MARMARA UNIVERSITY

FACULTY OF ENGINEERING

Investigation of the Factors Affecting the Exhaust Flow Rate of a Kitchen Hood

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GRADUATION PROJECT REPORT

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by

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ABSTRACT

This study presents a computational analysis of kitchen hood ventilation performance, focusing on the influence of mounting distance and hood surface area on airflow behavior and thermal dispersion. The objective is to identify optimal geometric parameters for enhancing heat and fume extraction efficiency using Computational Fluid Dynamics (CFD) simulations in ANSYS Fluent.

Three hood configurations were investigated. In Case 1, the hood was mounted 1.0 meter above the heat source with a surface area of 1.5 m^2. Case 2 reduced the mounting height to 0.7 meters while maintaining the same surface area. Case 3 kept the 0.7-meter mounting height but expanded the hood area to 3.0 m^2. All simulations were performed under natural convection assumptions with constant inlet velocity and mass flow rate, allowing for isolated geometric comparison.

Results showed that Case 2 achieved the most efficient and stable flow behavior. The jet remained more centered, with minimal recirculation, and the flow rate increased compared to Case 1 due to the reduced mounting height, which enhanced suction effectiveness. Case 1, with a higher mounting distance, experienced more prominent recirculation zones and higher heat dispersion due to increased vertical space for air mixing; it also had the lowest volumetric flow rate among the three cases. Case 3, despite its larger surface area and increased outlet velocity, produced the highest flow rate overall. However, this configuration led to a diffuse jet with weakened directionality. While it resulted in fewer recirculation zones and the lowest heat dispersion, the reduced flow alignment indicated weaker extraction performance overall. In all cases, residuals dropped below 10^{-4} and inlet–outlet mass flow rates remained balanced, confirming numerical convergence.

These findings demonstrate that both mounting height and hood area significantly affect exhaust performance. The study highlights the importance of jet stability and flow control in achieving effective ventilation and offers valuable insight into the geometric optimization of kitchen exhaust systems for enhanced indoor air quality.

SYMBOLS

°C Celcius

K Kelvin

Q is the exhaust airflow rate (m^3/s),

v is the capture velocity at the hood inlet (m/s),

x is the vertical distance between the pollutant source and the hood (m),

A is the hood inlet area (m^2).

CO carbon monoxide

NO_2 nitrogen dioxide

VOCs volatile organic compounds

ABBREVIATIONS

AHJ Authority Having Jurisdiction

CFD Computational Fluid Dynamics

NFPA National Fire Protection Association

HVAC Heating, Ventilating and Air Conditioning

AC Alternating Current

DC Direct Current

FVM Finite Volume Method

RANS Reynolds-Averaged Navier–Stokes

SIMPLE (Semi-Implicit Method for Pressure Linked Equations)

ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers

UV-C Ultraviolet Type

CFM cubic feet per minute

BLDC Brushless DC Motor

1. INTRODUCTION

In industrial and commercial kitchens, exhaust hood systems play a crucial role in maintaining indoor air quality and ensuring a safe working environment. These systems remove heat, smoke, grease vapors, and other pollutants generated during cooking, thereby protecting the health of kitchen staff and reducing fire hazards. However, for exhaust systems to function efficiently, airflow management must be optimized. In this regard, the exhaust airflow rate (exhaust volume flow) is one of the key parameters directly affecting system performance.

Several factors influence the exhaust airflow rate. Parameters such as hood geometry, exhaust duct design, fan capacity, air velocities, indoor airflow patterns, external environmental conditions, and filtration systems directly impact exhaust efficiency. While traditional design processes rely on experimental studies and empirical calculations, these methods can be time-consuming and costly. In recent years, Computational Fluid Dynamics (CFD) has emerged as a powerful tool for analyzing such systems.

CFD simulations enable detailed examination of fluid flow behaviors, including airflow patterns, pressure distributions, temperature variations, and turbulence characteristics, using mathematical models. By leveraging CFD, optimized design solutions can be developed to improve system efficiency and enhance energy performance.

In this study, the parameters affecting exhaust airflow rate in kitchen hood systems will be investigated using CFD simulations. A comprehensive literature review will be conducted to analyze the CFD models, turbulence approaches, and accuracy levels of airflow simulations used in exhaust system studies. Based on the findings, recommendations will be provided to enhance the performance and efficiency of exhaust hood systems.

2. Kitchen Hoods

Kitchen hoods serve a critical role in maintaining indoor air quality and ensuring safety in cooking environments, particularly in commercial kitchens. They are designed to capture and remove pollutants generated during the cooking process, such as heat, smoke, steam, grease, and odors, which can pose serious health risks and affect the comfort of the cooking space . [1] The primary objective of kitchen hoods is to improve the air quality within a kitchen by efficiently capturing these contaminants before they disperse into the rest of the space. Without proper ventilation, the accumulation of these pollutants can lead to poor air quality, which in turn can impact the health of kitchen staff and potentially damage kitchen equipment [2]

One of the most important functions of a kitchen hood is to enhance indoor air quality by removing harmful substances like carbon monoxide (CO), nitrogen dioxide (NO_2), and volatile organic compounds (VOCs) that are produced during cooking. These gases can be hazardous if inhaled in large amounts over extended periods. Kitchen hoods, especially those with advanced filtration systems, effectively reduce exposure to these harmful compounds, ensuring that kitchen staff are not exposed to dangerous levels of airborne pollutants. [1] Effective exhaust systems also help in removing moisture and odors, which can linger in the kitchen and dining areas, ensuring a more comfortable and pleasant environment for both staff and customers [3]

Kitchen hoods are also crucial in minimizing the risk of fires in cooking environments. Cooking appliances such as deep fryers, grills, and stoves produce grease-laden vapors that, if not properly vented, can accumulate in the ductwork and on surfaces, creating a significant fire hazard. Modern kitchen hoods are equipped with grease filters and fire suppression systems to mitigate this risk. Baffle filters are commonly used to capture grease particles, and in more advanced systems, electrostatic precipitators or even UV-C lighting are incorporated to further reduce the buildup of grease [4]These measures help ensure that cooking processes can occur safely while preventing the spread of dangerous grease fires, which are among the most common causes of commercial kitchen fires.

Thermal comfort is another important consideration in kitchen ventilation systems. The high heat generated during cooking can make kitchens uncomfortable and potentially hazardous for workers. Kitchen hoods capture the heat produced by cooking appliances and remove it from the environment, maintaining a more comfortable working temperature. By regulating the temperature, hoods help reduce heat stress on kitchen staff, which is particularly important in commercial kitchens that operate for long hours. This also helps in preventing the degradation of kitchen equipment due to excessive heat exposure [2]

While the primary goal of kitchen hoods is to improve air quality and safety, they must also operate efficiently to minimize energy consumption. Over-extraction of air can lead to increased energy costs, as it requires more power to operate the exhaust fans and air conditioning systems. Modern hoods are designed to balance adequate ventilation with energy efficiency, using features like variable-speed fans and optimized duct designs to minimize energy waste. Additionally, kitchen hoods must comply with various regulations and standards set by authorities like the National Fire Protection Association (NFPA 96) and ASHRAE**,** ensuring that the systems meet the necessary performance, safety, and fire prevention criteria [4]. Compliance with these standards not only ensures safety but also helps avoid potential legal liabilities for restaurant owners and kitchen managers.

These standards specify the necessary requirements for kitchen ventilation systems, including air exchange rates, filter types, and exhaust duct configurations. These regulations ensure that kitchens are adequately ventilated and that cooking byproducts are safely removed from the environment, protecting both employees and customers [1]

2.1 Types of Kitchen Hoods

2.1.1 Classification by Filtering Feature

Many types, categories, and styles of hoods are available, and selection depends on many factors. Hoods are classified by whether they are designed to handle grease; Type I hoods are designed for removing grease and smoke, and Type II hoods are not. Model codes distinguish between grease-handling and non-grease-handling hoods, but not all model codes use Type I/Type II terminology. A Type I hood may be used where a Type II hood is required, but the reverse is not allowed. However, characteristics of the equipment and processes under the hood, and not necessarily the hood type, determine the requirements for the entire exhaust system, including the hood.

A **Type I hood** is used for collecting and removing grease particulate, condensable vapor, and smoke. It includes grease filters, baffles, or extractors for removing the grease and fire-suppression system. Type I hoods are required over cooking equipment that produce smoke or grease-laden vapors (e.g., ranges, fryers, griddles, gas underfired and electric broilers, ovens).

A **Type II hood** collects and removes steam and heat where grease or smoke is not present. It may or may not have grease filters or baffles and typically does not have a fire-suppression system. It is usually used over dishwashers. A Type II hood is sometimes used over ovens, steamers, or kettles if they do not produce smoke or grease-laden vapor and as authorized by the AHJ (Authority Having Jurisdiction). [1]

While a Type I hood may be used where a Type II hood is required, the reverse is not allowed due to fire safety concerns. The specific requirements for an exhaust system depend on the equipment and processes under the hood rather than just the hood type itself. Ensuring proper ventilation and compliance with safety codes is essential for maintaining a safe and efficient kitchen environment [3]

2.1.2 Classification by Functioning

Kitchen hoods come in two main types by their function: ducted and recirculating. These two types determine how the kitchen ventilation system works.

Ducted hoods are designed to expel contaminated air directly outside. These hoods draw air from the kitchen, filter it, and then push it out of the building through ventilation ducts, which are usually routed through the roof or exterior walls. The major advantage of this system is that it efficiently removes smoke, grease, and odors from the kitchen, improving indoor air quality. However, ducted systems tend to be more expensive to install and require more space for the ducts.

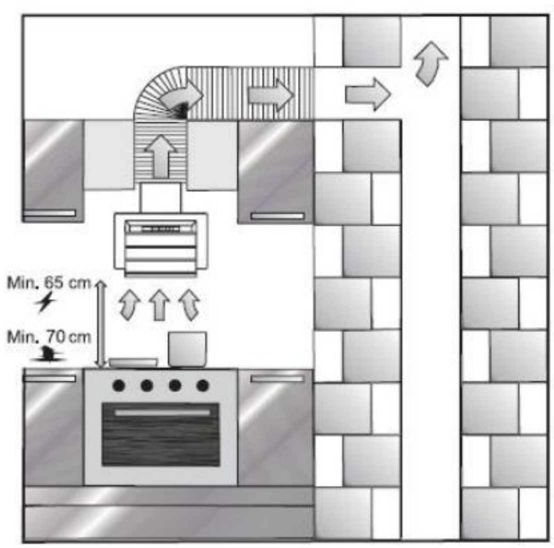

Figure 2.1: Ducted [5]

Recirculating hoods, on the other hand, do not expel air outside. Instead, they filter the air through various filters (such as activated carbon filters) and then recirculate the cleaned air back into the kitchen. This type of hood can be more cost-effective to install since it doesn't require ductwork or any external venting. However, because the air is continuously circulated within the kitchen, this system may not be as effective as ducted hoods in removing smoke, grease, and odors. Also, the filters need to be regularly cleaned or replaced to maintain their performance.

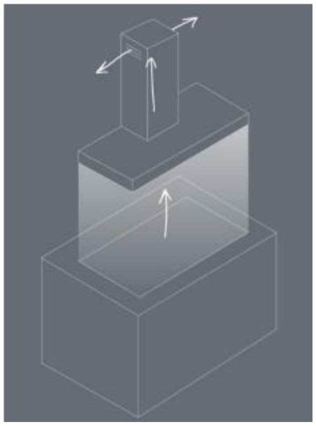

Figure 2.2: Recirculating [5]

Both systems have specific advantages and disadvantages. Ducted systems are generally more efficient but come with higher installation costs and more space requirements. Recirculating systems may be more affordable and practical to install but may not offer the same level of air quality improvement as ducted systems

2.1.3 Classification by Design Style

There are six basic styles for hood applications. These style names are not used in all standards and codes but are well accepted in industry. The styles are as follows:

2.1.3.1 Wall-Mounted Canopy

It is used in cooking units based on the wall. The fact that one surface of the hood is based on the wall increases the exhaust capacity due to the shield effect caused by the wall. The flow rate of the exhausted air can be increased by 3-5% in hoods with one closed side.

Filters are usually located on the wall side in wall-mounted hoods. The width measurements in wall-mounted hoods are usually around 1500mm at most. It is recommended to use island-type hoods in larger devices. The maximum length in wall-mounted hoods should not exceed 10000mm. If it exceeds this, it is recommended to use two hoods side by side.

The exhaust outlets of wall-mounted hoods can be circular or square; circular outlets are preferred for hygiene reasons, because oil accumulation is greater in square outlets and the risk of fire increases. There should be more than one exhaust outlet in long hoods and the suction of each outlet should be provided equally. In addition, there should be an adjustment damper in each outlet and more than one oil collection area is beneficial in terms of safety and hygiene. It is important to have quality grease filters in hot process hoods; otherwise, chimney ignition and hygiene problems may occur. Grease channels must be leak-proof and of sufficient size to prevent overflow. Wall-type hoods can be mounted on the wall, ceiling or feet, depending on the carrying capacity of the wall. [6]

Figure 2.3: Wall Mounted Canopy [7]

2.1.3.2 Back Shelf

Due to the close proximity of back shelf hoods to the cooking surface, when these hoods are properly placed over appropriate appliances, significant energy savings can be achieved in exhaust airflow, exhaust fan motor energy consumption, and makeup air energy. In addition to lower airflow, back shelf hoods offer better air health and comfort benefits by exhausting cooking gases away from and below the operator's breathing zone. Proximity to the appliance also allows for more efficient use of ceiling space, which can be utilized for placing ceiling lights to properly illuminate kitchen and appliance workstations, as well as providing open ceiling areas for HVAC diffuser placement.

Back shelf hoods operate most efficiently for appliances with flat horizontal cooking surfaces but are not suitable for vertical appliances such as ovens. Matching appliance and hood ratings is critical to ensuring proper airflow. Gas lines and electrical connections can affect appliance placement. The use of these hoods requires operational analysis and coordination; proper exhaust duct arrangements must comply with fire safety and health regulations. They should not be placed over appliances that cannot be adequately protected by an approved fire suppression system.

Figure 2.4: Back Shelf [7]

2.1.3.3 Pass-Over

A pass-over type hood is a type of exhaust system commonly used in commercial kitchens. It is designed to capture and remove heat, smoke, grease, and cooking vapors produced by cooking equipment. Unlike other hoods that have an exhaust fan and are intended to pull air out of the cooking area, a pass-over hood operates by allowing air to "pass over" the cooking equipment, drawing heat and contaminants upward. These types of hoods typically do not have an exhaust fan or duct system for venting, instead, they rely on natural airflow to remove the air. They are particularly useful in certain types of cooking environments where direct exhaust is not possible, or where minimizing the impact on the surrounding space is a priority.

