

INNOVATION SCIENCE AND TECHNOLOGY

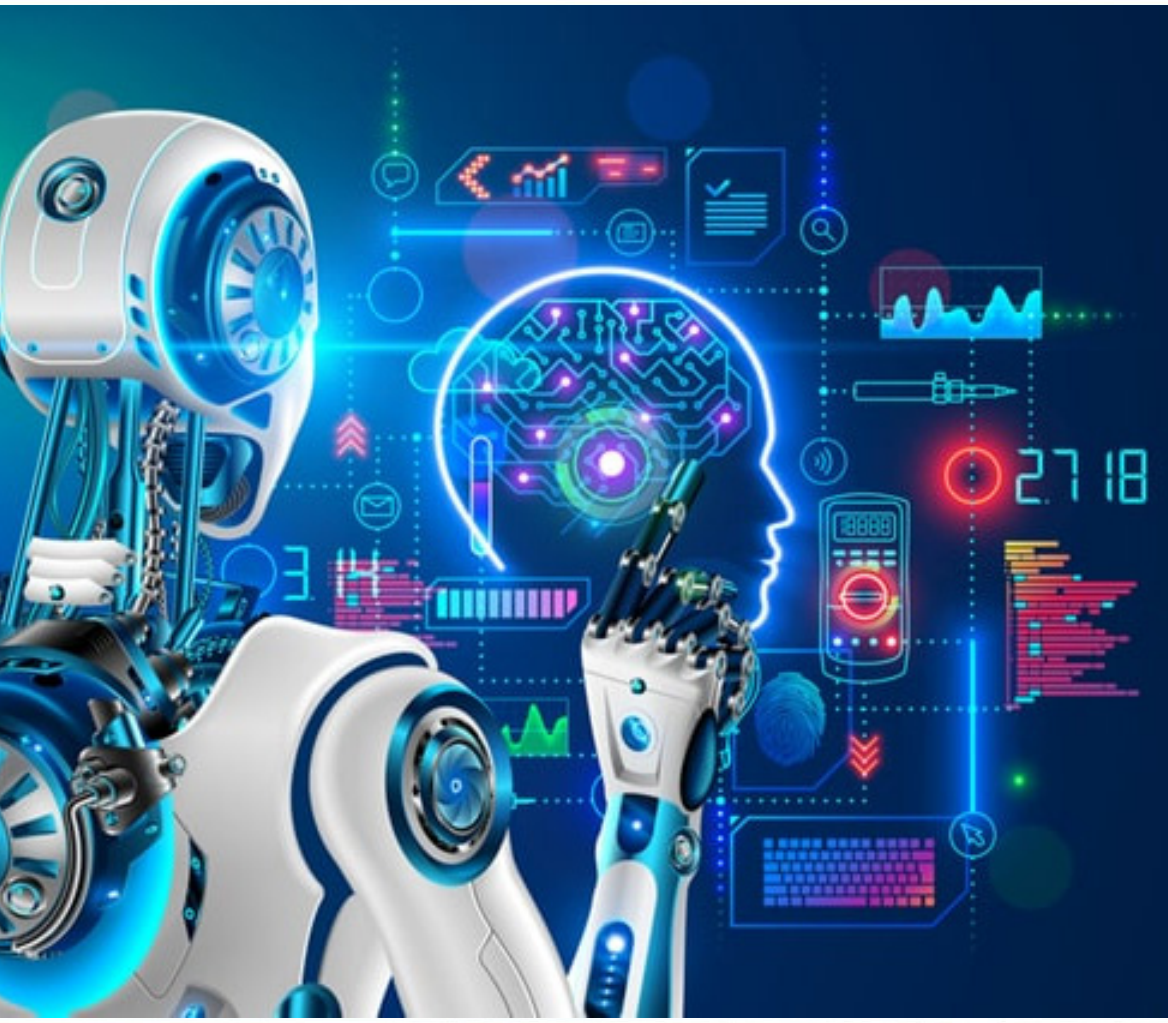


Scopus || Electronic journal specializing in Scopus

ISSUE 12



Acceptance of papers **December, 2025**



Acceptance of papers

Published monthly



Topics

economics, technology, social sciences

ISSN 3060-5229



Digital Object Identifier



Visit the website t.me/scopus_IST2100



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THE SCIENTIFIC-POPULAR ELECTRONIC
JOURNAL **"INNOVATION SCIENCE AND
TECHNOLOGY"** HAS BEEN REGISTERED
UNDER THE NUMBER **C-5669633** BY THE
AGENCY FOR INFORMATION AND MASS
COMMUNICATIONS (AOKA) OF THE
REPUBLIC OF UZBEKISTAN, EFFECTIVE
FROM OCTOBER 9, 2024.

CONTACTS

Phone: **+998 50 737 87 88**

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The scientific electronic journal "Innovation Science and Technology" has been included in the list of scientific publications recommended for the publication of main scientific results of dissertations for the award of PhD and DSc degrees in economics and technical sciences, in accordance with the Resolution No. 370 of the Presidium of the Higher Attestation Commission of the Republic of Uzbekistan, dated May 8, 2025.

Electronic publication, Issue 12. 257 pages.
Approved for publication on December, 2025.

