HEAT TRANSFER AUGMENTATION OF COOLING EQUIPMENT FOR AMRITHAM NUTRIMIX PLANT

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Abstract

The reduced production rates and industry closures caused by the COVID pandemic have impacted the availability of Nutrimix powder, which is crucial for children's health. Meeting the high demand for Nutrimix within the required quantity and timeframe has become a challenge.During our assessment of a production plant, we identified several obstacles affecting production rates and cycle time, with one prominent issue being the extended cooling time during the manufacturing process.To tackle this problem, we developed a cooling chamber specifically designed for the pulverized wheat-air mixture produced by the grinding mill. The mixture, initially at a temperature of 60 degrees Celsius, undergoes cooling by passing through a pipe equipped with fins to enhance efficiency. It then enters a larger cylindrical chamber with the assistance of a suction blower, creating a vacuum pressure. To prevent the entry of pulverized wheat, a filter is positioned in front of the blower.For effective cooling, we implemented a copper-wound system utilizing a water-glycol mixture that flows through the copper tube. The copper is wound around an enclosed aluminum chamber and the larger pipe to optimize the cooling process. Prior to recirculating the coolant, it passes through an air reservoir to eliminate any air bubbles.Additionally, we conducted a CFD Fluent analysis to evaluate various aspects such as velocity variation, pressure variation, adjacent surface temperature variation, and volumetric rendering of the coolant and pulverized wheat-air mixture. These analysis results played a crucial role in fine-tuning the design and improving the overall efficiency of the cooling system.

Index Terms—Cooling chamber, Pulverized wheat, Suction blower, CFD Fluent analysis, Copper-wound system

INTRODUCTION

As part of this project, we have developed a specialized cooling chamber to efficiently cool the pulverized wheat-air mixture produced by the grinding mill. The primary objective of the cooling chamber is to maintain the quality of the flour by reducing the temperature generated during the milling process. It consists of several essential components, including a pipe, fins, a suction blower, a filter, and a copper-wound system.

The first component of the cooling chamber is a pipe with an outer diameter of 50 mm and a thickness of 3 mm. The pulverized wheat-air mixture is directed through this pipe, which is placed over a larger pipe with a 3 mm thickness and an outer diameter of 150 mm. To enhance the cooling process, 16 fins are evenly spaced at a distance of 20 mm along the larger pipe, ensuring effective cooling of the pulverized wheat- air mixture as it flows through the system.

Once cooled, the pulverized wheat-air mixture is transferred to a larger cylindrical chamber using a suction blower posi- tioned at the top end. This chamber has a diameter of 200 mm and a thickness of 3 mm. The suction blower generates a vacuum pressure of 40.369 Pa to facilitate the movement of the mixture. To prevent the entry of pulverized wheat into the suction chamber, a filter is placed in front of the blower. The larger chamber is vertically oriented and equipped with an airlock system at the bottom, which is operated by a motor. This airlock system efficiently traps and removes the air, allowing only the cooled pulverized wheat to be expelled from the chamber.

To achieve effective cooling of the pulverized wheat, a copper-wound system with a flow of a 1:1 water-glycol mixture is employed. This system involves winding the copper tube initially around a smart, fully enclosed aluminum cham- ber with a diameter of 80 mm and a length of 495 mm, which is situated inside the larger chamber with a diameter of 200 mm. Subsequently, the copper tube is wound over the larger pipe. This design ensures that the coolant first cools the inside chamber and then the outer chamber, maximizing the cooling efficiency. Before recirculating the coolant through the copper tube, it passes through an air reservoir to eliminate air bubblesand ensure smooth operation.