Pass-over hoods are generally more effective when used in areas with lower cooking demands or in combination with other ventilation systems, such as in ovens or grills where excess heat and odors need to be mitigated but without strong suction.

Figure 2.5: Pass over type [7]

2.1.3.4 Single-Island Canopy

In systems with single suction, the width of the range hood should not exceed 2500 mm. Single suction island-type range hoods are generally used for light and medium-duty tasks. For heavy and extra-heavy tasks, double suction island-type range hoods are recommended. The maximum length of island-type range hoods is 10,000 mm. For devices longer than this, it is recommended to use multiple island-type devices or kitchen ceilings. [8]

Island-type range hoods, especially single-island style, have become popular in open kitchen operations such as university food services. A single-island range hood requires significantly more exhaust than a wall-mounted range hood. Single-island range hoods present the most challenging capture and containment difficulties in range hood applications.

For example, while an exhaust speed of 460 to 620 (L/s)/m may be sufficient for full capture and containment with a wall-mounted range hood on a heavy-duty appliance line, a single-island range hood may require an exhaust speed of over 770 (L/s)/m in many cases. In fact, in some test scenarios, exhaust speeds of over 1080 (L/s)/m were required for single-island range hoods. [1]

Figure 2.6: Single Island Canopy [7]

2.1.3.5 Double Island Canopy

The performance of double-island hoods with balanced replacement airflow can be similar to back-to-back wall-mounted hoods for a given appliance duty class. For example, a double-island hood with a heavy-duty front line and a light-duty rear line measured an exhaust airflow rate of approximately 470 L/(s·m) (on each side of the hood). This rate is comparable to the ventilation rate for similar appliance duty classes under wall-mounted hoods. The double-island hood configuration performed as if there were a wall between them. Additionally, the back-to-back appliances created a converging heat plume that helped direct the air toward the filter bank. However, without a wall, the double-island hood system was more susceptible to cross drafts than the wall-mounted hood configuration.

The configuration, volume, and temperature of the replacement air are critical to the performance of the double-island hood. Consistent with previous research [9] reducing local replacement airflow rates and velocities has been shown to reduce capture and containment exhaust rates in most cases. When the air volume, velocity, and turbulence under the hood are minimized, the exhaust gases from the device are more stable and the hood can capture and contain at a lower exhaust rate. [1]

Figure 2.7: Double Island Canopy [7]

2.1.3.6 Eyebrow

Eyebrow type hoods are a type of hood used in ovens and similar applications. Eyebrow type hoods are mounted right above the device. The exhaust air flow rate of eyebrow type hoods is like backshelf type hoods.

Eyebrow type hoods require lower exhaust flow rates compared to other hoods due to their lower cross-sectional areas.

Figure 2.8: Eyebrow type hood [7]

2.2 Materials of Kitchen Hood Construction

Kitchen hoods are integral components of modern kitchen ventilation systems, designed to improve air quality by removing heat, smoke, grease, and odors generated during cooking. Their performance is directly influenced by the materials used in their construction, the structural design, and the manufacturing processes employed. This section outlines the key aspects of the materials, structure, and manufacturing methods of kitchen hoods, drawing on recent studies and standards in the field.

The materials selected for kitchen hoods are critical for both performance and safety. These materials must withstand the heat, humidity, and chemical exposure typical in a kitchen environment while maintaining durability and efficiency.

Stainless Steel is the most common material used in kitchen hood construction is stainless steel due to its corrosion resistance, durability, and ease of cleaning. Stainless steel hoods are preferred for their ability to resist grease buildup and their aesthetic appeal in modern kitchens. Stainless steel is the material of choice for most commercial kitchen hoods due to its robustness and ability to handle high-temperature cooking environments. Stainless steel is widely preferred in kitchen environments where hygiene is critical because it is easy to clean and durable. AISI 304 is the most commonly used type of stainless steel in kitchen equipment, particularly in hoods, because it is both durable and resistant to corrosion.

AISI 316, on the other hand, is suitable for use in extreme heat and corrosive conditions. It is especially preferred in kitchens where seafood is cooked or in environments with high levels of acidity. Although this material is somewhat more expensive, it provides a significant long-term durability advantage [6]

Aluminum and Zinc-Coated Steel is mostly for less demanding applications, some kitchen hoods may be made from aluminum or zinc-coated steel. These materials offer lighter weight and cost advantages but may not provide the same longevity or heat resistance as stainless steel. These materials are often used in residential, non-commercial applications where less exposure to heavy-duty cooking environments is expected. [2]Aluminum, while an economical option, is less durable than stainless steel and may not meet hygiene requirements adequately. Galvanized sheet metal is another material that can be used in environments where hygiene is less of a concern, such as industrial kitchens or low-cost applications. [6]

Carbon Steel and Galvanized Steel are used in some cases, kitchen hoods are manufactured from carbon steel coated with a protective layer of zinc (galvanized steel). These are typically found in mid-range models and are suitable for both residential and light commercial use . [1]Thus, the choice of material for kitchen hoods generally depends on usage conditions, hygiene requirements, and budget. Stainless steel stands out as the most common and correct choice in terms of hygiene and durability. [6]

2.3 Manufacturing Methods of Kitchen Hoods

The manufacturing process of kitchen hoods is critical to achieving high-performance standards and ensuring safety compliance.

With the developing technology and competitive conditions, kitchen hoods produced today must not only have visual appeal but also functional features that win users' approval. According to this, the joints of the hoods should be concealed and invisible. When viewed from the outside, hoods should be aesthetic and stylish. They should be easy to access and clean for maintenance. The attachment points should be minimal and hidden. They should have channels for collecting condensation liquids, and these liquids should be able to be drained. The exhaust outlets should be of sufficient size and capacity. The installation of the hoods should be solid and stable, without allowing any wobbling or flexing. In this way, the vibration effects in the system can be minimized, improving comfort and ensuring the system operates for a longer time without damage. [8, 6]

Various methods are used, depending on the material, design, and intended use of the hood. The most common method for producing kitchen hoods is sheet metal fabrication, where sheets of stainless steel, aluminum, or galvanized steel are cut, bent, and welded into shape. The fabrication process involves precise cutting to achieve the desired dimensions and a smooth, seamless structure that can support the weight of the filters and motor assembly.

For mass production, manufacturers may use forming and stamping techniques to produce standardized parts. This is particularly common for components like filters, fan housings, and the outer shell of the hood. Stamping allows for high-volume production at a lower cost, which is beneficial for residential and non-commercial kitchen hoods.

Once the individual parts are formed, the pieces are welded or mechanically fastened together. Welding is commonly used for joining stainless steel components, ensuring the hood's integrity and strength. The final assembly includes mounting the fan and motor, installing the filters, and ensuring all electrical and mechanical systems are securely connected.

After assembly, the hood undergoes a **surface finishing** process, which may involve polishing, brushing, or coating the surface. Stainless steel hoods are often brushed to create a matte finish that resists fingerprints and enhances their appearance. Some hoods may also be treated with a protective coating to prevent corrosion and reduce the buildup of grease [2]

2.4 Structural Design of Kitchen Hoods

The structure of a kitchen hood is designed to ensure optimal airflow while maintaining stability and safety. The key components of this structural design include the hood shape and overhang, filter placement and configuration, and the fan and motor mounting.

2.4.1 Shape and Size

The shape and size of the hood plays an important role in capturing rising cooking fumes. Hoods are usually designed with a protrusion that extends beyond the cooking surface to effectively capture smoke and grease. The depth and width of the hood are calculated according to the size and heat output of the cooking appliance. The depth of the hood should be at least 400 mm and at most 600 mm. A 400 mm deep hood is suitable for normal use in grills, stoves, fryers, etc. In applications where there is intense and rapid particle emission, such as over steam cookers, a 600 mm deep hood is recommended. A hood with the dimensions and features within the standards should be installed between 1900 mm and 2100 mm in height.

The hood should extend at least 300 mm beyond the cooking surface on all sides to ensure maximum efficiency.

The size of the exhaust hood relative to the cooking appliances is important in determining hood performance. Generally, the hood must extend horizontally beyond the cooking appliances to capture the expanding thermal currents rising from the appliances. The overhang varies with the hood style, the distance between the hood and the cooking surface, and the characteristics of the cooking equipment (setback). These hoods may require a higher front inlet velocity to capture and contain the expanding thermal currents. All styles can have full or partial side panels to enclose the area between the appliances and the hood. This can eliminate the need for side overhangs and often reduces the exhaust flow rate requirement. [1]

2.4.2 Filters

The primary function of the filters used in kitchen hoods is to prevent grease, liquids, and various particles from entering the ducts. By trapping particles, these filters also help in capturing odors. Additionally, certain types of filters are designed to prevent flames and fire from reaching the exhaust ducts. The placement of these filters is also crucial, as they must effectively trap grease and particulates from the cooking air. Typically, filters are arranged in a baffle, mesh, or cartridge configuration, allowing for easy removal and cleaning. The structure should ensure that the filters are securely fixed yet easily accessible for maintenance, ensuring both efficiency and ease of upkeep [2]

Most grease removal devices in Type I hoods operate on the same general principle: exhaust air passes through a series of baffles that create a centrifugal force to throw grease particles out of the airstream as the exhaust air passes around the baffles. The amount of grease removed varies with baffle design, air velocity, temperature, type of cooking, and other factors.

2.4.2.1 Mesh Filters

This is the simplest filter used in kitchen hoods. Its purpose is to prevent any large particles from escaping into the exhaust duct. It has some ability to retain moisture and grease. It is typically made from expanded metal or a wire mesh with 3 to 5 mm spacing. Stainless steel or aluminum is used as the material. To increase moisture retention capability, they are used in one or two layers. The pressure drop is low, and their moisture retention efficiency is between 25% and 35%. The collected grease has a high potential to break off and escape. Therefore, it is recommended to be used as a pre-filter or protective filter. This is why NFPA Standard 96 does not allow the use of mesh-filters as primary grease removal filters on Type 1 hoods. As pollution increases, pressure drops also rise. If used directly in the hood and exposed to flames, it can be flammable. The air velocity in these filters should be 2 to 5 m/s. It is a low-cost filter [10]

2.4.2.2 Baffle Filters

In kitchen hoods, filter cabinets, industrial applications, and kitchen ceilings, baffle filters are the most commonly used type of filter. Manufacturers have their own specific baffle filter designs. Depending on their structure, baffle filters have varying pressure drops and particle retention capabilities. The pressure drops are typically low to medium. They are usually made of steel, stainless steel or aluminum. Baffle filters are an economical filter type, and their prices vary depending on their design. Their moisture retention capability ranges from 25% to 75% efficiency. The air velocities in baffle filters should be between 2.5 m/s and 5.5 m/s. There is no risk of the collected grease breaking off and escaping. They also have the ability to prevent flames and sparks from passing through. Pollution does not significantly change the pressure drops. Filters are cleaned by running them through a dishwasher or by soaking and rinsing. Each hood typically has two or more baffle filters, which are generally constructed of aluminum, steel, or stainless steel, and come in various standard sizes.

2.4.2.3 Cartridge Filters

Removable extractors (also called cartridge filters) have a single horizontal-slot air inlet. The filters are arranged in a channel or bracket for easy insertion and removal for cleaning. Each hood usually has two or more removable extractors, which are typically constructed of stainless steel and contain a series of horizontal baffles designed to remove grease and drain it into a container. Available in various sizes, they are cleaned by running them through a dishwasher or by soaking and rinsing. Removable extractors may be classified by a nationally recognized test laboratory in accordance with UL Standard 1046.

Cartridge filters are used in kitchens with high levels of grease and steam. They are typically made from expanded metal or similar materials. Manufacturers have their own unique filter designs. Cartridge filters are made from stainless steel, aluminum, or a combination of both materials. Cartridge filters can be used alone or as a secondary filtration stage after baffle filters. They have high pressure drops. Their particle retention capabilities range from 70% to 95% efficiency. The airflow through the filters should be between 3.5 m/s and 5.5 m/s. Cartridge filters are not recommended for use in areas exposed to flames due to their flammability. They are more expensive compared to other filters. [10]

2.4.2.4 Multistage Filters

Multistage filter use two or more stages of filtration to remove a larger percentage of grease. They typically consist of a baffle filter or removable extractor followed by a higher-efficiency filter, such as a packed bead bed. Each hood usually has two or more multistage filters, which are typically constructed of aluminum or stainless steel and are available in standard sizes. Filters are cleaned by running them through a dishwasher or by soaking and rinsing.

The grease particle capture efficiency of both removable filters and fixed extractors, such as those used in water wash hoods, is determined. The filters are evaluated based on pressure drop and particle capture efficiency. A controlled amount of oleic acid particles, ranging in size from 0.3 to 10 μm, is released into a hood to represent cooking waste. The particles are then sampled and counted downstream in the duct with an optical particle counter, with and without the filter or extractor in place. The difference in counts is used to calculate the particle capture efficiency, which is plotted against particle size.

2.4.2.5 Stationary Extractors

Stationary extractors are integral to the listed water-wash exhaust hoods and are typically constructed of stainless steel and contain a series of horizontal baffles that run the full length of the hood. The baffles are not removable for cleaning, though some have doors that can be removed to clean the extractors and plenum.

2.4.2.6 Water Wash Filters

It is developed for washing filters in high-use kitchens without removing them. These filters are typically louvered filters. There are two methods for washing automatic wash filters: manual automatic wash filters and programmed automatic wash filters. The washing of these filters is done by spraying detergent and rinse water onto the filters. Therefore, in hoods where wash-type filters are used, the drainage pipe is thicker and must be connected to the wastewater drain.

2.4.2.7 Ultra-Violet Filters

This is a system that has developed in recent years. It is preferred in situations where cleaning the ducts is important. Since it does not have a flame-retardant feature, a louvered filter is used in front of them. They have the ability to clean 99% of grease particles. They are used after louvered filters, mesh filters, and cartridge filters inside hoods. They operate with electrical energy and have very low maintenance requirements [10]

2.4.3 Exhaust Fans

Fans are machines that pressurize the air and ensure its evacuation within a specific geometry. The expected characteristics of a good fan during its performance are listed below:

- Low energy consumption
- Operation as quietly as possible
- Low cost
- Compact size

Fans are generally powered by electric motors. Fans of various types have a wide range of applications in industries, residential areas, commercial buildings, tunnels, parking garages, and more. With their broad usage, fans consume a significant amount of electricity. Therefore, improving the efficiency of fans in terms of energy efficiency has become increasingly important today. Along with this efficiency, it is also expected that the noise levels are minimized.