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SOLIDWORKS-BASED MODELING OF AN AIR-BLOWING SYSTEM TO ENSURE HIGH-QUALITY FIBER REMOVAL FROM SAW TEETH

Mirzakarimov Mirsharoffiddin Mirzaabdurahimovich

Associate Professor of the Department of Higher Mathematics,
Namangan State Technical University
Email: mmirsharoffiddin@gmail.com

Abstract: This study presents the development and SolidWorks-based modeling of an air-blowing system designed to efficiently remove fibers from saw teeth. The effects of airflow direction, velocity, and pressure on fiber separation efficiency were analyzed. Aerodynamic characteristics of the structure, optimal geometric parameters, and methods for reducing process losses were determined. An improved design of the air-blowing system is proposed, enabling higher fiber extraction quality and increased overall technological process efficiency in industrial applications.

Key words: Saw teeth, fiber separation, air-blowing system, SolidWorks, modeling, aerodynamics, optimization, technological process.

Annotatsiya: Ushbu tadqiqotda arra tishlaridan tolalarni samarali ravishda olib tashlash uchun mo'ljallangan havo puflash tizimining ishlab chiqilishi va SolidWorks asosidagi modellashtirilishi taqdim etiladi. Havo oqimi yo'nalishi, tezligi va bosimining tolalarni ajratish samaradorligiga ta'siri tahlil qilindi. Tuzilmaning aerodinamik xususiyatlari, optimal geometrik parametrlar va jarayon yo'qotishlarini kamaytirish usullari aniqlandi. Sanoat qo'llanmalarida tolalarni yuqori sifatli ajratib olish va umumiy texnologik jarayonlar samaradorligini oshirish imkonini beruvchi havo puflash tizimining takomillashtirilgan dizayni taklif qilindi.

Kalit so'zlar: Arra tishlari, tolalarni ajratish, havo puflash tizimi, SolidWorks, modellashtirish, aerodinamika, optimallashtirish, texnologik jarayon.

Аннотация: В данном исследовании представлена разработка и моделирование в SolidWorks системы обдува воздухом, предназначенной для эффективного удаления волокон с зубьев пилы. Проанализировано влияние направления, скорости и давления воздушного потока на эффективность отделения волокон. Определены аэродинамические характеристики конструкции, оптимальные геометрические параметры и методы снижения технологических потерь. Предложена улучшенная конструкция системы обдува воздухом, обеспечивающая более высокое качество извлечения волокон и повышение общей эффективности технологического процесса в промышленных условиях.

Ключевые слова: зубья пилы, отделение волокон, система обдува воздухом, SolidWorks, моделирование, аэродинамика, оптимизация, технологический процесс.

INTRODUCTION

Efficient removal of cotton fibers from saw teeth is a critical stage in the ginning process, directly influencing fiber quality, machine productivity, and the overall energy efficiency of the technological line. In traditional ginning systems, fiber accumulation on saw teeth leads to reduced operational stability, increased friction, higher power consumption, and accelerated wear of mechanical components. Ensuring continuous and high-quality fiber separation therefore requires reliable auxiliary mechanisms, among which air-blowing systems represent one of the most effective solutions.

Conventional mechanical cleaning methods often fail to maintain stable operation and may damage fiber structure due to intensive mechanical contact. In contrast, air-blowing (pneumatic assisted) systems rely on aerodynamic principles to safely detach fibers without compromising their physical properties. However, the

efficiency of such systems greatly depends on the correct selection of airflow direction, velocity, pressure distribution, and geometric configuration of the blowing channels. Many existing industrial designs suffer from non-optimal airflow alignment, uneven pressure distribution, and improper nozzle geometry, all of which limit fiber-removal performance.

Advances in computational modeling and 3D design technologies have opened new opportunities for optimizing pneumatic fiber-removal systems. SolidWorks, equipped with integrated CFD (Computational Fluid Dynamics) tools, allows for detailed simulation of airflow within complex geometries, enabling the analysis of pressure fields, velocity gradients, turbulence zones, and separation efficiency under various operating conditions. Such modeling significantly reduces the need for costly physical prototyping and accelerates the development of improved industrial designs.

The relevance of this study is driven by the increasing demand for higher fiber quality, reduced operational costs, and improved automation in modern ginning facilities. Effective fiber removal ensures stable machine operation, prolongs the service life of saw cylinders, decreases energy losses, and enhances the consistency of the final product. Furthermore, optimization of air-blowing systems contributes to cleaner working environments and greater technological reliability.

The present research aims to design and simulate an improved air-blowing system capable of efficiently detaching fibers from saw teeth using controlled airflow. By employing SolidWorks and CFD tools, the study evaluates the aerodynamic behavior of the system, identifies optimal structural parameters, and proposes a refined design suitable for industrial application. The simulated results serve as a scientific basis for developing a more efficient, energy-saving fiber-removal mechanism adaptable to modern ginning machines.

LITERATURE REVIEW ON THE TOPIC

The efficiency of fiber separation from saw teeth has long been a key research direction in cotton ginning technology. Early foundational studies by Knowlton and Van der Sluijs emphasized the mechanical behavior of fibers in saw-gin environments, highlighting how saw-tooth geometry, rotational speed, and fiber-metal interaction determine the degree of fiber entanglement and cleaning performance [1]. Their findings demonstrated that improper tooth geometry or insufficient cleaning mechanisms significantly increases fiber retention and reduces machine productivity.