RELATED WORKS

In the study titled ”Design of Cooling System to Control the Temperature of Domestic Flour Mill” by Omkar Sutar, Manish S. Ubhe, Sahil Padwal, Saurabh Salunke, and Prof.
G.A. Ghatole, it was observed that the temperature of flour increases significantly during the crushing and grinding pro- cess, reaching up to 60 to 70 degrees Celsius. This elevated temperature negatively affects the nutritional value and quality of the flour, as well as the lifespan of the flour and the grinder itself.To address this issue, the study proposes the use of an air cooling system to reduce the temperature of both the flour mill and the flour during the grinding process. The primary objective of the project is to design and develop an effective air-cooling system that can mitigate the temperature rise in the grinder and flour. By doing so, the system aims to preserve the nutritional content of wheat flour and minimize the mainte- nance requirements of the grinder.The implementation of this cooling system has several benefits, including the maintenance of consistent nutritional values and the preservation of the quality of the flour. Additionally, the system can contribute to reducing the temperature of the grinder, thereby extending its lifespan. The authors emphasize that the system’s design focuses on maintaining the constant nutritional values and healthy qualities of the flour.The potential application of this cooling system extends to various commercial flour mills, where it can be installed to ensure the consistent quality of flour production. By adopting this system, commercial flour mills can effectively control and manage the temperatureduring the grinding process, leading to improved flour quality and customer satisfaction.

In the study titled ”Design, Fabrication, and Evaluation of an Electrically-operated Groundnut Roasting Machine” by Alao Adeyinka Idowu, Akande Olamide Abigael, Adeoye Ba- batunde Kazeem, and Owoyemi Modupe Beatrice, the authors focus on the design, fabrication, and performance evaluation of a groundnut roasting machine. The performance evaluation of the machine was conducted at the AGE Workshop, Federal University of Technology in Akure, Nigeria.

The design of the machine took into consideration various factors such as the volume of groundnuts to be roasted, reduction of heat loss, and roasting temperature. The aim was to develop a more efficient method of roasting ground- nuts compared to traditional roasting techniques, ensuring improved time efficiency and overall quality of the roasted groundnuts.The performance test conducted on the developed roasting machine demonstrated that it produced hygienic and superior-quality roasted food items compared to the traditional roasting method. The machine proved to be a more effec- tive and reliable solution for roasting groundnuts, offering advantages in terms of hygiene, quality, and efficiency.This research provides a comprehensive examination of a groundnut roaster that can be utilized in the manufacturing process of nutrimix. By incorporating the developed roasting machine, the production of nutrimix can be enhanced, ensuring the delivery of well-roasted groundnuts for the manufacturing process..

In the publication titled ”Food Powder Handling and Pro- cessing: Industry Problems, Knowledge Barriers, and Research Opportunities” by John J. Fitzpatrick and Lilia Ahrné, the authors discuss the outcomes of a European Union (EU) commission Accompanying Measure focused on food pow- ders. The primary aim of this work was to identify and address the significant industrial problems, knowledge barriers, research challenges, and opportunities related to food powders. Additionally, the paper aimed to foster the establishment of a sustainable network of excellence in the field of food powders.The project had specific objectives, which included identifying research and development needs and opportunities concerning the handling, processing, and production of safe and high-quality food powders. These identified needs would serve as a basis for targeted research initiatives aimed at resolving the specific problems faced by the industry. Fur- thermore, the project sought to facilitate the establishment of a sustainable network of excellence, bringing together experts and stakeholders in the field of food powders to foster collaboration and knowledge sharing.The publication sheds light on the current challenges and gaps in knowledge within the food powder industry. By highlighting these issues, it aims to encourage further research and development efforts in addressing the identified problems. The ultimate goal is to enhance the handling, processing, and production of food powders, ensuring their safety and quality. Additionally, the es- tablishment of a sustainable network of excellence is expected to facilitate ongoing collaboration and knowledge exchange among researchers and industry professionals, fostering ad- vancements in the field of food powders.

In their review article titled ”Antimicrobial Edible Films in Food Packaging: Current Scenario and Recent Nanotech- nological Advancements,” Rekha Chawla, S. Sivakumar, and Harsimran Kaur address the growing consumer awareness and demand for high-quality foods packaged in environmentally friendly materials. As a result, researchers have redirected their efforts towards sustainable advancements in active packaging systems that can effectively preserve food quality and sensory attributes throughout the storage period.The review article provides an analysis of the present situation and explores the applications of antimicrobial biodegradable films within the food packaging industry. These films are designed to possess antimicrobial properties, thereby offering an additional layer of protection to extend the shelf life of packaged food products. The article also highlights recent advancements in nanotechnology that have contributed to the development of novel techniques and materials for enhancing the antimicrobial efficacy of these edible films.By examining the current state of antimicrobial edible films and their role in food packaging, this review article aims to shed light on the potential benefits and applications of such innovative packaging systems. The focus is on addressing the need for sustainable packaging solutions that can ensure food safety and quality while meeting the growing consumer expectations for eco-friendly practices in the food industry.