The type of fan — centrifugal(radial) or axial — and the motor placement depend on the type of exhaust system, whether ducted or recirculating. Centrifugal fans, known for their ability to handle higher static pressure, are commonly used in ducted systems [1]Radial-type fans are used in hoods and exhaust fans. Motors with high suction power and high energy efficiency are preferred. Additionally, the fan and motor assembly within the hood is often located either within the canopy or in a separate unit above the kitchen area.

2.4.3.1 Centrifugal (Radial) Fans

A radial fan is a system that absorbs air axially and expels it outside with a radial motion. When the rotating impeller turns, the air between the blades is pushed toward the scroll walls. The airflow created from the center to the walls results in low air pressure at the center and high air pressure at the walls. The compressed air is sent to the working area with high pressure.

There are two main components that make up radial fans. The first is the rotating area called the impeller or wheel. The other component is the casing, known as the scroll, which directs the air compressed by the impeller. The impeller is driven by a shaft in the electric motor, causing it to rotate. The electric motor is mounted in the scroll using the mounting sockets on the motor cover. For this reason, the scroll is positioned in a way that the motor is inside it.

The advantages of radial fans are listed below:

- They have a wide application area.
- They are resistant to high temperatures and corrosion, depending on the material selected.
- They are easier to service compared to axial fans.
- They are quieter and more efficient in applications with variable flow resistance.
- They can operate under high flow rates and pressures.

Radial fans are designed according to the needs and it is possible to come across more than one type in industrial applications. It is possible to examine radial fans in 4 basic areas. These are;

straight-bladed radial fans, forward-curved-bladed radial fans, backward-curved-bladed radial fans.

2.4.3.1.1 Straight-Bladed Radial Fans

Radial fans with flat blades have blades that are close to each other and long in length. The blade structure is simple, and they are not suitable for use at high speeds. Their efficiency is lower compared to other radial fans. The main advantage of these fans is that they are easy to manufacture. They are well-suited for dusty and dirty environments, and their price is more affordable compared to other fan types. These fans are typically used in industrial facilities for material handling or in high-pressure air conditioning systems. In flat-bladed radial fans, the blade structure is designed with a blade exit angle of 90°. These fans are preferred in applications that require high pressure and low airflow. They can also be used when there are materials like sand or sawdust in the air, which is an advantage, but they are the least efficient type of radial fan. In cases where back pressure and flow are high, the load on the motor continuously increases, which can lead to motor burnout.

2.4.3.1.2 Forward-Curved-Bladed Radial Fans

Radial fans with forward-curved blades have their blade tips oriented in the same direction as the rotation. This results in the exit velocity of the air from the blades being greater than the blade's peripheral speed. As a result, forward-curved blade radial fans achieve a higher flow rate when the same rotor diameter is used, compared to other types. However, due to the higher flow rate, their static pressures are lower than other types.

These fans are the most commonly used type in motor blocks within range hoods. Depending on the size of the block, the number and angle of the blades may vary. In forward-curved blade radial fans, the blades are designed to be tilted in the same direction as the rotation of the impeller. In these fans, the air exit speed from the blades is greater than the impeller's peripheral speed. As a result, the impeller provides a higher airflow at lower rotational speeds compared to other blade types. They are preferred in applications that require low pressure and high airflow.

2.4.3.1.3 Backward-Curved-Bladed Radial Fans

In backward-curved bladed radial fans, the fan blades are tilted in the opposite direction of the rotation. This results in the air velocity at the blade exit being lower than the peripheral speed of the blades. The reverse direction of the airflow relative to the blade's peripheral speed leads to a lower flow rate compared to forward-curved radial fans. These fans have high static pressure when operating at low flow rates. In these fans, the blades are designed to be tilted opposite to the rotation direction. As a result, the exit air velocity is lower than the peripheral speed of the wheel. This causes high static pressure but a lower flow rate.

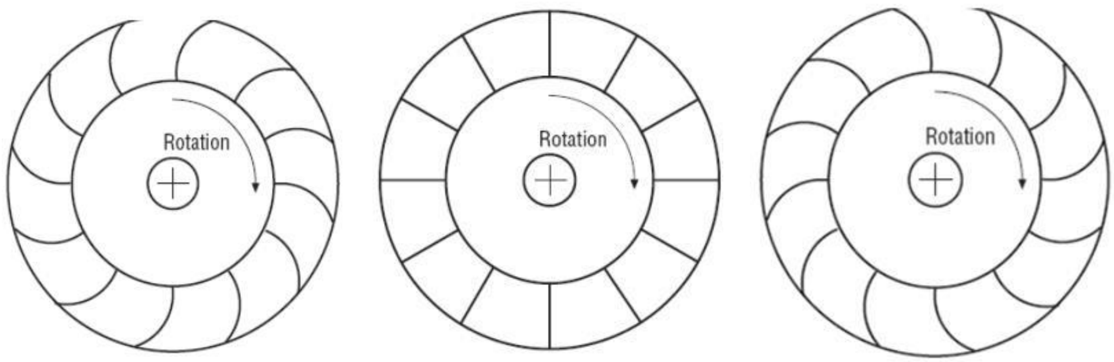

Figure 2.9: Forward-Curved, Straight, Backward-Curved Bladed Radial Fans [11]

2.4.4 Motors

Electric motors are devices that convert electrical energy into mechanical energy through the interaction of magnetic fields inside them. Electric motors consist of two main parts: one is fixed (stator) and the other rotates around its axis (rotor). These main parts are further divided into various components, such as parts that conduct magnetic flux (steel components), parts that conduct electrical current (windings, brushes), and parts that support the internal structure (bearings, screws).

The use of electric motors has become widespread today. These motors are used in various fields, including household appliances, air conditioning, electrical household devices, robotic automation, automotive, factory automation, heavy industry, and even children's toys.

Fans are typically powered by electric motors. Fans of various types have a wide range of applications in industries, residential buildings, commercial buildings, tunnels, parking lots, and more. Given their extensive use, fans consume a significant amount of electricity. Therefore, improving the efficiency of fans in terms of energy consumption is crucial today. Along with this efficiency, it is also expected that the noise level be minimized.

2.4.4.1 Alternating Current (AC) Electric Motors

Alternating current electric motors convert electrical energy received from the stator windings into rotational movement in the rotor section. An electric machine that converts this rotational movement into mechanical energy is called an alternating current electric motor.

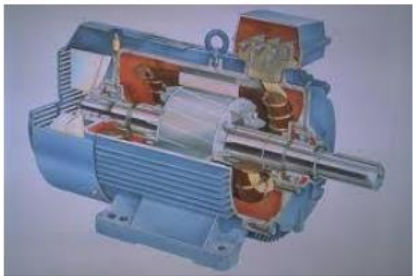

Figure 2.10: AC Motor [5]

AC motors are widely used, especially in range hoods and applications where air circulation systems are present.AC motors are also referred to as asynchronous motors.

AC motors do not require continuous maintenance, their speed does not change under load, and their speed can be easily adjusted using speed control circuits. Additionally, they are preferred due to their lower cost.

2.4.4.1.1 Single-Phase Asynchronous Motor

Single-phase asynchronous motors are typically used in places where three-phase power sources are not available. Since they are generally manufactured with power ratings below 2 kW, they are widely used in households and small businesses.

In single-phase asynchronous motors with a single winding, a rotating magnetic field does not occur. Therefore, an auxiliary winding is required. These windings are placed in slots at a 90° angle and connected in parallel with the main winding. The number of rotor slots is usually designed to be fewer than the stator slots to facilitate the motor's initial startup [12]

When single-phase voltage is applied to these parallel-connected windings, the resulting magnetic field is in the same phase as the applied voltage. However, an artificial phase shift occurs between the main and auxiliary windings. By creating two phases from a single phase, a rotating magnetic field is generated.

During startup, the auxiliary winding supports the magnetic field of the main winding. As the single-phase AC electric motor approaches its normal operating speed, the auxiliary winding creates a reverse effect on the main winding and rotor. To ensure normal operation, the auxiliary winding is disconnected from the circuit. If the auxiliary winding remains in the circuit, it will draw excessive current due to its thin cross-section, leading to overheating and burning.

Single-phase asynchronous motors come in different types to cater to various applications. Some common types include:

- Split-Phase Motors: These motors have a start winding and a run winding. They are used in appliances like fans, blowers, and small pumps.

Shade-pole motors are considered as subtype of split phase motors and provide low starting torque by using a shading coil instead of a start winding. These motors operate with a small shading coil placed on the stator poles, which creates a phase shift and generates a rotating magnetic field. With low starting torque, they are commonly used in devices that carry light loads, such as fans, cooling systems, and household appliances. While they offer advantages due to their simple design and low cost, they are inefficient for applications requiring high torque. Shaded pole motors are low maintenance, long-lasting, and can operate efficiently. On the other hand, they tend to overheat.

- Capacitor-Start Motors: These single-phase motors have a start winding and a capacitor to provide high starting torque. Capacitor motors are quiet and have good energy efficiency. They are more efficient than shade-pole motors, and overheating is less common in these motors. As the motor power increases, the value of the capacitor used also increases. They are suitable for applications that require a higher starting torque, such as air compressors and refrigeration equipment.
- Capacitor-Start Capacitor-Run Motors: Single-phase electric motors have two capacitors, a start capacitor, and a run capacitor. They offer improved starting performance and are commonly used in larger appliances, such as air conditioners and washing machines.

- Permanent Split-Capacitor Motors: These motors have a capacitor connected to the auxiliary winding, providing high starting torque and efficient operation. They are commonly used in fans, pumps, and small appliances.

Each type of Single-Phase Induction Motor has its own characteristics and is selected according to the specific requirements of the application such as starting torque, efficiency and size constraints. These motors are generally manufactured for small power ratings. When higher power is required, their sizes increase and costs increase. Their biggest advantage is that they can operate on a single-phase network. They are most commonly used in electrical appliances and machine tools. The most common types used in hoods are shade pole and capacitor start motors [12]

2.4.4.2 DC Motors

DC motors are electrical machines that convert electrical energy into mechanical energy. These machines can operate as either a DC generator or motor. They are preferred in situations where direct current is used, especially when the use of alternating current may pose a danger. DC motors contain copper windings, and when electric current passes through these windings, it creates a magnetic force in the opposite direction to the fixed magnets inside. DC motors can be produced in two types: permanent magnet and electromagnet versions There are no structural differences between permanent magnet and electromagnet versions, except for the inductor. DC motors consist of stationary and rotating parts. The stationary part is the stator, and the rotating part is the rotor. Brushless DC motors are commonly used in applications like exhaust fans [13]

2.4.4.2.1 Brushless DC Motor (BLDC)

Devices that convert electrical energy into mechanical energy are called BLDC motors. These motors are highly efficient and have excellent control capabilities. Brushless motors are a type of electric motor that operates with a direct current source and replace traditional brushes with electronic components.

BLDC motors are commonly used in the automotive industry, aerospace, robotics applications, and household appliances. Due to their high efficiency, they contribute to reduced power consumption. BLDC motors require less maintenance, making them more durable compared to brushed motors. They produce more output power and have lower rotor inertia than their brushed counterparts [14]

With the help of drivers, the direction of rotation can be adjusted, and the desired speed can be achieved. Overheating issues are less common in BLDC motors. However, to enable these features, sensors are placed on the motor, which increases the overall cost.

Figure 2.11: Brushless DC Motor [13]

2.5 Factors Affecting Exhaust Airflow

The exhaust airflow rate (typically measured in cubic feet per minute, CFM) is a critical parameter in determining the effectiveness of a kitchen ventilation system. Multiple interdependent factors influence the performance of the range hood and the volume of air it is able to remove from the cooking area. Understanding these factors is vital for designing efficient ventilation systems, especially in commercial or high-load residential kitchens.

2.5.1 Hood Capture Area and Geometry

The size and shape of the range hood significantly influence how well it can capture rising cooking fumes. A larger hood surface area provides a greater capture zone, allowing more cooking effluents to be drawn into the exhaust system. The design—whether canopy, back-shelf, or proximity-style—also affects the airflow behavior and capture efficiency. [15] The overhang of the hood should ideally extend beyond the cooking appliance by at least 150 mm on all sides to effectively capture the plume.

To theoretically estimate the required exhaust airflow rate for a given setup, the following empirical expression may be used:

$$Q = v.(10x^2 + A) \tag{2.1}$$

Where;

Q is the exhaust airflow rate (m^3/s),

v is the capture velocity at the hood inlet (m/s),

x is the vertical distance between the pollutant source and the hood (m),

A is the hood inlet area (m^2). This equation allows for an approximate estimation of the ventilation demand based on geometric and operational parameters.

In engineering practice, the capture velocity (v) at the hood inlet is a critical parameter for determining the effectiveness of contaminant removal in ventilation systems. For simplified theoretical estimations of required exhaust airflow, a nominal capture velocity of 0.05 m/s is often assumed. This value represents a minimum threshold sufficient for lightly loaded or low-temperature environments where thermal buoyancy effects assist in carrying pollutants toward the hood. [15]

However, in practical applications and particularly in CFD analyses, significantly higher capture velocities are required to ensure effective entrainment of thermal plumes and airborne particles. For commercial or high-load kitchen environments, ASHRAE recommends capture velocities in the range of 0.25 to 0.5 m/s, while empirical studies and industry practices often adopt values between 1.0 and 1.5 m/s to reflect real operating conditions with moderate to high thermal loads [3]

Purpose / Scenario	Recommended Capture Velocity
Theoretical and minimum estimations	0.05 m/s
Low-temperature, natural convection cases	0.05 – 0.25 m/s
Commercial/heavy-duty kitchen environments	1.0 – 1.5 m/s

Table 2.1: Recommended capture velocity ranges for various application scenarios

2.5.2 Hood Mounting Height and Proximity to Cooktop

The vertical distance between the hood and the cooking surface plays a critical role. A closer proximity to the cooktop ensures better entrainment of fumes due to reduced plume dispersion before interception. Studies recommend an installation height between 600 mm and 750 mm for optimal performance [16].Mounting the hood too high results in significant plume dilution, making it difficult for the system to capture and exhaust contaminated air effectively.

2.5.3 Duct Design and Static Pressure Losses

The configuration, length, and diameter of the exhaust ductwork determine the system's resistance to airflow, commonly referred to as static pressure. Excessive bends or long duct runs increase frictional losses, thereby reducing effective exhaust rates [17]. Smooth, short ducts with minimal turns are preferable to maintain target airflow.