Subsequent research has increasingly focused on pneumatic and aerodynamic methods for fiber removal. Khalfeev and Yuldashev investigated airflow-assisted separation in ginning systems, establishing theoretical principles for ejector-based cleaning mechanisms and identifying velocity thresholds required to detach fibers from saw surfaces [2]. Their experiments revealed that pneumatic cleaning not only reduces fiber damage but also stabilizes the cleaning process under varying operating loads. Similarly, Boykin and Baker analyzed airflow distribution in industrial gin environments and showed that optimized air-jet orientation can increase fiber-removal efficiency while lowering energy consumption [3].

Recent advancements in computational modeling have enabled more precise analysis of airflow behavior within ginning machinery. Islam and Jackson applied Computational Fluid Dynamics (CFD) to simulate air-fiber interactions in ginning ducts, demonstrating that detailed simulation can accurately predict turbulence levels, pressure drops, and airflow patterns that directly influence fiber behavior at the saw interface [4]. Their research validated CFD as a reliable tool for improving pneumatic system design. Parallel studies by Kerekes and Bennington on fiber suspensions in turbulent flows established fundamental insights into how aerodynamic forces act on fibrous particles—insights now widely applied in textile and ginning equipment optimization [5].

Within Uzbekistan's scientific community, several researchers have contributed significantly to the development of modernized ginning equipment. Azizov, Uzoqov, and Mirzakarimov conducted structural and aerodynamic analyses of saw-gin components, proposing new rib geometries, evaluating stress distributions in gin frames, and developing cost-efficient ginning machine variants [6–11]. Their studies highlight the necessity of integrating aerodynamic design with mechanical durability to create next-generation gins capable of handling variable cotton conditions. These works also emphasize that improved airflow systems can reduce fiber loss, improve quality, and extend equipment service life.

Overall, the literature indicates that achieving high-quality fiber removal requires a combination of optimized mechanical design and well-structured pneumatic cleaning systems. While traditional mechanical approaches remain widely used, modern ginning increasingly depends on precise airflow control, computational modeling, and geometry optimization. Despite significant progress, many existing systems still lack adequate airflow distribution and often fail to ensure consistent fiber removal. This gap underscores the relevance of the present study, which applies SolidWorks-based CFD modeling to develop an aerodynamically optimized air-blowing system designed specifically for effective fiber separation from saw teeth.

RESEARCH METHODOLOGY

In this study, the air-blowing system for fiber removal was modeled in SolidWorks to analyze airflow behavior around saw teeth. CFD (Flow Simulation) was used to evaluate velocity, pressure distribution, and airflow trajectories under different nozzle gaps and distances. Several geometric configurations were tested to identify the optimal airflow parameters ensuring efficient fiber detachment. Simulation results formed the basis for proposing an improved, energy-efficient air-blowing system design.

ANALYSIS AND RESULTS

At present, various mechanical and pneumatic methods are used in industrial enterprises to separate fibers and fine impurities. One of the most effective among them is the air-blowing (pneumatic cleaning) system, which operates based on aerodynamic principles. This system redirects the particle flow formed around the saw teeth into a safe direction through air pressure, ensuring continuous cleaning of the working zone. However, in many existing designs, insufficient airflow orientation, improper pressure distribution, or inaccurately selected geometric parameters lead to reduced operational efficiency.

Modern computer technologies—particularly 3D modeling and virtual simulation tools—provide extensive opportunities for addressing such technical challenges. SolidWorks software enables three-dimensional modeling of complex mechanical systems and facilitates the analysis of airflow movement, pressure distribution, turbulence intensity, flow velocity, and other key parameters. Utilizing these capabilities makes it possible to improve the air-blowing system, develop an optimal structural design, and enhance its operational performance.

The relevance of this research lies in the fact that high-quality fiber separation from saw teeth directly contributes to improved product quality, enhanced stability of the technological process, and reduced energy consumption. Moreover, it plays an important role in automating production and improving working conditions.

During cotton processing, fiber removal from saw teeth is typically carried out using various air-blowing devices; however, in many cases, they fail to fully perform their function—either due to insufficient airflow or improper airflow direction. To address this problem, we designed a new air-blowing and fiber-extraction system equipped with an automated airflow control mechanism.

During the 3D modeling stage, simulation makes it possible to avoid such errors. Let us examine how this process was carried out.

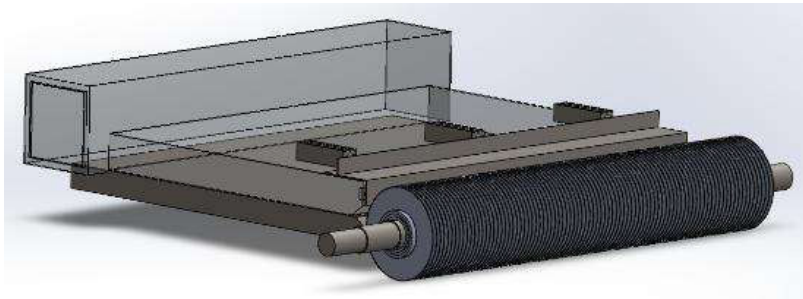


Figure 1. Automatically controlled air-blowing system

As a demonstration basis, let us take a simple model: in the SolidWorks add-ins tab, we enable the SolidWorks Flow Simulation add-in (if it is not already activated).

