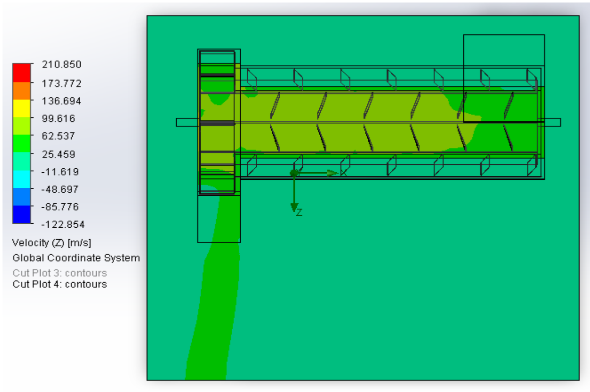

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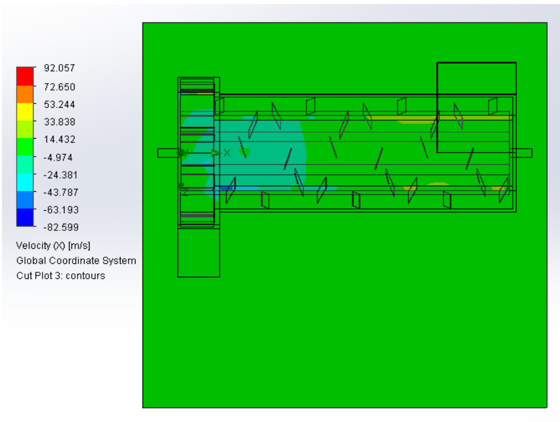
Fig. 9. Velocity (a) x-axis; (b) y-axis; (c) z-axis contour of Model 1.



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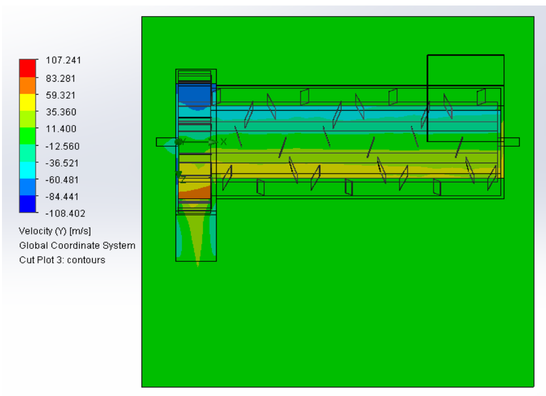

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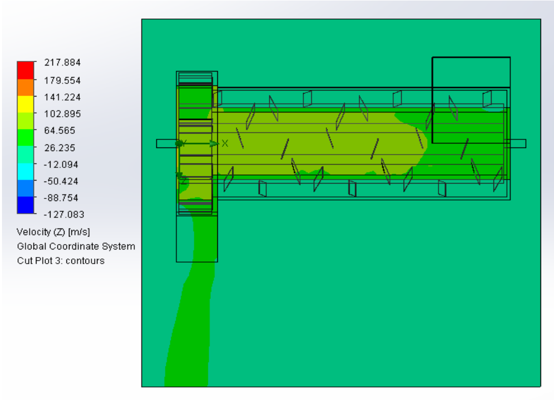

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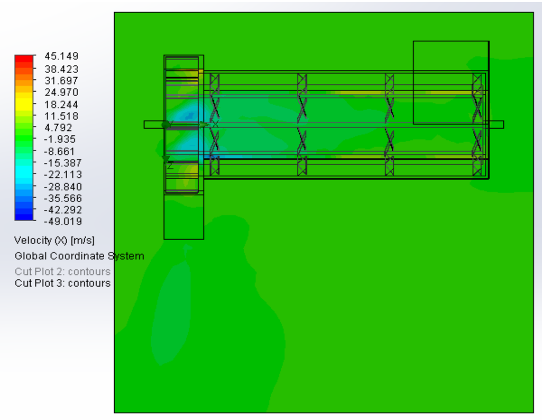
Fig. 10. Velocity (a) x-axis; (b) y-axis; (c) z-axis contour of Model 2.