2.5.4 Filter Condition and Resistance

Grease filters can become clogged over time, increasing resistance across the hood and reducing the system's total airflow. Dirty or overloaded filters diminish capture efficiency and increase the workload on the fan, potentially leading to premature motor failure. Regular filter maintenance is essential to sustaining optimal exhaust rates [18]

2.5.5 Exhaust Fan Capacity and Pressure Matching

The performance of the exhaust fan must match the system's static pressure requirements. If the fan cannot overcome the total resistance in the system, the airflow rate will drop, and fumes may escape into the kitchen. High-efficiency fans capable of operating at moderate static pressures are commonly recommended for commercial applications [19]

3. METHOD AND MATERIAL

3.1 CFD Analysis

Computational Fluid Dynamics (CFD) is a branch of engineering that aims to solve fluid mechanics problems through numerical methods. Using this approach, complex processes such as gas or liquid flows, heat transfer, turbulence behavior, and pressure distributions within a physical system can be modeled in a virtual environment. CFD offers an effective and reliable alternative for engineering analysis, particularly in cases where experimental studies are costly, time-consuming, or potentially hazardous. With the recent advances in computational power and software capabilities, CFD has become an indispensable tool in engineering projects for both design optimization and performance evaluation.

CFD analysis typically consists of three main stages: pre-processing, solving, and post-processing. In the pre-processing stage, the geometry of the system under investigation is created and a suitable mesh structure is generated. During this step, physical properties, boundary conditions, and solver parameters are also defined. In the solving stage, the discretized governing equations are solved using numerical algorithms to obtain flow behavior. This process is generally carried out iteratively, where the solution progresses through multiple cycles until convergence criteria—typically defined in terms of residuals—are satisfied. Finally, in the post-processing stage, results are visualized to analyze physical outputs such as velocity distributions, pressure contours, and turbulence fields. [20]

One of the key advantages of CFD analysis is its ability to provide detailed information that may be difficult or impossible to obtain through physical testing. In internal flow analyses especially, CFD allows observation of flow characteristics in inaccessible regions, such as boundary layer development or vortex formation. Moreover, numerous design variations can be simulated to identify the most efficient configuration. Since CFD enables virtual verification prior to prototype production, it significantly shortens product development cycles and reduces overall costs [21]

In this study, ANSYS Fluent—a widely used commercial CFD solver—was employed. ANSYS Fluent operates based on the Finite Volume Method (FVM) and is capable of delivering high-resolution results even for complex geometries. It offers a wide range of turbulence models (e.g., k-ε, k-ω SST, and LES) for solving turbulent flows and provides extensive user control over the simulation process. Furthermore, with the integrated ANSYS Workbench platform, the entire workflow from geometry creation to solution and result analysis can be managed efficiently. This software has been successfully used in various engineering applications such as HVAC systems, automotive aerodynamics, indoor airflow distribution, and industrial processes.

Numerical CFD (Computational Fluid Dynamics) analyses performed in a virtual environment generally consist of five main steps. These steps are as follows:

- Creating the geometry to be analyzed, or modifying an existing geometry to make it suitable for CFD analysis,
- Generating surface and volume mesh structures for geometry,
- Defining the initial and boundary conditions specific to the CFD analysis model,
- Executing the CFD simulation (run),

- Visualizing the results of the completed CFD model, extracting the relevant data, and evaluating the outcomes. [22]

3.1.1 Geometry

In CFD analyses conducted to evaluate the airflow performance of a kitchen hood system, it is essential that the computational geometry be modeled as a clean, simplified, and watertight solid body that closely represents the physical setup. Ideally, the model should consist of a single solid part to ensure mesh continuity and reduce the risk of numerical errors during the solution process. The hood body, along with its surrounding environment (such as the stove, walls, and ceiling), should be included in the domain, and the flow volume should be generated around these structures. While preparing the geometry, flow-critical features such as suction inlets, outlets, and walls must be preserved in detail, whereas geometrically insignificant elements (e.g., screws, tiny chamfers, or fine surface gaps) should be excluded to avoid unnecessary mesh refinement.

Excessive geometric complexity due to small edges or surfaces can cause significant issues during the meshing process, especially in transition zones between fine and coarse elements. For this reason, the smallest edge lengths in geometry should be increased wherever possible, particularly in regions where airflow is not significantly affected. Failure to simplify such features may result in automatic mesh densification by the software, which unnecessarily increases computational cost and solution time. Therefore, generating a unified, simplified solid model—free of redundant fine details—is a critical step that directly influences mesh quality, convergence stability, and overall simulation accuracy.

3.1.2 Mesh

One of the most critical steps in a CFD (Computational Fluid Dynamics) analysis is the generation of surface and volume mesh structures applied to the created geometry. The numerical mesh enables the definition of the geometry and the extraction of data. The quality of the generated mesh and its suitability for the type of analysis directly affect the reliability and accuracy of the CFD results. Therefore, even minor modifications to the mesh structure can cause significant variations in the simulation output.

The quality of the numerical mesh is not solely determined by the total number of mesh elements. Instead, it is defined by metrics such as the number of elements in regions of interest, skewness, and orthogonality—especially in regions where critical flow behavior is expected, as well as in surrounding flow domains that influence those regions.

One of the primary parameters used to assess mesh quality is skewness, which can be evaluated in two ways: equilateral-volume-based skewness and normalized equiangular skewness. The equilateral-volume-based method depends on the deviation from ideal cell size and shape while the normalized equiangular skewness method is based on the angles within a surface or volume cell.(Equation 3.1) For wedge or pyramidal elements that contain both triangular and quadrilateral faces, both methods can be applied. Typically, equilateral-volume-based skewness is used for triangular faces, while normalized equiangular skewness is preferred for quadrilateral faces and 3D elements.(Equation 3.1a)

A skewness value approaching 0 indicates high mesh quality, whereas a value approaching 1 indicates poor quality. To ensure accuracy and reliability in CFD results, the average skewness of the numerical mesh should ideally be within the range of 0.0 to 0.25. Additionally, the maximum skewness value should remain below 0.80

$$Skewness = \frac{\text{Optimal Cell Size – Cell Size}}{\text{Optimal Cell Size}} \tag{3.1}$$

$$Skewness = \frac{\theta_{max}-\theta_e}{180-\theta_e}, \frac{\theta_e-\theta_{min}}{\theta_e} \tag{3.1a}$$

- θ_e : Ideal (equiangular) angle
- θ_{max} : Maximum angle in the element
- θ_{min} : Minimum angle in the element

Equilateral	**Excellent**	**Good**	**Acceptable**	**Poor**	**Unacceptable / Degenerated**
0.00	>0 – 0.25	0.25 – 0.50	0.50 – 0.75	0.75 – 0.90	0.90 – 1.00

Table 3.1: Skewness value ranges and corresponding mesh quality classifications

Another important parameter used to evaluate the quality of the numerical mesh is **orthogonality**. For a mesh cell, the orthogonality value depends on the angle between the normal vector of the cell face and the vector drawn from the centroid of the cell to the centroid of the face.

Similarly, for a mesh face, it depends on the angle between the normal vector of an edge and the vector drawn from the centroid of the face to the centroid of that edge. As the orthogonality value approaches 0, the quality of the mesh decreases, indicating poorly aligned elements. Conversely, as the orthogonality value approaches 1, the mesh quality improves, representing more ideally shaped and aligned elements.

$$Orthogonality = \frac{\vec{A_i} \times \vec{f_i}}{|\vec{A_i}| \times |\vec{f_i}|} \tag{3.2}$$

$$Orthogonality = \frac{\vec{A_i} \times \vec{c_i}}{|\vec{A_i}| \times |\vec{c_i}|} \tag{3.2a}$$

$$Orthogonality = \frac{\vec{A_i} \times \vec{e_i}}{|\vec{A_i}| \times |\vec{e_i}|} \tag{3.2b}$$

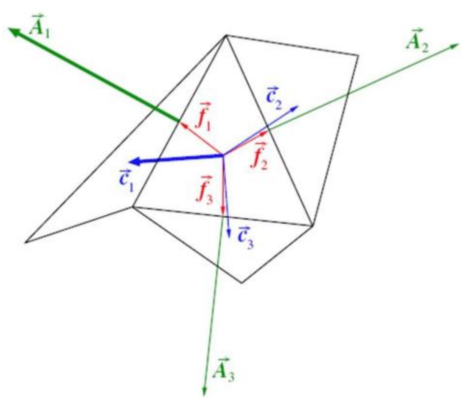

Figure 3.1: Vectors used in orthogonality calculation for mesh cells

3.1.3 Set Up

The CFD (Computational Fluid Dynamics) method is based on the conservation equations of fluid dynamics. From a general perspective, these equations are derived from the conservation of mass, the conservation of momentum according to Newton's Second Law, and the conservation of energy based on the First Law of Thermodynamics. During CFD analyses, iterations are performed to balance the conservation equations, meaning the residuals are driven toward zero or within a predefined convergence threshold. These iterations are carried out in accordance with the convergence criteria defined under the simulation conditions. Typically, a convergence criterion of $\mathbf{10^{-4}}$ is selected, and iterations continue until all conservation equations meet this threshold.

3.1.3.1 Conservation of Mass (Continuity)

The continuity equation is the mathematical expression of mass conservation in fluid dynamics. It states that the mass flux across the surface (S) of a control volume (V), at a given time and location in space, is equal to the rate of change of mass within that control volume [23](Equation 3.3).

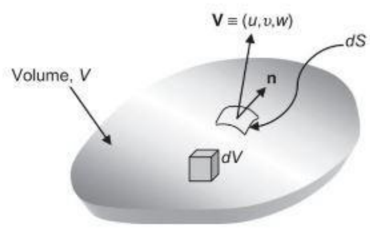

figure 3.2: A stationary finite control volume in space [23]

$$\frac{d}{dt}\int_V \rho dV = -\int_S \rho V.ndS \tag{3.3}$$

By applying the Gauss divergence theorem to Equation 2.6, the surface integral is converted into a volume integral, resulting in the continuity equation (Equation 3.4).

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho V) = 0 \tag{3.4}$$

The continuity equation expressed in Cartesian coordinates is given in Equation 3.5.

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0 \tag{3.5}$$

3.1.3.2 Conservation of Momentum

According to Newton’s second law of motion, the total force acting on a fluid is equal to the product of its mass and acceleration, as expressed in Equation 3.7

$$\sum F_x = ma_x \tag{3.6}$$

Acceleration in the x-direction is defined as the time derivative of the velocity component in that direction

$$a_x = \frac{Du}{Dt} \tag{3.7}$$

The mass of the fluid within a control volume is given by:

$$m = \rho \Delta x \Delta y \Delta z \tag{3.8}$$

Substituting this into Newton's second law yields the momentum expression in the x-direction:

$$\rho \frac{Du}{Dt} \Delta x \Delta y \Delta z \tag{3.9}$$

In Equation (4.5), the forces acting in the x-direction consist of surface forces (normal and shear stresses) and body forces (e.g., gravity, centrifugal, or electromagnetic forces). By combining Equations (3.6) and (3.9), the momentum conservation equation in the x-direction is obtained:

$$\rho \frac{Du}{Dt} = -\frac{\partial \rho}{\partial x} + \frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \sigma_{yx}}{\partial y} + \frac{\partial \sigma_{zx}}{\partial z} + \rho \sum F_x^{Body} \tag{3.10}$$

Similarly, the momentum equations for the y and z directions are written as follows:

$$\rho \frac{Dv}{Dt} = -\frac{\partial \rho}{\partial y} + \frac{\partial \sigma_{xy}}{\partial x} + \frac{\partial \sigma_{yy}}{\partial y} + \frac{\partial \sigma_{zy}}{\partial z} + \rho \sum F_y^{Body} \tag{3.11}$$

$$\rho \frac{Dw}{Dt} = -\frac{\partial \rho}{\partial z} + \frac{\partial \sigma_{xz}}{\partial x} + \frac{\partial \sigma_{yz}}{\partial y} + \frac{\partial \sigma_{zz}}{\partial z} + \rho \sum F_z^{Body} \tag{3.12}$$

To derive the Navier–Stokes equations, the continuity equation (Equation 3.5) is applied to (Equations 3.11–3.13), resulting in the following formulations:

$$\frac{\partial(\rho u)}{\partial t} + \nabla.\left(\rho u \vec{V}\right) = -\frac{\partial \rho}{\partial x} + \frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \sigma_{yx}}{\partial y} + \frac{\partial \sigma_{zx}}{\partial z} + \rho \sum F_x^{Body} \tag{3.13}$$

$$\frac{\partial(\rho v)}{\partial t} + \nabla.\left(\rho v \vec{V}\right) = -\frac{\partial \rho}{\partial y} + \frac{\partial \sigma_{xy}}{\partial x} + \frac{\partial \sigma_{yy}}{\partial y} + \frac{\partial \sigma_{zy}}{\partial z} + \rho \sum F_y^{Body} \tag{3.14}$$

$$\frac{\partial(\rho w)}{\partial t} + \nabla.\left(\rho w \vec{V}\right) = -\frac{\partial \rho}{\partial z} + \frac{\partial \sigma_{xz}}{\partial x} + \frac{\partial \sigma_{yz}}{\partial y} + \frac{\partial \sigma_{zz}}{\partial z} + \rho \sum F_z^{Body} \tag{3.15}$$

3.1.3.3 Conservation of Energy

The principle of energy conservation is based on the first law of thermodynamics. It states that the rate of change of energy within a control volume is equal to the net heat transfer rate into the control volume plus the network rate done on the fluid.(Equation 3.16)

$$Rate\ of\ Energy\ Change = \sum \dot{Q} + \sum \dot{W} \tag{3.16}$$

The net work performed on the fluid consists of pressure and stress forces (Equation 3.19), while the net heat transfer includes both volumetric heat generation and heat conduction across the boundaries

The total energy per unit mass of a moving fluid is the sum of its internal energy and kinetic energy

$$E = \rho\ \frac{D}{Dt}\left(e + \frac{\overrightarrow{v^2}}{2}\right) dxdydz \tag{3.17}$$

Substituting the heat and work expressions and total energy expression (Equation 3.17) into the general energy balance yields the conservation of energy equation:

$$\rho \frac{D}{Dt}\left(e + \frac{\overrightarrow{v^2}}{2}\right) = Heat\ terms + Work\ Terms + \rho F_{Body} \tag{3.18}$$

The differential form of energy equation is expressed as

$$\frac{\partial}{\partial t}\left(\rho\left(e + \frac{\overrightarrow{v^2}}{2}\right)\right) + \nabla.\left(\rho\left(e + \frac{\overrightarrow{v^2}}{2}\right) \underset{v}{\rightarrow}\right) = Heat\ terms + Work\ Terms + \rho F_{Body} \tag{3.19}$$

3.1.3.4 Turbulence Models

Turbulence is a complex flow regime characterized by irregular velocity fluctuations, mixing, and energy transfer in space and time. Since it does not follow deterministic rules, directly solving turbulent flows with the Navier–Stokes equations is computationally expensive. Therefore, in practical applications, turbulence models based on the Reynolds-Averaged Navier–Stokes (RANS) approach are commonly used. Among these, the standard k–ε and standard k–ω models are widely preferred in engineering simulations.