In the research article titled ”Experimental Study of Ef- ficiency in Pneumatic Conveying System’s Feeding Rate,” Giovani Aud Lourenço, Thais Logetto Caetité Gomes, Claudio Roberto Duarte, and Carlos Henrique Ata´ıde investigate the challenges encountered when feeding materials to pneumatic conveying systems using a rotary valve. These challenges arise due to the pressure gradient between the pipeline and the storage silo where the material is stored.One common approach to mitigate such issues is to operate the pneumatic conveying system with a closed silo, particularly when han- dling low-density materials like biomass. The objective of this study is to determine the optimal rotation speed of the valve and the air velocity that can ensure the highest efficiency in the feeding system. By conducting detailed experiments, the researchers aim to analyze the feeding efficiency in relation to different air velocities and valve rotation speeds. The focus is on maximizing and achieving uniformity in the solids’ feed rate for the pneumatic conveying system, thereby reducing the risks of line clogging and excessive energy consumption.The findings of this study will provide valuable insights for design- ing pneumatic conveying systems and optimizing their feeding processes. The recommended approach involves a thorough examination of feeding efficiency, considering the interaction between air velocities and valve rotation speed. This analysis is crucial for achieving consistent and efficient solids’ feed rate in pneumatic conveying systems while minimizing the potential issues associated with line clogging and excessive energy usage.

The research article titled ”Numerical Investigation of Heat Transfer Characteristics of Aluminium and Copper Heat Spreader,” authored by Md. Mahmodul Alam, Rizwanur Rah- man, Ahmad Kibria Al Kawsar, Hamza Ahmed, Saif Islam Uday, Samiul Alam, and Tasfia Tasnim, focuses on conductinga computational fluid dynamics (CFD) analysis to examinethe heat transfer characteristics of aluminium and copper heat spreaders. The study involves varying several geometric and thermal parameters of the heat spreader through a series of parametric studies.The analysis of the heat spreader involves assessing the temperature difference across it, which enables the evaluation of the total thermal resistance and thermal flux. By employing CFD models, a comparison can be made between the performance of copper and aluminium spread-

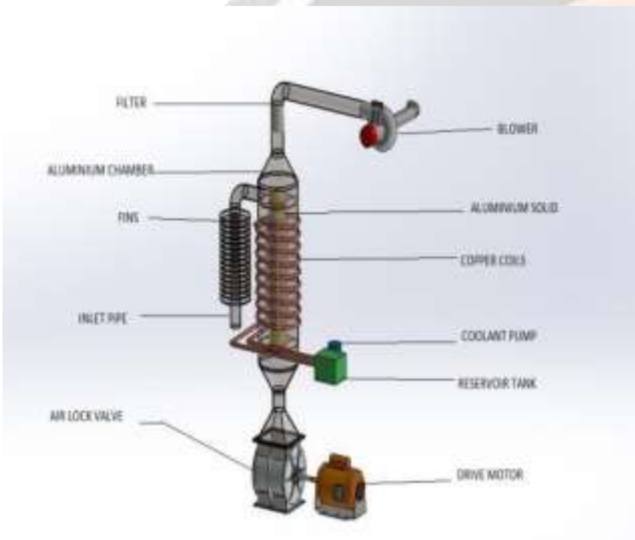
ers.The findings indicate that copper exhibits higher thermal conductivity compared to aluminium, while aluminium hasa lower specific heat. Consequently, copper has a greater capacity for carrying heat than an aluminium plate of similar area. However, due to the variable power of aluminium, the total thermal resistance associated with this material is higher than that of copper.Copper is known for its high thermal conductivity and thermal coefficient, although it is also more expensive. On the other hand, aluminium has good heat-carrying capacity and a higher resistance capabil- ity, albeit lower than copper. Moreover, aluminium is more cost-effective. Therefore, conducting a parametric comparisonbetween copper and aluminium assists in understanding whichmaterial is more suitable for cooling operations.Overall, this numerical investigation provides insights into the heat trans- fer characteristics of aluminium and copper heat spreaders, allowing for a comparative analysis of their performance and aiding in the selection of the appropriate material for cooling applications.