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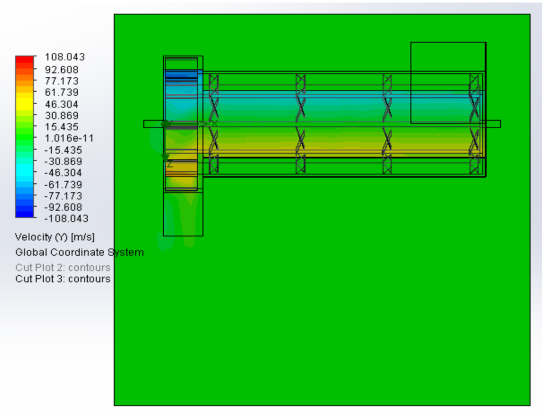

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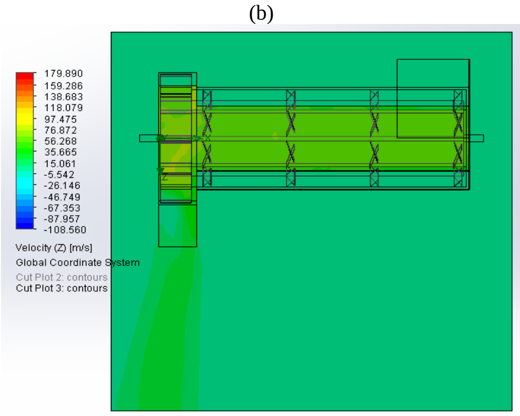

(c)

Fig. 11. Velocity (a) x-axis; (b) y-axis; (c) z-axis contour of Model 3.

The development cleaning machine has been constructed and tested for practical use, as illustrated in Fig. 12. The comparison between the development (Model 1) and conventional (Model 3) machine demonstrates a cleaning capacity of 25 kg/h and 16.25 kg/h, respectively. The improvement has consequently increased by 54%. Additionally, the methodology and test results under various conditions will be discussed in the next research paper.

Fig. 12. The development plastic cleaning machine [Left] and the conventional plastic cleaning machine [Right] at landfill.

IV. Conclusion

In conclusion, the study focused on evaluating airflow behavior within a waste plastic cleaning machine across three distinct models. The impacts of propeller arrangement on rotor, the propellers and drum rotational speed on the tangential velocity that will be effects to the cleaning efficiency. The main conclusions were obtained as follows:

(1) The propeller pattern on the rotor significantly influences airflow characteristics within the machine. Rotor rotation simulations revealed that increasing rotor speed had a notable impact on centrifugal force and tangential velocity along each axis of the models. To illustrate, the machine can improve when the plastics with particle have been moved in centrifugal force, then, the particles will be separated from plastics by tangential velocity.

(2) The type of thread in simulations influences the waste movement rate of machine which it had a notable impact on axial velocity along axis of the rotor. Consequently, the double thread indicates the capacity machine. Model 1 and 2 are slightly different capacity of cleaning. The capacity of cleaning is proportional to rotation of rotor from 500 to 1500 rpm.

(3) The model 1 exhibits the highest maximum velocity value. This superiority in airflow velocity can be attributed to the specific propeller pattern providing continuous and uninterrupted airflow within the machine. Comparative analyses highlighted Model 1 as the most efficient in terms of axial velocity along the x-axis.

These findings underscore the critical role of propeller pattern in optimizing airflow behavior within waste cleaning machines. Overall, the study contributes valuable insights into the design and optimization of waste cleaning machines, facilitating the development of more efficient and cost-effective solutions for waste management. However, practical considerations such as the impact of debris on airflow velocity suggest the need for further simulations with real loads to enhance prediction accuracy. For future work, the two-phase cleaning process should study by using water to enhance efficiency of machine.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

S.S.: Conceptualization, data analysis, methodology, writing—original draft preparation, writing—review and editing, project administration.; S.A.: research design, data analysis; W.F.: data curation, writing—reviewing and editing, project administration; M.H.R.: methodology and data curation; R.A.: Research design, data analysis, writing—original draft preparation, writing—review and editing, project administration. All authors have read and agreed to the published version of the manuscript.

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