The k–ε model solves two separate transport equations for the turbulent kinetic energy and the dissipation rate ε. Supported by empirically derived constants, this model offers a good balance between accuracy and computational efficiency, particularly in high Reynolds number and fully developed internal flows. However, its performance decreases in flows with separation or strong pressure gradients.

The k–ω model, on the other hand, solves equations for k and the specific dissipation rate ω. It performs better in low Reynolds number flows and in boundary layers affected by wall proximity, making it suitable for aerodynamic applications. While it is more accurate near walls, it may be less robust in free-shear flows compared to the k–ε model. [24]

3.1.3.5 Solution Algorithms

In pressure-based computational fluid dynamics (CFD) solvers, various algorithms are used to handle the coupling between pressure and velocity fields. These algorithms help ensure that the continuity and momentum equations are solved in a consistent and stable manner. Among the available methods, SIMPLE and COUPLED are two of the most commonly used in both steady and unsteady flow simulations due to their balance of accuracy and efficiency.

The SIMPLE (Semi-Implicit Method for Pressure Linked Equations) algorithm is an iterative method that solves the momentum equations, estimates pressure corrections, and updates the velocity field to satisfy mass conservation. It is widely used in steady-state simulations with relatively simple flow behavior. Although the method may converge slowly in more complex or transient flows, its stability and ease of implementation make it a popular choice for industrial applications. The enhanced version, SIMPLEC, is often used when the SIMPLE algorithm encounters convergence issues.

The COUPLED algorithm differs by solving the continuity and momentum equations simultaneously as a single system. This fully coupled approach offers faster convergence, especially in transient simulations involving poor mesh quality or large time steps. Although more computationally demanding, the COUPLED method provides improved numerical stability and is particularly useful in simulations where pressure–velocity interaction plays a significant role. However, it may not be suitable for multiphase flows or periodic boundary conditions involving mass flow variations.

3.2 Hood Analysis

3.2.1 Solid Modeling

In this study, a solid model was created using SolidWorks to provide the geometric foundation for the analyses. Initially, a rectangular room with dimensions of 3 meters in length, 5 meters in height, and 4 meters in depth was designed. A stove and a hood were placed inside this volume. In order to evaluate the effects of various geometric parameters on the exhaust flow rate of the hood, three different scenarios were constructed, each with different hood sizes or mounting distances.

In the first scenario, the stove was sized as 1 meter by 1.5 meters, and a hood of the same dimensions was placed directly above it. The vertical distance between the hood and the stove was set to 1 meter.

In the second scenario, the hood and stove geometry remained the same, but the hood was lowered so that the distance between the stove and the hood was reduced to 0.7 meters. In both cases, the exhaust duct diameter was kept constant, with an outer diameter of 300 mm and an inner diameter of 298 mm.

In the third scenario, the size of the stove and mounting distance remained unchanged as second case, while the dimensions of the hood were increased to 1.5 meters by 2 meters. This allowed the investigation of cases where the hood was larger than the stove and how this configuration would affect exhaust performance. Upon completion in SolidWorks, all geometries were exported to Ansys workbench geometry section in step file format. These geometry files were then imported into the ANSYS Fluent module using the “Import Geometry” feature and prepared for computational flow analysis.

After the geometry is imported into ANSYS, named selections are defined to facilitate boundary condition assignment and mesh refinement. By assigning specific names to selected surfaces, ANSYS can automatically recognize and classify them during the boundary condition setup stage. This approach also simplifies mesh operations, particularly when applying local sizing or inflation layers.

In this study, to define the flow domain, the upper surface of the stove representing the region where smoke is released was defined as the inlet. The exhaust opening of the hood, where the airflow exits the domain, was designated as the outlet. All solid enclosure surfaces, including the room boundaries and device walls, were defined as walls.

To achieve more accurate results in the region near the hood, especially around the exhaust and its internal surfaces, named selections were also applied to the hood’s geometry. These selections allowed for more controlled application of local mesh sizing and inflation layers, improving solution accuracy in critical flow regions. The same set of named selections was consistently applied across all analysis cases to ensure uniformity and comparability between scenarios. This method ensures a structured and efficient setup in both the meshing and simulation phases, reducing manual input errors and enhancing reproducibility across different geometrical configurations.

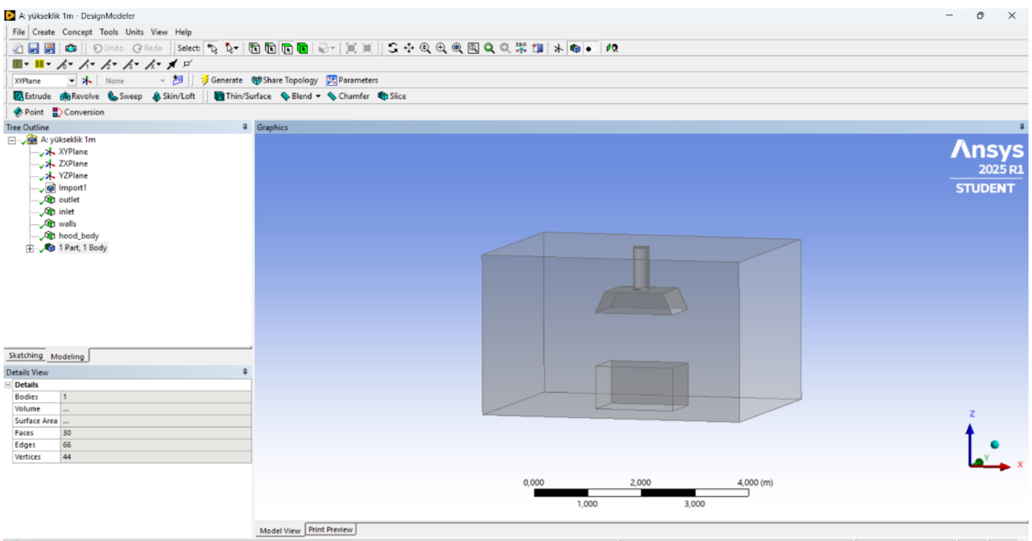

Figure 3.3: Solid model for 1st case

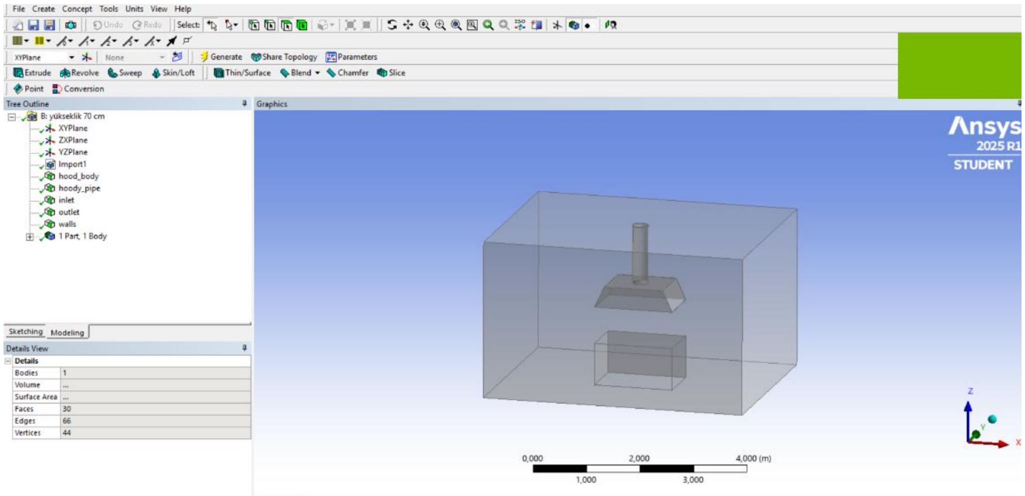

Figure 3.4: Solid model for 2nd case

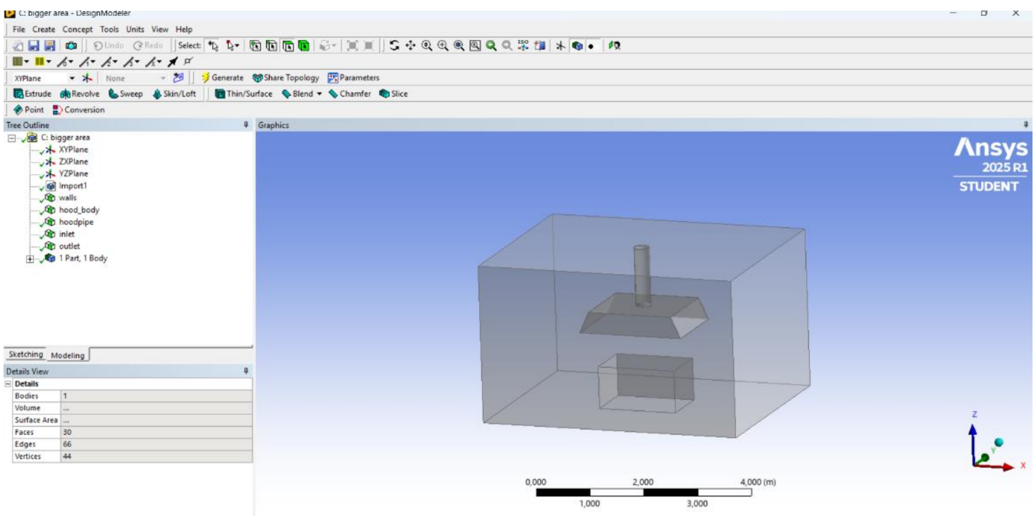

Figure 3.5: Solid model for 3rd case

3.2.2 Mesh

In the meshing process, the global element size was set to 0.3 m to achieve a balanced resolution across the entire domain. To obtain higher accuracy in critical flow regions near the hood, a local body sizing was applied to the hood geometry with an element size of 0.02 m. Additionally, an inflation layer was introduced to more accurate capture the velocity and pressure gradients in the near-wall region, which are especially important in turbulent flow simulations.

Inflation was applied with a growth rate of 1.2, a maximum of 8 layers, and a first layer thickness of 0.003 m. The purpose of inflation is to create a layered mesh structure perpendicular to the wall, allowing for more accurate resolution of the boundary layer where steep gradients in velocity and shear stress occur. This is particularly important for turbulence models, which rely on precise near-wall treatment to predict flow separation and energy dissipation.

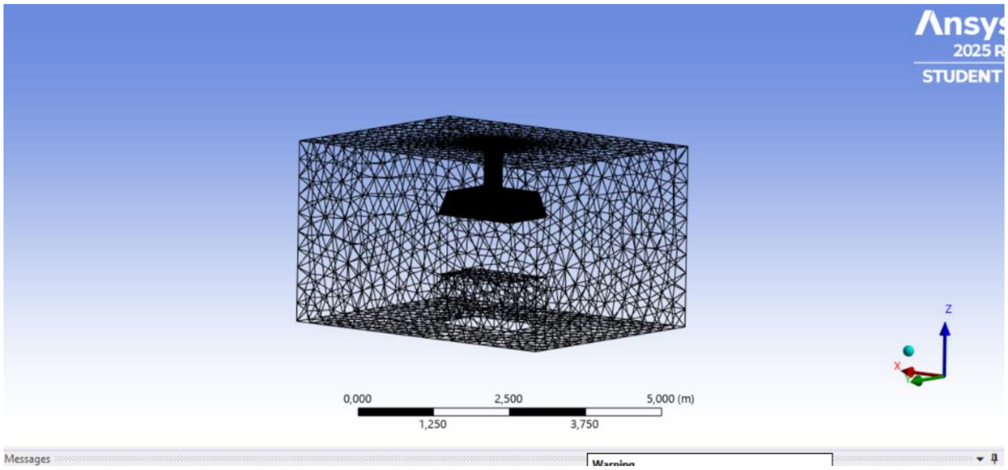

Figure 3.6: Mesh structure for 1st case

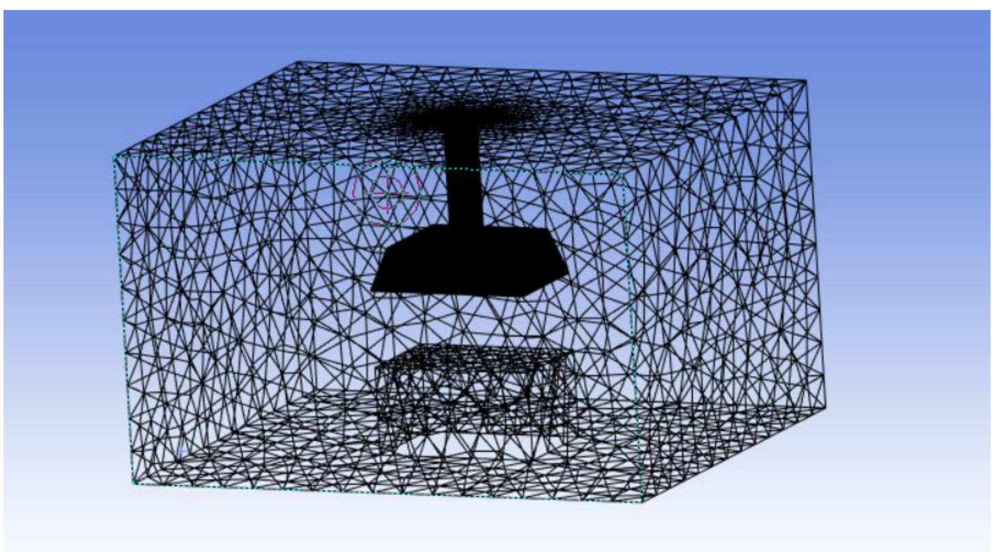

Figure 3.7: Mesh structure for 2nd case

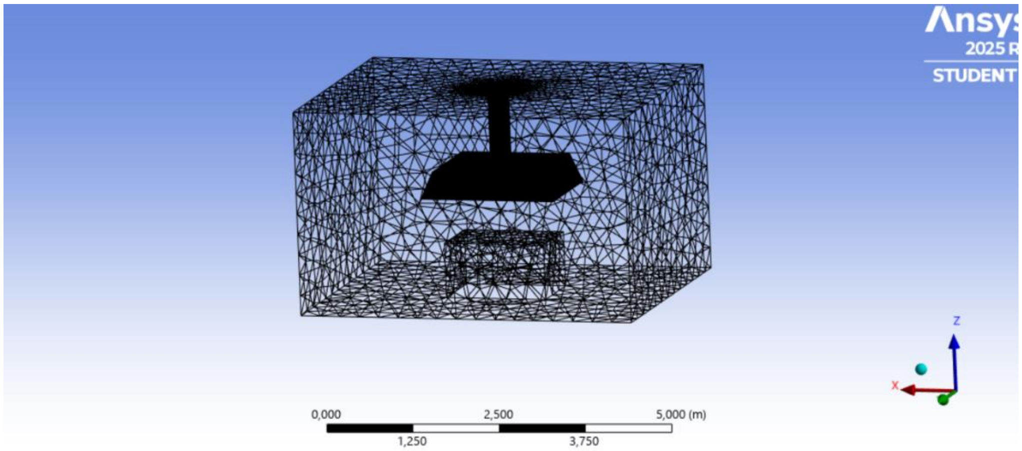

Figure 3.8: Mesh structure for 3rd case

```
Mesh Quality:

Minimum Orthogonal Quality =  1.08194e-01 cell 80892 on zone 3 (ID: 538110 on partition: 2) at location (-7.41312e-01,  5.03867e-01,
1.80949e+00)

Maximum Aspect Ratio =  2.49381e+01 cell 131012 on zone 3 (ID: 113986 on partition: 0) at location (-2.10659e-01, -5.01008e-01,
1.79378e+00)
```