The research paper titled ”Experimental Study of HeatTransfer Enhancement Using Water/Ethylene Glycol-BasedNanofluids as a New Coolant for Car Radiators,” authoredby S.M. Peyghambarzadeh, S.H. Hashemabadi, S.M. Hoseini,and M. Seifi Jamnani, investigates the convective heat trans-fer enhancement of water and ethylene glycol (EG) basednanofluids in flat aluminum tubes of car radiators. The studycompares the heat transfer performance of pure water and pureEG with their binary mixtures containing nanoparticles.Theexperimental results show significant increases in the totalheat transfer rates when nanofluids are used. The highestenhancement in the Nusselt number, indicating convective heattransfer, reaches up to 40 percentage under optimal conditionsfor both nanofluids. The research findings highlight that theheat transfer behavior of the nanofluids is mainly influencedby the particle concentration and flow conditions, while beingless dependent on temperature variations.The outcomes of thestudy demonstrate the potential of nanofluids for enhancingheat transfer. The research suggests that nanofluids are well-suited for practical heat transfer processes due to their abil-ity to significantly improve heat transfer rates. Overall, thisinvestigation explores the use of water/ethylene glycol-basednanofluids as innovative coolants for car radiators, aiming toenhance heat transfer efficiency in automotive cooling systems.The project titled ”Heat Transfer Enhancement Using He-lical Coil Heat Exchanger,” authored by Murugapandi, D.Parthiban, S. Parri Surendra, Kumar M. P., and Mr. S.Gopinath, aims to improve the effectiveness of a heat ex-changer using water. The study involves analyzing variousparameters that impact the effectiveness of a heat exchangerand includes a performance analysis by manipulating parame-ters such as flow rate and temperature.The research comparesthe results of a helical coil heat exchanger with a straighttube heat exchanger in both parallel and counter flow con-figurations. Parameters such as temperature, fluid flow rate,and the number of turns in the helical coil are varied duringthe analysis. Fluid flow analysis is conducted using ANSYS CFD (Computerized Fluid Dynamics) software.The findings indicate that the helical coil heat exchanger demonstrates an increase in heat transfer rate, effectiveness, and overallheat transfer coefficient compared to the straight tube heat exchanger across various mass flow rates and operating condi-tions.The design of the helical coil allows for a longer contact time between the fluid and the heat exchanger, resulting in enhanced heat transfer when compared to a straight tube heat exchanger. A comparative study reveals that the helical coil heat exchanger outperforms the straight tube heat exchangerin terms of overall performance.In conclusion, this projectfocuses on enhancing heat transfer in a heat exchanger throughthe use of a helical coil. The results demonstrate improved heattransfer rate, effectiveness, and overall performance comparedto the traditional straight tube heat exchanger.

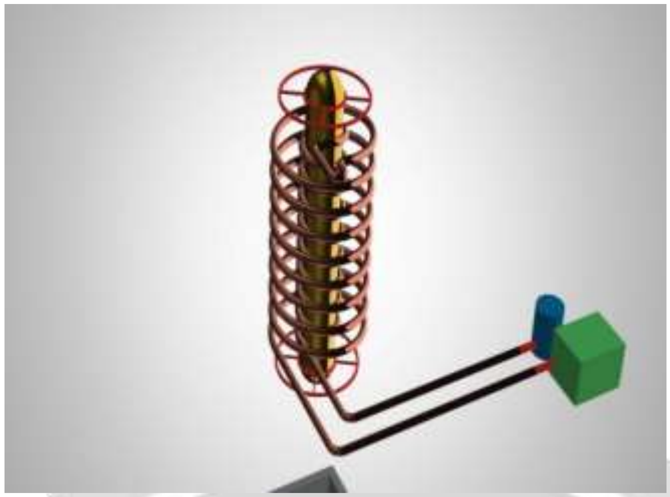
The paper titled ”Effects of Fin Parameters on Performance of Latent Heat Thermal Energy Storage Systems: A Review,” authored by M. Eslami, F. Khosravi, and H.R. Fallah Koha, aims to provide a comprehensive review of different fin de- signs proposed for latent heat thermal energy storage (LHTES) systems. The focus is on discussing the effects of various geometrical parameters, including fin length, number, thick- ness, spacing, angle, and shape, on the performance of these systems. Additionally, the interaction between fin configura- tions and other design parameters such as enclosure geometry, fluid flow rate, and temperature is explored.The study presents an in-depth review of the application of fins in phase change materials within the context of LHTES systems. The effects of different parameters on the melting and solidification processes are critically examined. The paper delves into the intricate interactions between various geometrical fin parameters, the heat transfer fluid (HTF) tube, enclosure shape, and flow parameters associated with the heat transfer fluid.Based on the reviewed investigations, several common and important findings emerge. It is generally observed that increasing the number and length of fins enhances heat transfer. However, there exists an optimum value for these parameters since fins have a significant impact on the convection heat transfer within the confined space of the liquid phase change material (PCM). Moreover, a large number of fins can restrict convective flows and limit the extent of improvement. The study concludes that the performance of the system is more influenced by fin length and fin number compared to fin thickness..