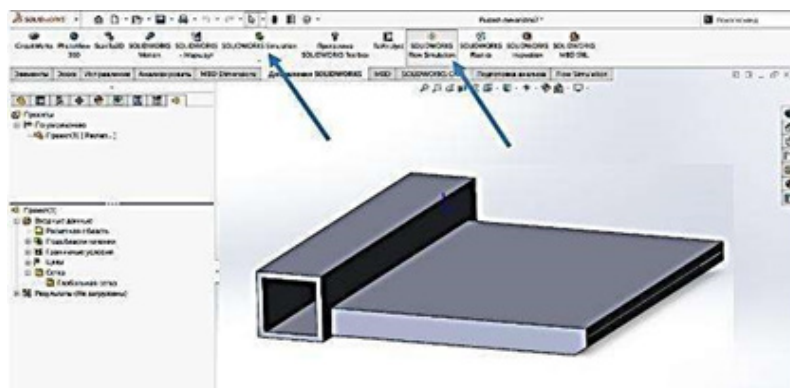


Figure 2. Automatically controlled air-blowing system

After that, a new tab with the necessary tools will appear.

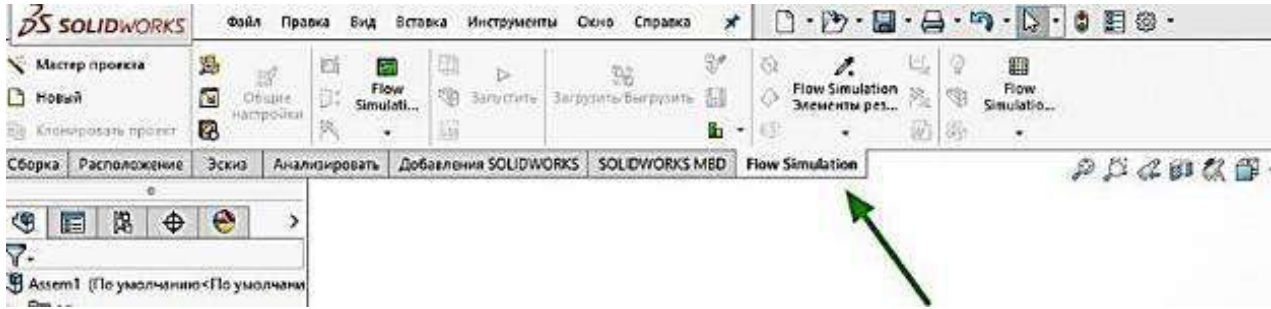


Figure 3. Automatically controlled air-blowing system

Let us create the air-blowing plane. The easiest way to do this is by placing a cover over the slots. We select the blowing plane (1) and confirm the selection (2).

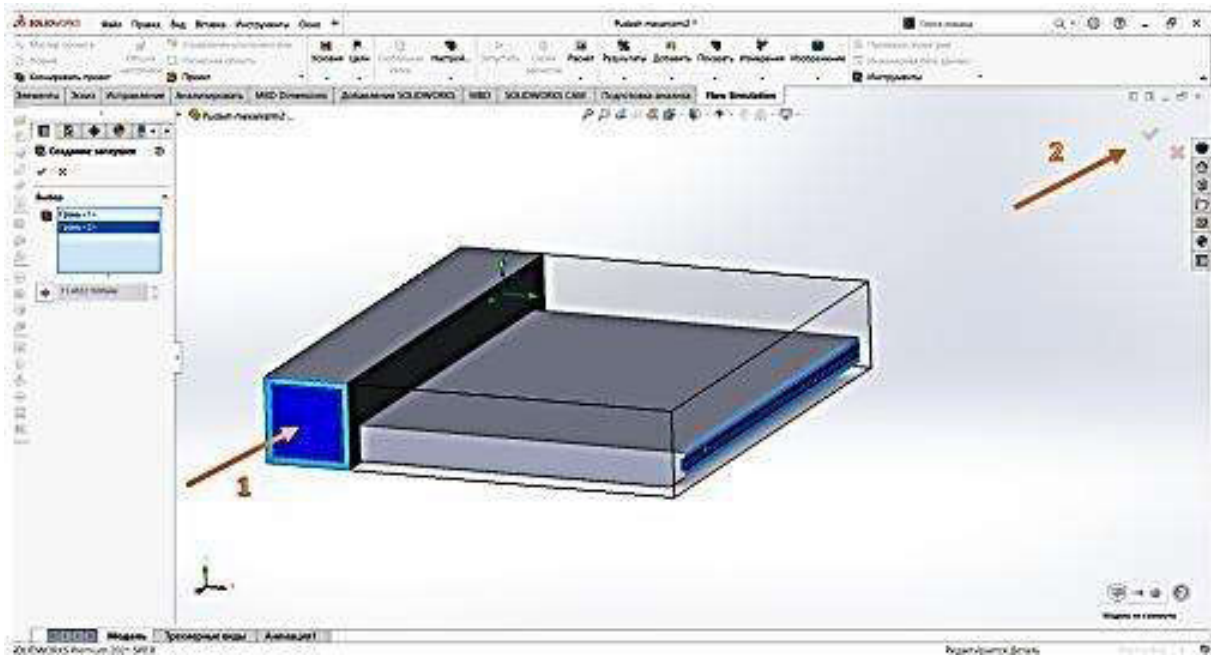


Figure 4. Automatically controlled air-blowing system

As a result, covers were created for the air inlet and air outlet slots.