Figure 3.9: Mesh quality for 1st case

```
Mesh Quality:

Minimum Orthogonal Quality =  1.04547e-01 cell 12856 on zone 3 (ID: 569909 on partition: 3) at location (-7.41840e-01, -5.04213e-01,
1.50937e+00)

Maximum Aspect Ratio =  2.49775e+01 cell 123030 on zone 3 (ID: 210611 on partition: 3) at location (-3.41162e-01,  5.00945e-01,
1.49380e+00)
```

Figure 3.10: Mesh quality for 2nd case

```
Mesh Quality:

Minimum Orthogonal Quality =  1.09130e-01 cell 179888 on zone 3 (ID: 864328 on partition: 1) at location (-9.98185e-01,  7.49399e-01
1.50959e+00)

Maximum Aspect Ratio =  2.48379e+01 cell 33360 on zone 3 (ID: 740224 on partition: 0) at location (-3.20700e-01, -7.50999e-01,
1.49380e+00)
```

Figure 3.11: Mesh quality for 3rd case

To evaluate the mesh quality of the large-scale canopy model, orthogonal quality and aspect ratio metrics were analyzed. The results indicate a minimum orthogonal quality of 0.109 and a maximum aspect ratio of 24.84**.**

The minimum orthogonal quality exceeds the critical threshold of 0.1, which is widely regarded as the lower bound for acceptable cell orthogonality in CFD simulations. Although values above 0.2 are typically considered good, the obtained value is still within the range that allows for numerically stable and convergent solutions. This suggests that the mesh is of sufficient quality in terms of cell alignment, particularly in regions where flow gradients are significant.

In conclusion, the mesh used for the large-scale canopy geometry demonstrates acceptable quality for CFD simulations. Although not optimal, the orthogonal quality and aspect ratio remain within tolerable limits for achieving stable and reliable computational results.

3.2.3 Set Up

In the setup stage of the simulation, the energy model was enabled in order to account for temperature-dependent behavior within the domain. The standard k-omega turbulence model was selected due to its proven ability to accurately capture near-wall flow characteristics and boundary layer effects, which are critical in scenarios involving confined spaces and strong temperature gradients. Additionally, the k-omega model generally provides improved performance over the k-epsilon model in low Reynolds number regions and in cases where wall effects are dominant. This made it a suitable choice for the present study, in which accurate resolution near solid surfaces such as the stove and hood were essential.

Gravity was activated in the negative Z-direction to reflect natural convection behavior, and air was selected as the working fluid for its simplicity and relevance to indoor environmental conditions. The material properties of air were considered as constant. Boundary conditions were assigned automatically based on the previously defined named selections. The top surface of the stove, where heat and flow are generated, was defined as a velocity inlet with a magnitude of 0.1m/s in the positive Z-direction. To replicate natural ventilation, the exhaust surface of the hood was set as a pressure outlet with a gauge pressure of zero.

In terms of thermal boundary conditions, the inlet surface representing the stove was assigned a temperature of 373 K, corresponding to the boiling point of water (100°C), to simulate hot vapor release. The outer surfaces of the computational domain were defined with a temperature of 298 K to represent ambient room temperature (25°C).

The SIMPLE algorithm was used for pressure–velocity coupling due to its stability and wide applicability in steady-state flow problems. Residual monitors were configured to observe the convergence behavior of continuity, momentum, turbulence, and energy equations throughout the iterative process. Standard initialization was performed using the “compute from inlet” method, which allowed the solution to begin with physically meaningful initial conditions derived from the inlet boundary. The simulation was continued until all residuals decreased below 1×10^{-4}, which was determined to be an acceptable threshold for convergence in this study.

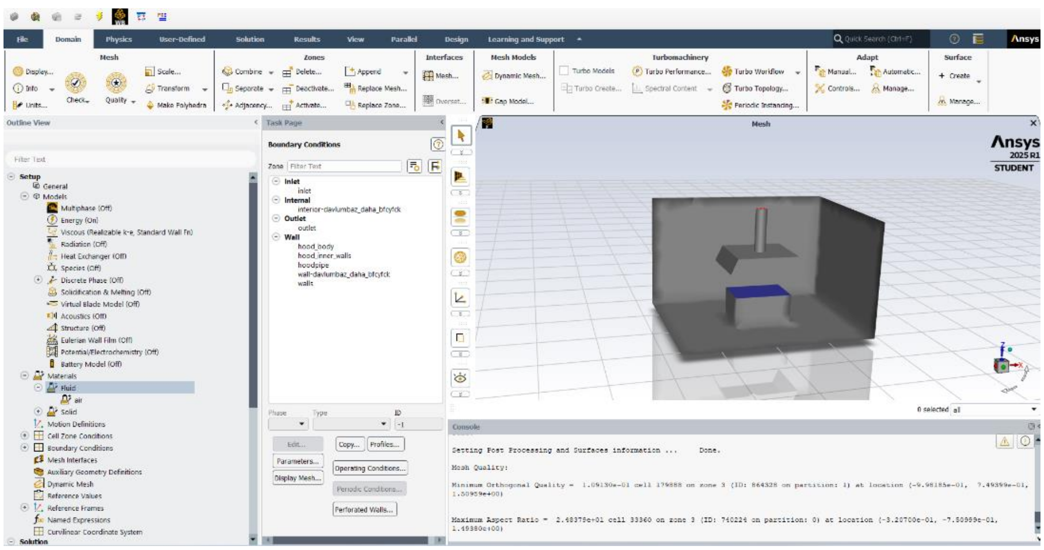

Figure 3.12: Boundary conditions zones

4. RESULTS AND DISCUSSION

4.1 Case 1 – Baseline Geometry

This case models a 1 m mounting distance between a stove and a hood inlet, both having inlet surface dimensions of 1 m × 1.5 m, to analyze the thermal and flow characteristics in a kitchen environment.