I. PROPOSED MODEL

Designing and analyzing the cooling chamber for the pulverized wheat-air mixture is a challenging task that ne- cessitates the utilization of advanced software tools. Solid- Works 2019 and ANSYS 2021 R2 are two widely used software applications in the engineering field for 3D mod- eling and simulation. For this particular project, the cool- ing chamber design was created using SolidWorks 2019, while the analysis was carried out using ANSYS 2023 R2.



Employing SolidWorks 2019 for designing the cooling chamber offers several benefits. Firstly, it is a user- friendly software application that provides a wide array of tools and features for creating 3D models. The software encompasses various design functionalities, such as extrusion, revolve, sweep, and loft, which can be utilized to generate intricate geometries. Additionally, SolidWorks offers design validation tools, including simulation, tolerance analysis, and interference detection, enabling designers to optimize the design and ensure its functionality.Furthermore, SolidWorks 2019 offers a diverse set of design automation tools, facilitating the creation of templates and the utilization of design tables. This empowers engineers to swiftly and efficiently develop intricate designs, resulting in time and resource savings. The software also encompasses a variety of data management tools, enabling the storage and sharing of design data, thereby promoting collaboration among team members.



Utilizing ANSYS 2023 R2 for the analysis phase presents numerous advantages. ANSYS 2023 R2 is a robust simulationsoftware application equipped with a wide range of analysis

capabilities, including structural, thermal, and fluid dynamics analysis. The software's advanced features enable the simu- lation of complex physical phenomena, making it particularly well-suited for simulating the cooling process of the pulverizedwheat-air mixture.

A. MATERIALS AND COMPONENTS

- Inlet pipe
- Cooling fins
- Aluminium vaccum chamber
- Air lock valve
- Drive motor
- Shaft coupling
- Filter
- Blower
- Cooling coils
- Coolant lift pump
- Reservoir tank

B. WORKING

The objective of this project was to design and construct a cooling chamber specifically tailored for the cooling of the pulverized wheat-air mixture produced by the grinding mill. The cooling process involved transferring heat from the mix- ture to a coolant circulating through a copper-wound system. To achieve this, a suction blower created a vacuum pressure, drawing the mixture into the cooling chamber. Inside the chamber, the mixture underwent efficient cooling as it passed through a finned pipe.The larger cylindrical chamber, equipped with a suction blower and a filter, effectively prevented the entry of pulverized wheat. The coolant used was a water-glycol mixture with a 1:1 ratio, which circulated within the copper- wound system and was purged of air bubbles after passing through an air reservoir.

To ensure the efficiency of the cooling chamber, various mechanical engineering principles were applied, including ma- terial selection, structural analysis, and system integration. The choice of materials was crucial in guaranteeing the system's durability and reliability, while structural analysis ensured its ability to withstand operational forces. System integration fo- cused on seamless collaboration among components to achieve the desired cooling effect.To further optimize the design and enhance overall cooling efficiency, computational fluid dynam- ics (CFD) analysis was employed. This analysis encompassed the study of velocity variation, pressure distribution, adjacent surface temperature fluctuation, and volumetric rendering of the coolant and pulverized wheat-air mixture. The results obtained from the CFD analysis guided the evaluation of the cooling chamber’s performance and informed necessary design modifications. The cooling chamber consisted of a smart, fully enclosed aluminum chamber with a copper-wound system wound around it, along with a larger pipe. The pulverized wheat-air mixture flowed through the copper-wound system, while the coolant was recirculated after passing through the air reservoir. The use of the coolant played a vital role inmaintaining the pulverized wheat-air mixture at an optimal temperature, ensuring the quality of the final product.