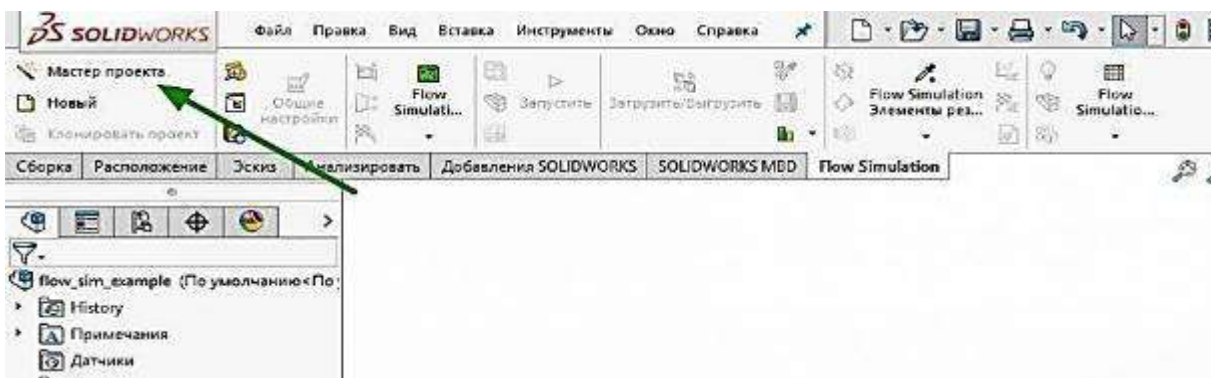


Figure 5. Automatically controlled air-blowing system

Using the “Master Project” button, we create the simulation project:

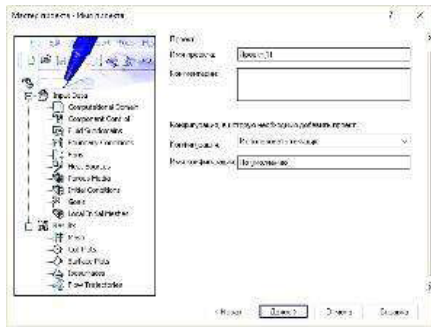


Figure 6. Project selection
The project name is useful only if the model contains multiple configurations. Otherwise, you may assign any name you wish.

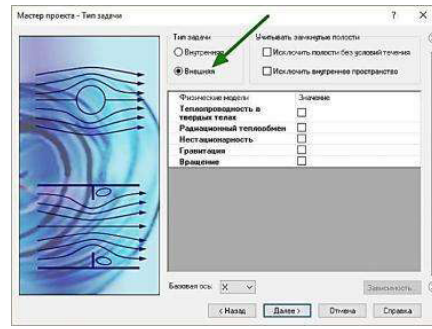


Figure 7. Selecting internal or external flow
The task type is set to internal flow, since the model is enclosed by covers on both sides. Additional physical models may be added if necessary, but using “ideal” conditions helps conserve computational resources.

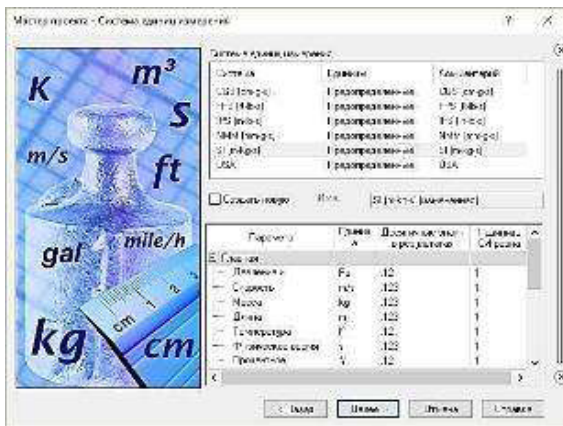


Figure 8. Selecting the AI calculation system

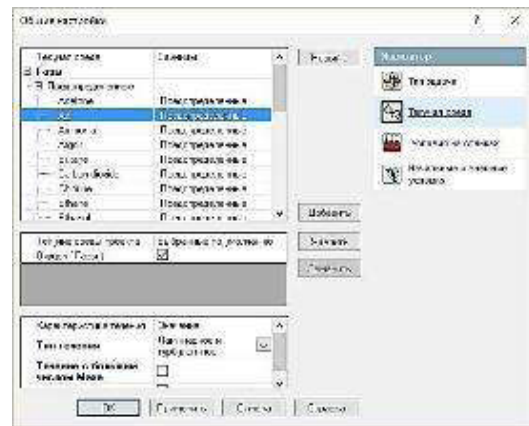


Figure 9. Selecting the air medium

By following the steps sequentially, an excessively large computational domain is generated. To reduce the simulation time, this domain must be trimmed.