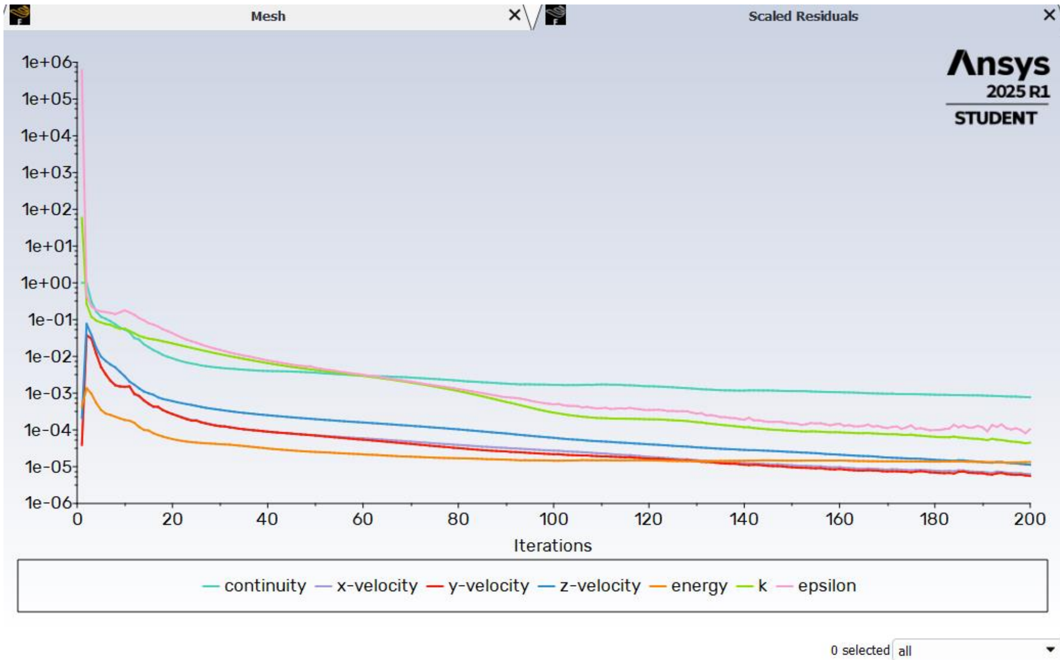

Figure 4.1: Residuals for case 1

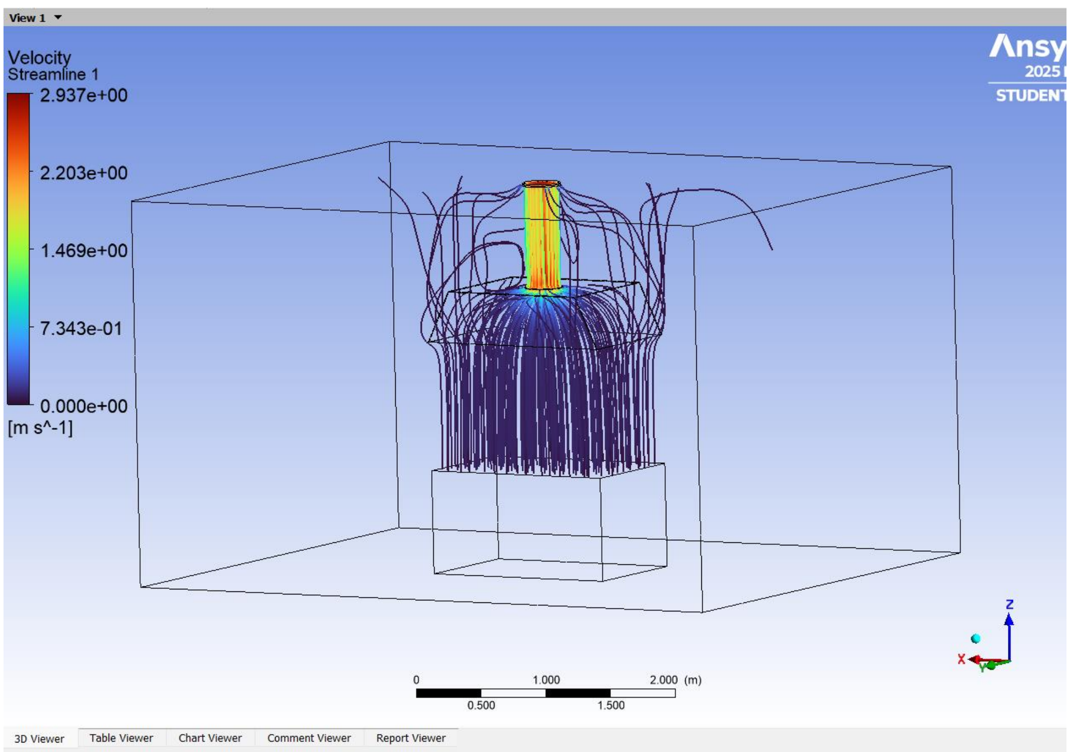

Figure 4.2: Streamline for case 1

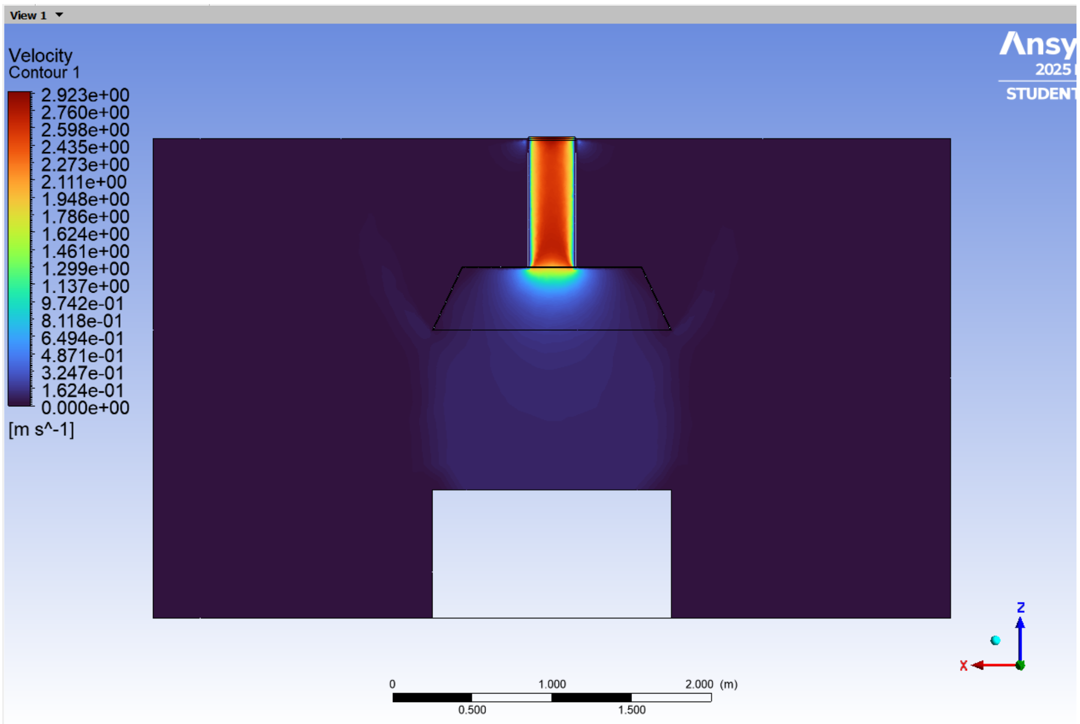

Figure 4.3: Velocity Contour for case 1

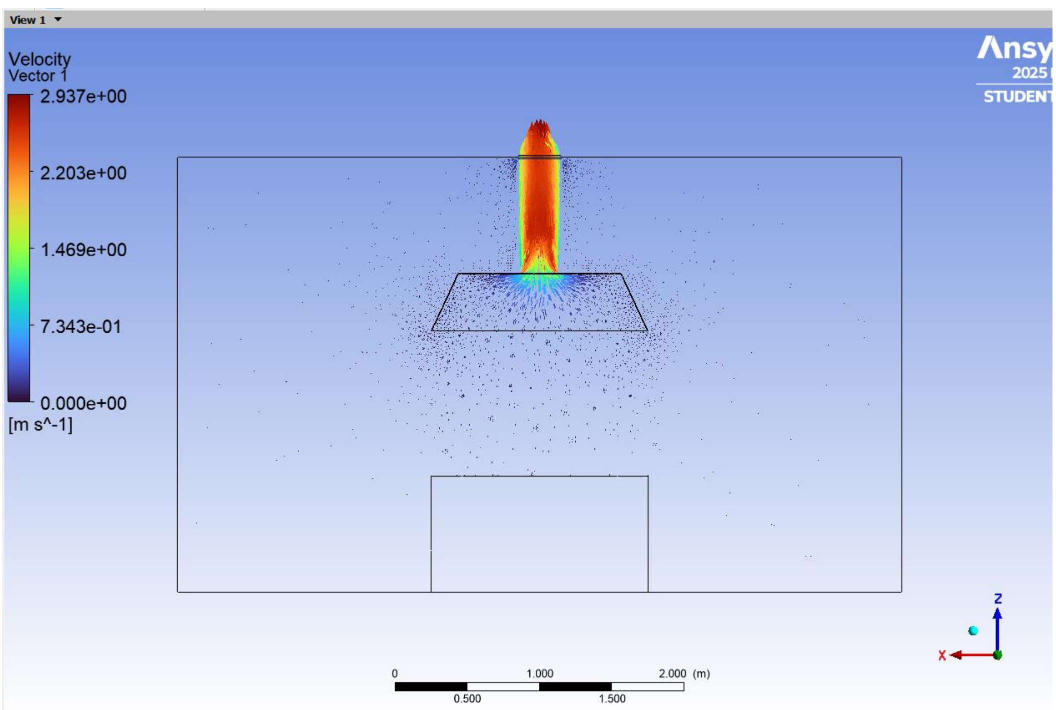

Figure 4.4: Vector plot for case 1

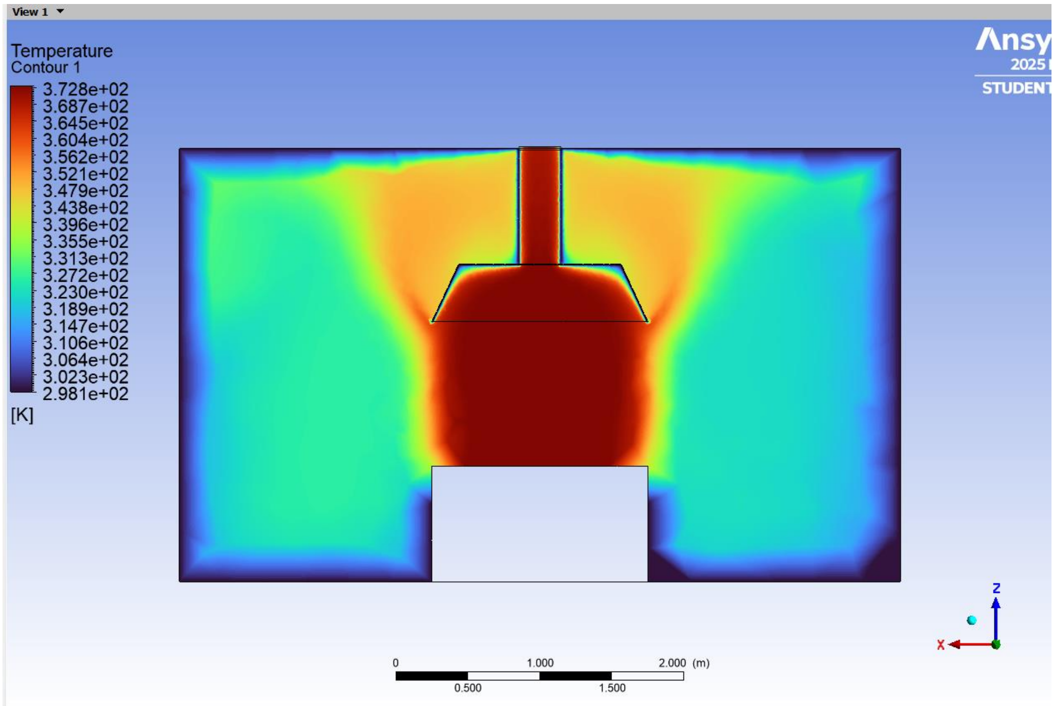

Figure 4.5: Temperature contour for case 1

```
Console
                              inlet             0.18375

                     Mass Flow Rate              [kg/s]
-------------------------------- --------------------
                             outlet         -0.18374688
```

Figure 4.6: Mass flow rates for 1st case

In Case 1, the hood was mounted at a height of 1.0 m with an area of 1.5 m². The streamline and vector plots (Figures 4.2 and 4.4) indicate that the jet effect was highly vertical and centered, forming a symmetric plume rising directly from the heat source toward the outlet. There was recirculation in the domain. Mass balance was well-preserved, with inlet and outlet values closely matching (inlet: 0.18375 kg/s, outlet: –0.18375 kg/s), demonstrating stable convergence.

4.2 Case 2 – Reduced Vertical Distance

In this case, the stove and hood inlet dimensions remain the same (1 m × 1.5 m), but the vertical distance between them is reduced to 0.7 m to investigate the effects of closer hood placement.