In conclusion, the developed cooling chamber significantly improves the cooling process of the pulverized wheat-air mix- ture derived from the grinding mill. By employing mechanical engineering principles, conducting CFD analysis, and employ- ing appropriate materials, the system demonstrates durability, reliability, and efficiency. The application of this system in the food processing industry can enhance product quality, safety, waste reduction, and overall efficiency..

C. BOUNDARY CONDITIONS

If the pulverized wheat is immediately taken after the pulverizing mill, its initial temperature is likely to be higher compared to storing it for some time. In such a scenario, the temperature of the pulverized wheat could range from 40°C to 60°C, depending on the efficiency and type of the pulverizing mill. Regarding the air temperature entering the chamber, it would typically fall within the range of 15°C to 25°C, as these temperatures are commonly found in the surrounding environment. However, the exact temperature of the air entering the chamber would depend on the specific cooling requirements, as well as the ambient temperature and humidity conditions in the facility. To determine the suitable coolant oil and inlet temperature for the cooling system, several factors need to be considered. These factors include the desired final temperature of the pulverized wheat, the cooling capacity of the system, and the properties of the coolant oil.

Suppose we aim to cool the pulverized wheat from 60°C to approximately 25°C. In that case, a viable coolant oil for the system could be a water-glycol mixture, which is commonly utilized for cooling purposes in various industries. The concentration of glycol in the mixture would depend on the desired freezing point and viscosity of the coolant oil.The inlet temperature of the coolant oil would rely on the cooling capacity of our system, determined by factors such as the surface area of the copper tube, the flow rate of the coolant, and the temperature difference between the coolant and the aluminum chamber. Generally, a lower inlet temperature leads to a higher cooling capacity. However, it is crucial to ensure that the coolant oil does not freeze or solidify at the operating temperature of our system.

Assuming a typical flow rate of 10 liters per minute and a temperature difference of 10°C between the coolant oil and the aluminum chamber, a suitable inlet temperature for the coolant oil might be approximately 15°C to 20°C. Neverthe- less, conducting a thorough analysis of our system is necessary to determine the optimal values for our specific application

FUTURE SCOPE

The cooling chamber designed for the pulverized wheat-air mixture offers several opportunities for future advancements and enhancements. Here are some potential areas for future research:

• Implementation of automation technology: The current cooling chamber system relies on manual control and moni- toring. Integrating automation technology, such as sensors and controllers, can provide real-time data and automated control, enhancing the system's efficiency and reliability.

• Exploration of alternative cooling methods: While the water-glycol mixture used as a coolant has proven effective, alternative cooling methods like compressed air or nitrogen could be investigated to further optimize cooling efficiency and reduce energy consumption.

• Optimization of cooling chamber design: The cooling chamber design can be further optimized by evaluating differ- ent geometries and cooling materials. Adjusting the number and spacing of the fins on the copper-wound system can also enhance cooling efficiency.

• Scaling up the system: Modifying the cooling chamber design and coolant flow rate would be necessary to scale up the system for higher production capacities.

• Integration with the grinding mill: Integrating the cooling chamber with the grinding mill can create a comprehensive system for pulverized wheat-air mixture production, leading to increased efficiency, reduced energy consumption, and lower operational costs.

• Study of the cooling process's impact on product quality: Future research can focus on examining how the cooling process affects the physicochemical properties and quality of the final pulverized wheat-air mixture.

• Comparison with other cooling methods: The developed cooling chamber can be compared with other cooling methodssuch as refrigeration, natural cooling, or forced air cooling to assess its effectiveness and efficiency.

• Environmental impact assessment: Assessing the envi- ronmental impact of the cooling system in terms of energy consumption, greenhouse gas emissions, and waste generation would be valuable for developing an efficient and environmen-tally friendly cooling solution.