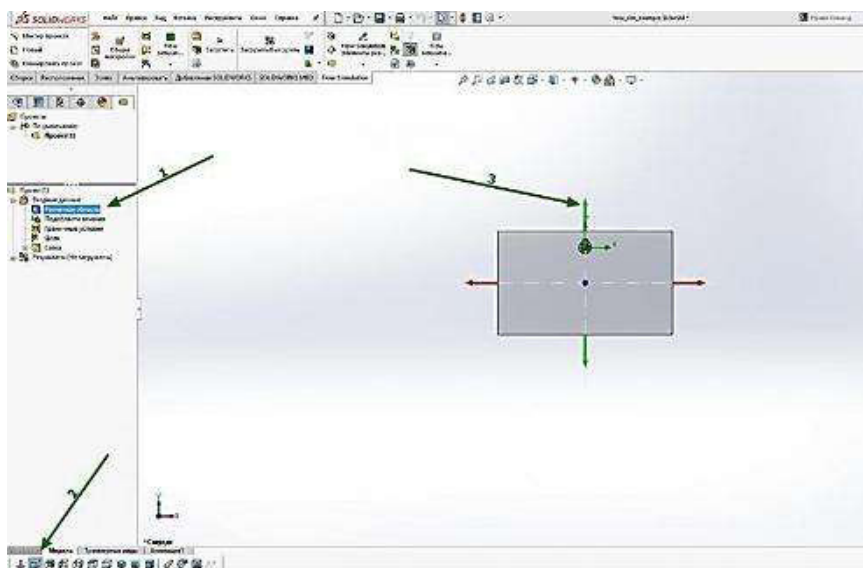


Figure 10. Limiting the computational domain

Select the “Computational Domain” (1), after which the dimension control arrows (2) will become highlighted. For convenience, you may switch viewing orientations (the control panel may differ, or you can open the view selector using the space bar). Adjust the arrows to reduce the domain to the required size (3).

Similarly, remove excess space on the opposite side.

In the air-blowing (“pudash”) zone, we leave slightly more space to observe how the airflow disperses externally.

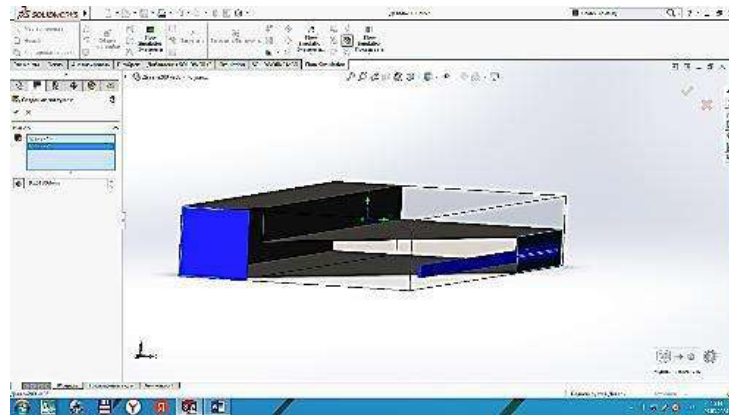


Figure 11. Closing openings and slots

We hide the computational domain from view. For convenience, we activate the section view of the model (1) and adjust it (2) to provide easy access to the inner surface of the cover (3).

Next, we select the inner surface of the cover (1), which performs the “air-blowing” function, and activate the fan feature on it (2).

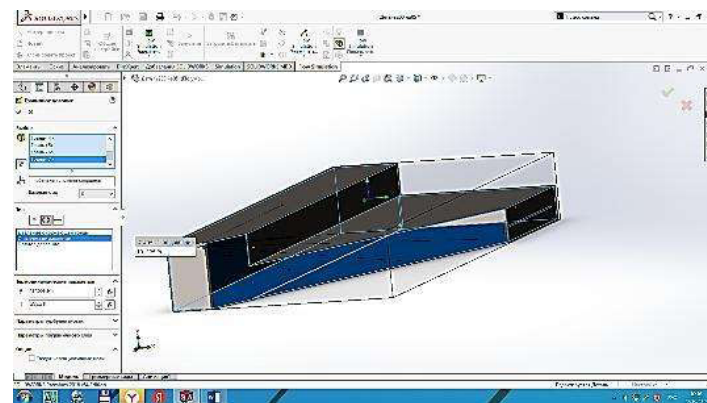


Figure 12. Selecting pressure for automatic calculation

We choose the airflow direction (1), select the type of fan (2), and apply the settings (3).

From the boundary conditions, we specify the static pressure for our design and set it to 101,325 Pascals.

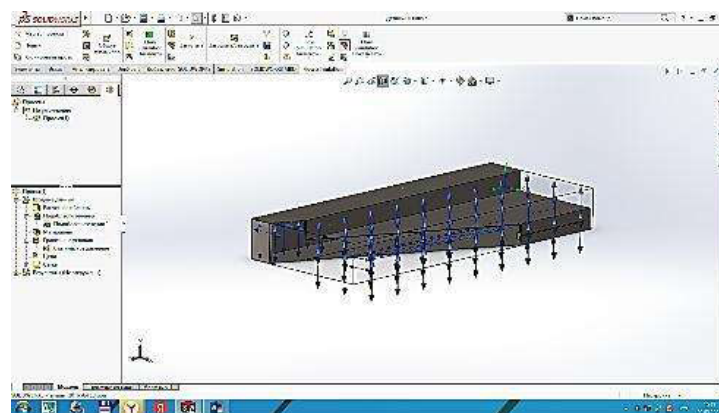


Figure 13. Pressure-affected surfaces

Next, we select the surfaces through which the airflow will move. As a result, the flow trajectories are generated, and green arrows appear on the model. After that, we specify the number of airflow particles—typically between 20 and 50—for both inlet and outlet flow visualization.