• Adaptation for other industries: The cooling chamber developed for the pulverized wheat-air mixture can be adaptedfor cooling applications in other industries, such as food, pharmaceutical, and chemical industries.

• Study of coolant flow rate's effect on cooling efficiency: Investigating the impact of different coolant flow rates onthe cooling efficiency of the system can provide insights for optimization.

• Integration with renewable energy sources: Integrating the cooling chamber with renewable energy sources like solar or wind power can reduce energy consumption and operational costs.

• Development of a predictive model: Creating a predictive model to forecast the cooling efficiency and performance under various operating conditions can aid in the design and optimization of the cooling chamber system.

• Study of coolant temperature's effect on cooling efficiency: Researching the influence of different coolant temperatures on the cooling efficiency of the system would provide valuable insights for optimization.Study of cooling's impact on energy consumption: An- alyzing the effect of cooling on energy consumption and finding ways to reduce energy usage while maintaining coolingefficiency is an important research direction.

• Development of a portable cooling chamber: Designing a portable cooling chamber suitable for remote areas or regions with limited electricity access can provide a solution for cooling pulverized mixtures in such locations.

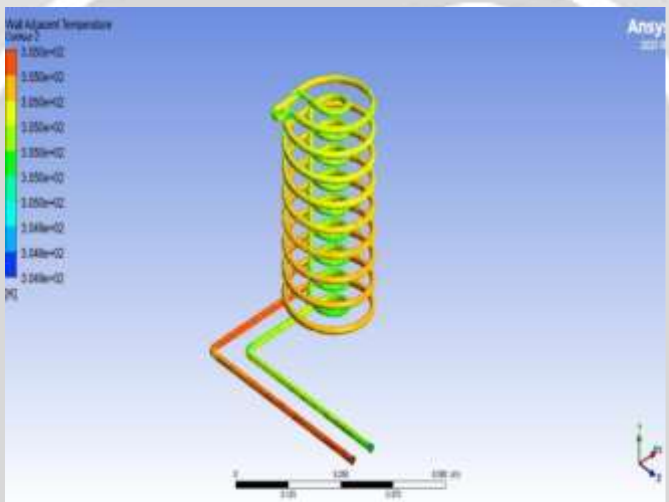
Additionally, the cooling chamber technology can be modi- fied and optimized for other industries such as pharmaceuticals and food processing, where cooling materials is essential. This opens up new opportunities for the application of the cooling chamber in various sectors.Integrating renewable en- ergy sources to power the cooling system is another potential future scope for this project. By utilizing solar or wind power, the efficiency and sustainability of the cooling chamber can be increased, addressing the limitations of relying solely on electricity.Furthermore, integrating the cooling chamber with other systems, such as the grinding mill, can create a more efficient and streamlined process, leading to improved productivity and reduced operating costs for industries that rely on these processes.The data obtained from the computational fluid dynamics (CFD) analysis can be used to develop more accurate models and simulations for optimizing

RESULT AND ANALYSIS

"The Ansys Fluent study identified that the variation in velocity observed can be attributed to factors such as the geometry of the copper-wound system, coolant flow rate, and pressure gradient within the system. At the entry point of the copper tube, the velocity is initially low at 0.371608 m/s because the coolant flow rate is still establishing momentum. As the fluid progresses through the copper-wound system, velocity increases due to the decreasing cross-sectional area of the winding. The highest velocity of 1.47472 m/s is reached at the starting point of the wounded coil in the inside chamber. As the fluid flows over the outer large chamber, the velocity decreases to 1.10175 m/s due to the increasing cross-sectional area, but it increases again to 1.23372 m/s as it reaches the bottom of the winding. Finally, as the fluid exits the system and enters the reservoir, the velocity further increases to 1.46344 m/s due to the decreased cross-sectional area and pressure gradient.