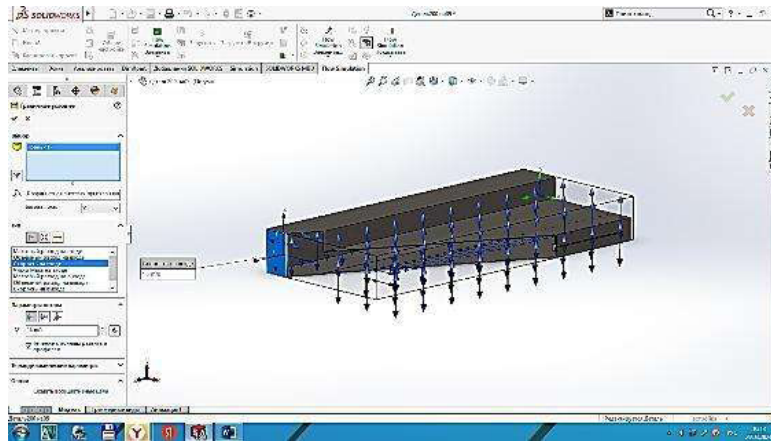


Figure 14. Setting the velocity at the inlet pipe

Next, we open the boundary conditions and assign the airflow velocity at the inlet pipe. Based on the performance characteristics of the VS-10 fan, we set the inlet velocity to 15 m/s. We also define the air outlet slot accordingly.

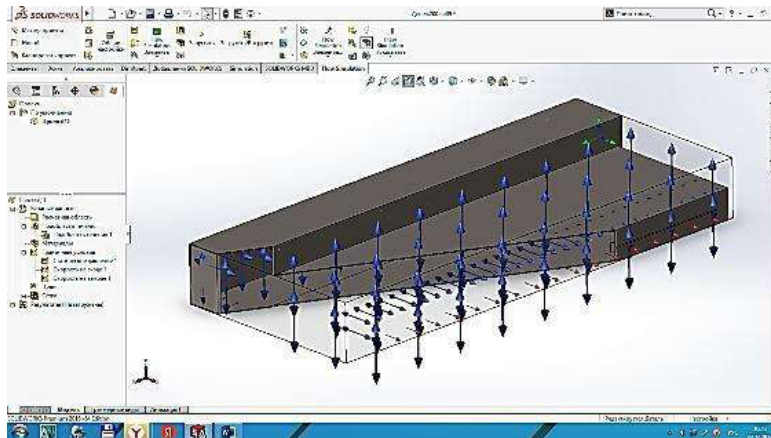


Figure 15. Airflow velocity direction

As a result, red arrows appear at the air inlet and outlet slots. To run the simulation, we click the Start (Запустить) button located on the standard toolbar.

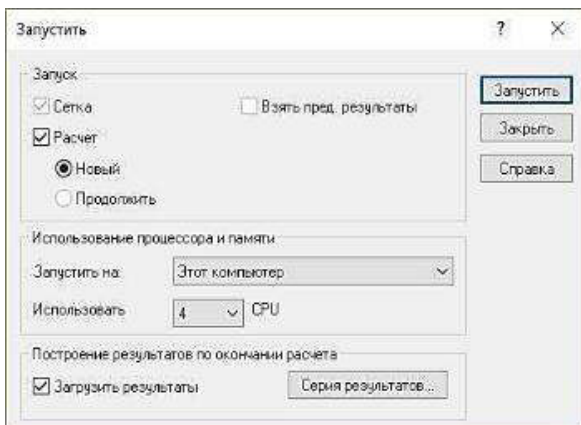


Figure 16. Starting the simulation We select the computer performance settings required for the calculation and then press the Start button to run the simulation.

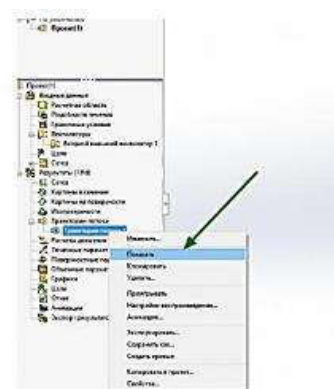


Figure 17. Displaying the contour plots After the simulation calculations are completed, the results appear in the Property Manager under the Results tab.

To visualize the airflow and velocities, we open the Results section in the Property Manager, select the Flow Trajectories option, and click Show to display them.

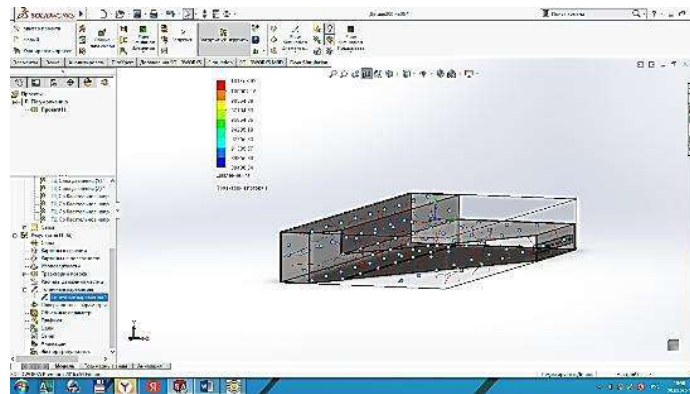


Figure 18. Pressure distribution and indicator diagram

A pressure contour and pressure distribution were obtained, as shown in the figure below.

The airflow contour at the outlet slot was also generated. Analysis of the contour and the corresponding color gradients revealed that the maximum airflow velocity at the outlet slot reaches 131 m/s, while the average exit velocity is approximately 120 m/s.

Based on these results, it was determined that the design parameters allow for the development of two independent air-blowing mechanisms.

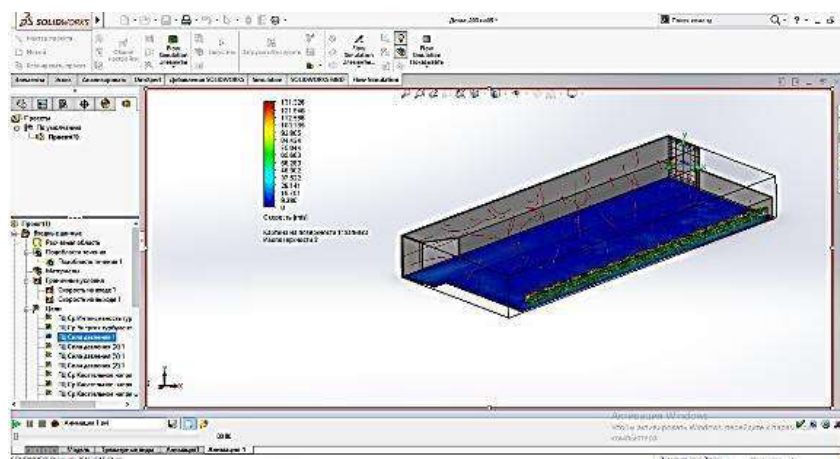


Figure 19. Airflow velocity contour at the outlet slot

As shown in the calculations, the method of compensating static pressure requires a more complex and extensive analysis compared to using a single main air duct along the entire system length. However, modern design and simulation tools make it possible to select the required parameters quickly and accurately.

After performing the simulation using the Flow Simulation module, the velocity plot indicates that the maximum airflow speed reaches 132 m/s, while the airflow exiting the slot in the air-blowing system averages around 120 m/s. This demonstrates that by adjusting the nozzle slot width through an actuator, it is possible to regulate airflow velocity and consequently improve the efficiency of fiber removal from saw teeth.

The developed three-dimensional model clearly confirms the effectiveness of the proposed design. The obtained results provide both theoretical and practical justification for constructing a functional prototype of the improved air-blowing mechanism.

CONCLUSION AND RECOMMENDATIONS

This study developed and analyzed an improved air-blowing (pudash) system designed to enhance fiber separation efficiency from saw teeth in cotton ginning machines. Using SolidWorks Flow Simulation, the airflow distribution, velocity profiles, and pressure gradients within the system were modeled and evaluated under different geometrical configurations.

Simulation results demonstrated that the optimized nozzle configuration generates a maximum airflow velocity of approximately 131–132 m/s, with a stable operating range near 120 m/s at the outlet slot—sufficient to ensure reliable fiber detachment from saw teeth. The improved aerodynamics reduce flow losses, stabilize pressure distribution, and minimize the risk of fiber re-adhesion.

The CFD-based approach confirmed that the proposed design significantly enhances operational performance compared to conventional air-blowing devices that frequently suffer from insufficient or poorly directed airflow. The validated 3D model provides a robust theoretical and practical foundation for fabricating a full-scale prototype.

Based on the findings of this study, the following recommendations are proposed:

- Manufacture a physical prototype using the optimized geometric parameters (slot width, nozzle curvature, airflow direction) identified in the simulations to validate performance under real operating conditions.
- Implement an actuator-based adjustable nozzle system to regulate slot width, allowing dynamic control of airflow velocity depending on cotton variety, moisture level, and ginning load.
- Conduct further analysis to examine energy consumption and fan efficiency, with the aim of reducing operational costs while maintaining high airflow velocity.
- Given that results show sufficient airflow capacity, consider integrating two synchronized air-blowing mechanisms for large-capacity gins to further enhance cleaning quality.
- Perform laboratory and industrial trials to compare actual fiber-removal performance with simulation predictions and quantify improvements in fiber quality, machine productivity, and residue reduction.
- Extend the model using turbulence models ($k-\epsilon$, $k-\omega$ SST) or transient (time-dependent) simulations to better understand unsteady flow behavior and optimize the design further.
- Evaluate the suitability of different nozzle materials to improve system durability and reduce erosion caused by high-velocity airflow.

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Proofreader: Zokir ALIBEKOV

Layout and Designer: Oloviddin Sobir ugli

2025. № 12

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