The pressure variation analysis in ANSYS Fluent demonstrated that the coolant circulated through the copper tube with a flow rate of 10 litres per minute. The pressure at the entry point of the copper tube was 185501 Pa, and it decreased as the fluid flowed through the system. The pressure dropped to 170967 Pa at the starting point of the coil, then further decreased to 120916 Pa at the top of the inside cooling chamber. As the fluid flowed through the winding over the outer large chamber, the pressure continued to decrease to 114886 Pa. At the bottom of the larger chamber, the pressure dropped to 17772 Pa before reaching 381 Pa at the pipe entering the reservoir. The pressure variation is caused by changes in fluid flow velocity and direction, with

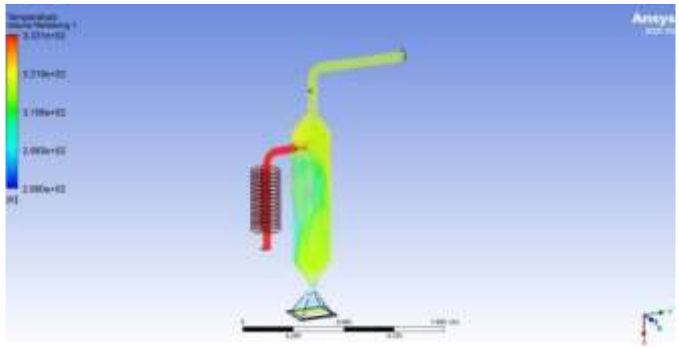
high pressure at the entry point due to resistance from the inlet pipe and decreasing pressure as the fluid encounters larger cross-sectional areas. The pressure drop is within acceptable limits, indicating efficient operation of the cooling chamber, and can be used to estimate energy requirementsand frictional losses.



Regarding temperature variation, the coolant flowing through the copper tube experiences minimal changes in temperature. The coolant temperature at the entry point of the tube is 304.97 K, and it increases slightly to 304.996 K at the starting point of the coil in the inside chamber due to heat transfer from the copper tube. As the fluid flows through the coil at the top of the inside cooling chamber, the tempera- ture decreases slightly to 304.973 K due to heat transfer to the surrounding air. The coolant temperature remains almost constant at 304.975 K as it flows over the coil wound in the outer large chamber, and it increases slightly to 304.982 K as it reaches the bottom of the winding. These minimal temperature changes indicate the copper tube’s effectiveness in maintaininga consistent coolant temperature and efficient heat dissipation.

For the inside cooling chamber made of aluminum, the temperature variation from bottom to top was observed. The bottom of the chamber where the copper tubing starts has a temperature of 318.4 K, which decreases to 301.8 K in the middle of the chamber. At the top of the chamber, where the pulverized air comes in contact with the surface, the temperature rises to 331.2 K. The temperature variation is attributed to heat transfer within the chamber, with the coolant removing heat from the aluminum walls and cooling the air in contact with the walls. The introduction of pulverized air also affects the temperature, increasing it due to enhanced heat transfer.

The velocity variation analysis of the pulverized wheat air mixture in the larger chamber revealed that the initial velocity at the inlet pipe with fins is 6.74467 m/s. As the air expands into the larger chamber, its velocity increases to 39.9448



CONCLUSION

In summary, the successful development of the cooling chamber for the pulverized wheat-air mixture from the grind- ing mill was achieved through the application of mechanical engineering principles. This involved material selection, struc- tural analysis, and system integration to design and construct the cooling chamber. Computational fluid dynamics (CFD) analysis played a crucial role in optimizing the design and enhancing the overall cooling efficiency.The purpose of the cooling chamber was to cool the pulverized wheat-air mixture, which is essential in the milling industry. The mixture is generated at high temperatures and requires cooling to prevent clogging and improve the quality of the final product. The implementation of a copper-wound system for cooling the mixture and recirculating the coolant through an air reservoir proved to be an effective approach for achieving efficient cooling.The design of the cooling chamber underwent opti- mization through CFD analysis, enabling the evaluation of its performance and necessary modifications to enhance cooling efficiency. CFD analysis also provided valuable insights into the velocity variation, pressure variation, adjacent surface temperature variation, and volumetric rendering of the coolant and pulverized wheat-air mixture.The project brought sev- eral industrial benefits, including improved product quality, reduced downtime due to clogging, and increased milling process efficiency. Additionally, it had social benefits such as minimizing occupational hazards and improving the health andsafety of workers.

Overall, the successful development of the cooling chamber stands as a significant achievement, highlighting the effective- ness of applying mechanical engineering principles and CFD analysis to solve real-world challenges in the milling industry. The project holds promising prospects for further optimization and scalability in larger milling operations.

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