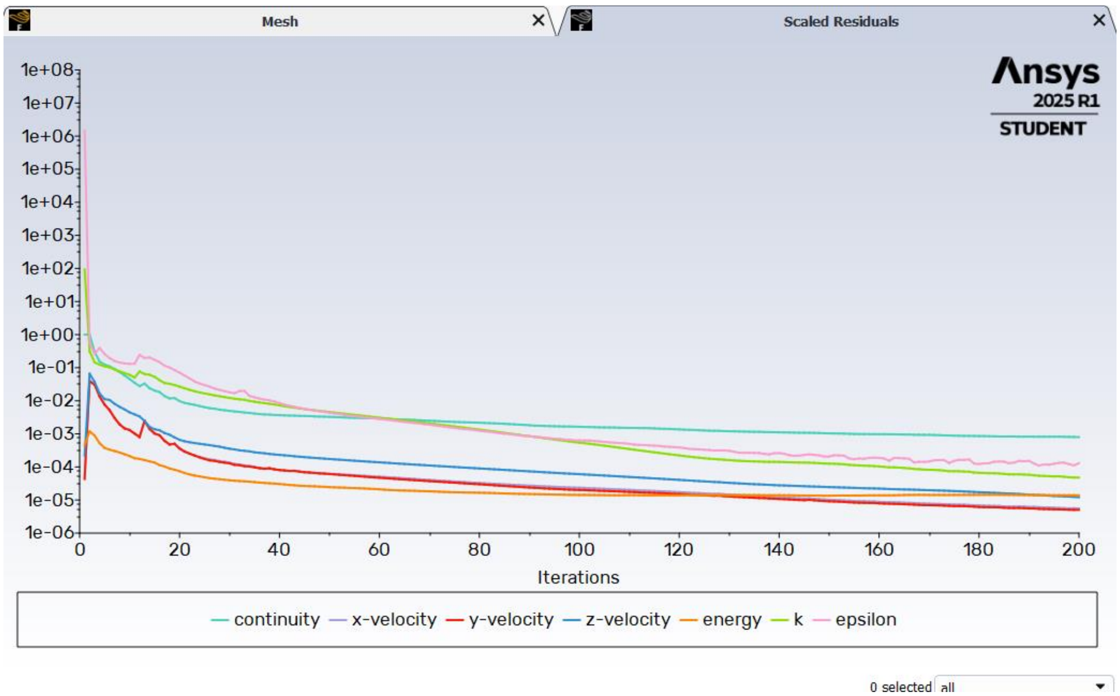

Figure 4.7: Residuals for case 2

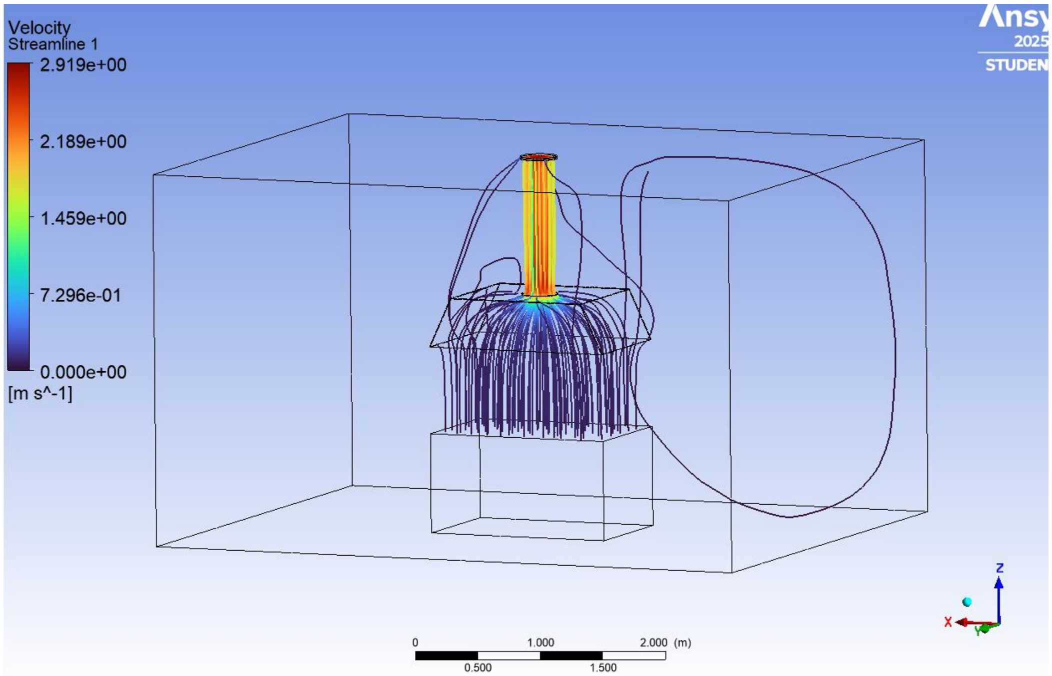

Figure 4.8: Streamline for case 2

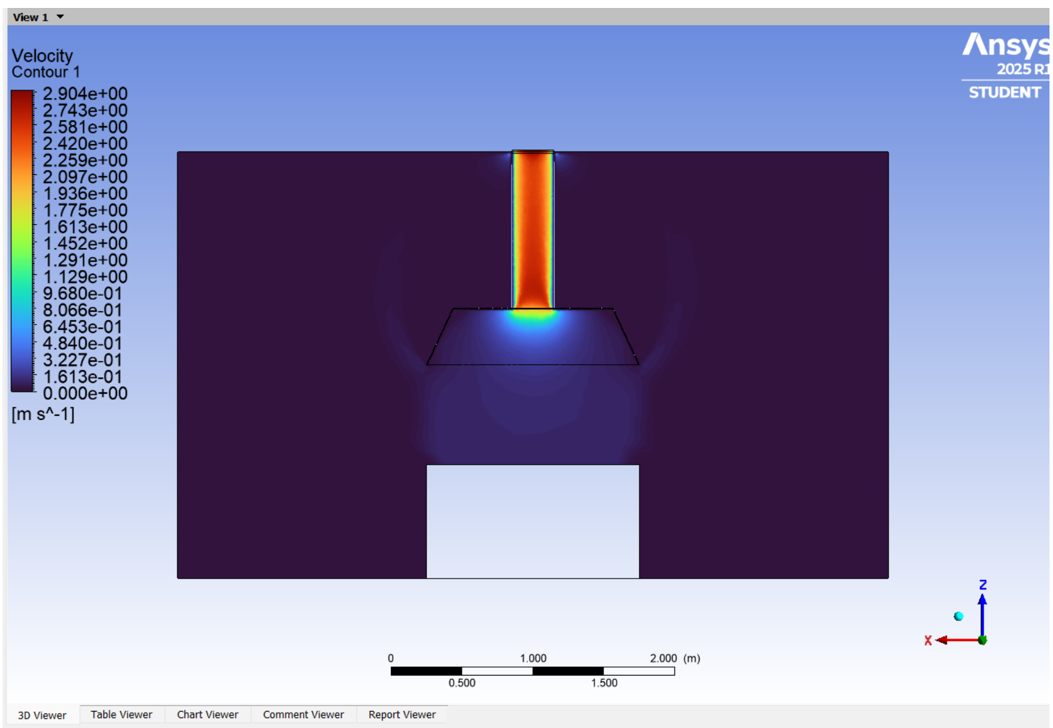

Figure 4.9: Velocity contour plot for case 2

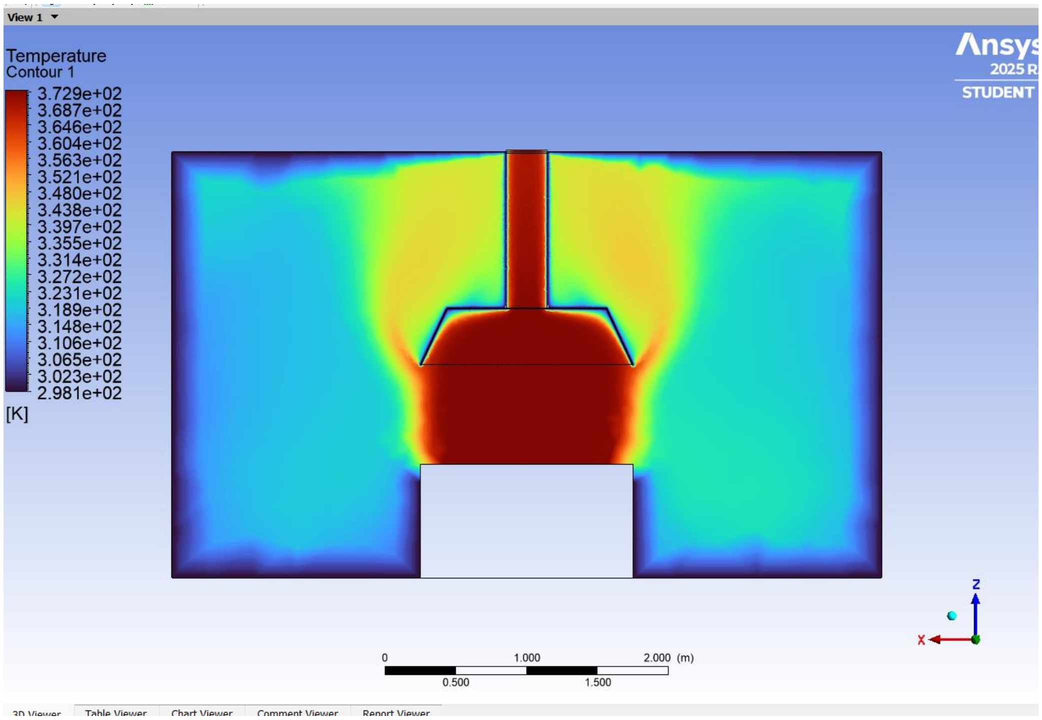

Figure 4.10: Temperature contour for case 2

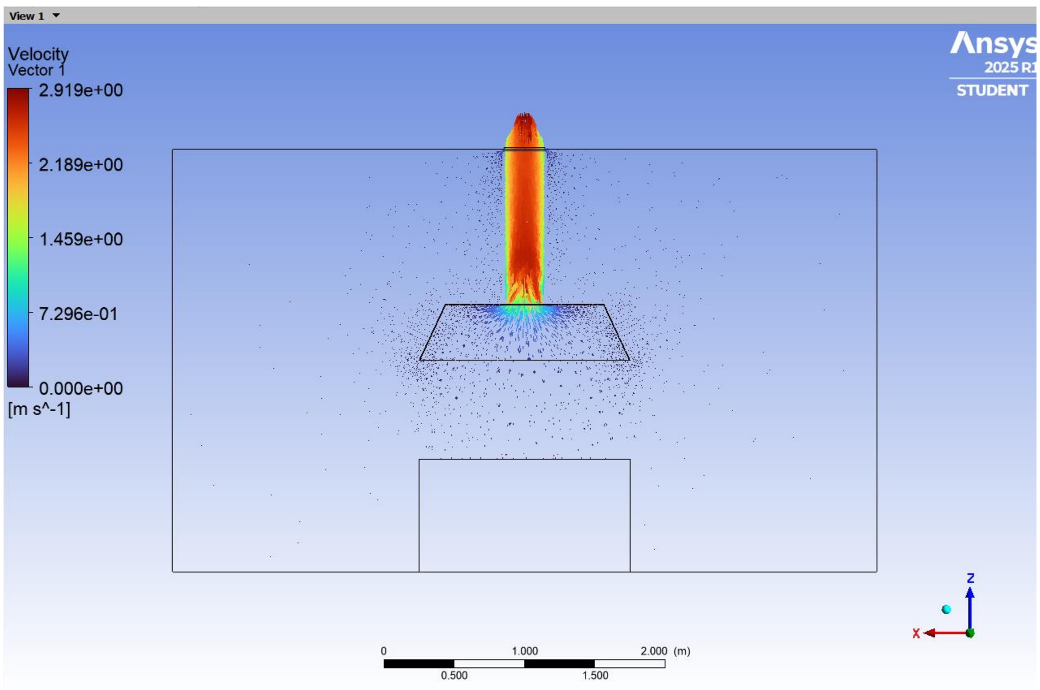

Figure 4.11: Vector Plot for case 2

```
                Mass Flow Rate            [kg/s]
-------------------------------- --------------------
                         inlet          0.18375

                Mass Flow Rate            [kg/s]
-------------------------------- --------------------
                        outlet      -0.18376161
```

Figure 4.12: Mass flow rate for 2nd Case

In Case 2, the installation distance was reduced to 0.7 m while maintaining the same hood area. The streamline pattern (Figure 4.8) still retained a centered jet effect, but the flow alignment improved. However, some recirculation zones began to form at the corners (still less than case 1), as visualized by the extended rotation cycles. The temperature distribution (Figure 4.10) remained similar to Case 1, but there was a marginal improvement in vertical heat capture due to reduced mounting distance. The velocity vectors (Figure 4.11) showed the smoke velocity between the hood and the pipe increased compared to the first case. The exhaust flow rate accelerated earlier between the hood and the pipe. The mass flow rates again showed almost perfect balance (0.18375 kg/s inlet, -0.18376 kg/s outlet), indicating stable numerical convergence.

4.3 Case 3 – Enlarged Hood Inlet Area

In this case, the vertical distance between the stove and the hood inlet remains at 0.7 m, and the stove dimensions are unchanged (1 m × 1.5 m). However, the hood inlet area is increased to 1.5 m × 2 m to examine the impact of a larger intake surface on flow and thermal behavior.

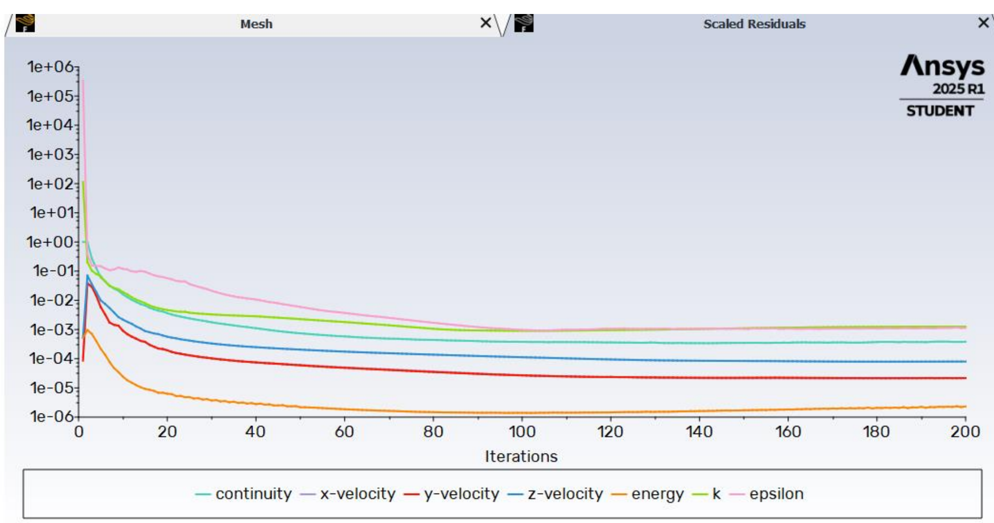

Figure 4.13: Residuals for case 3

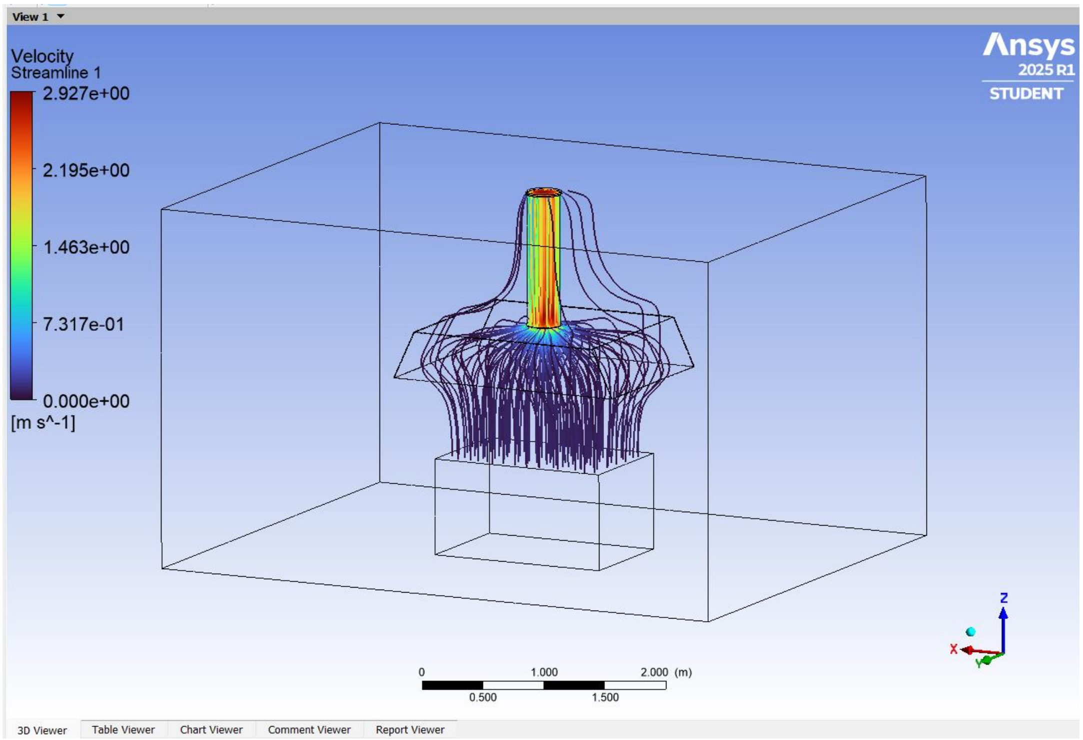

Figure 4.14: Streamline for case 3

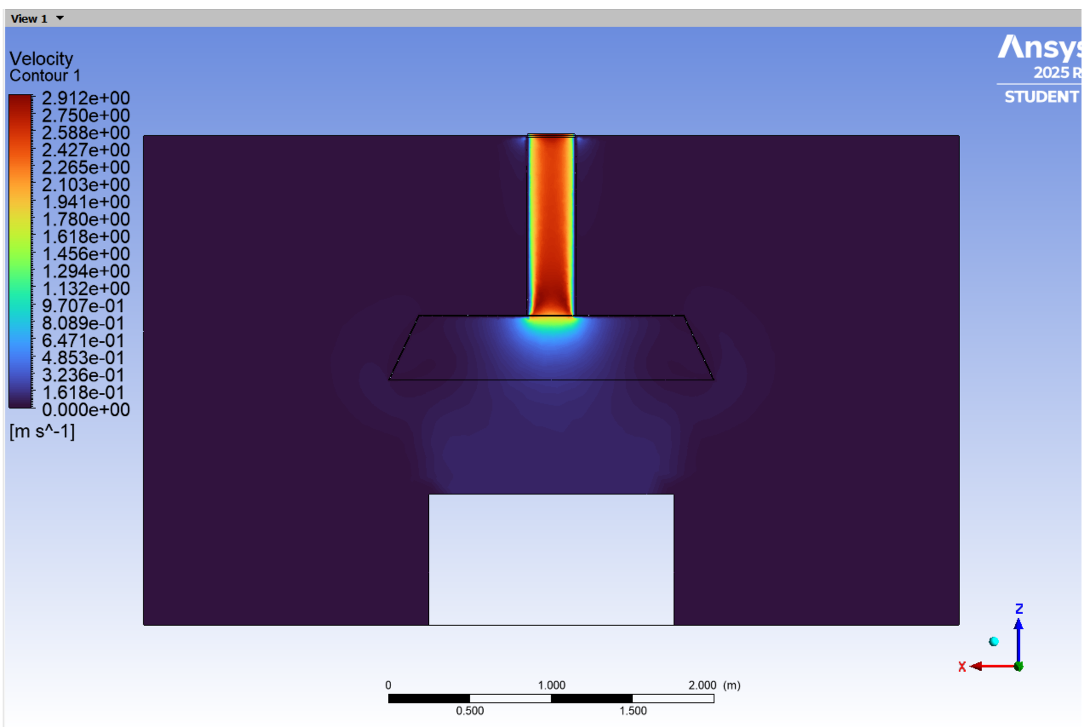

Figure 4.15: Velocity contour for case 3

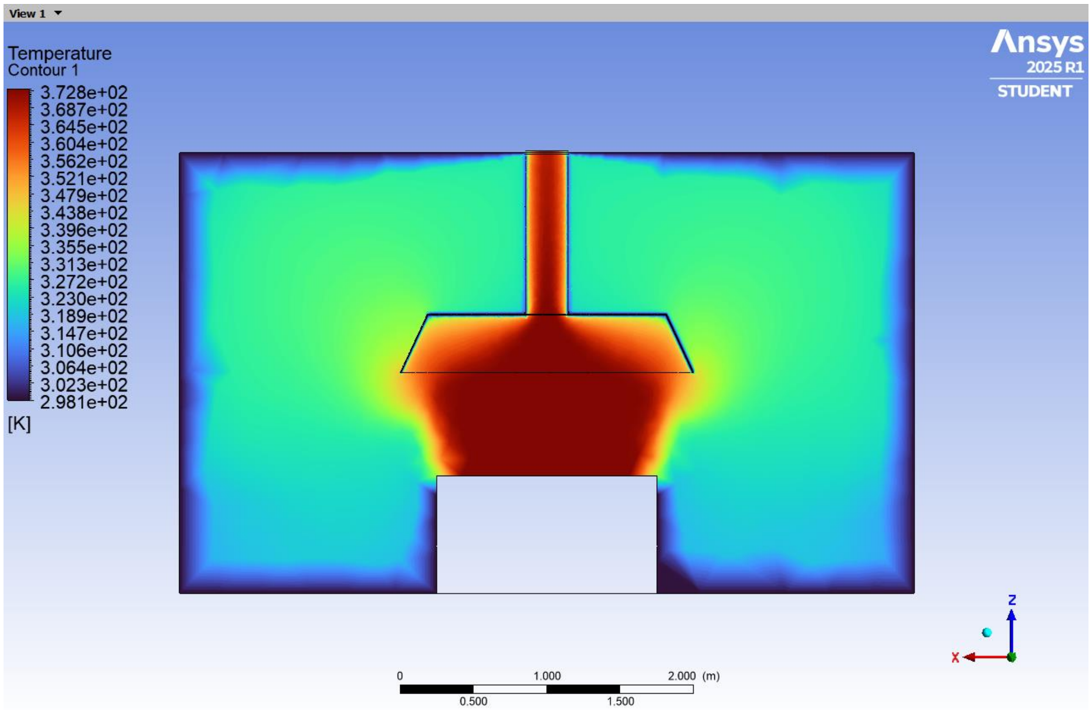

Figure 4.16: Temperature Contour for case 3

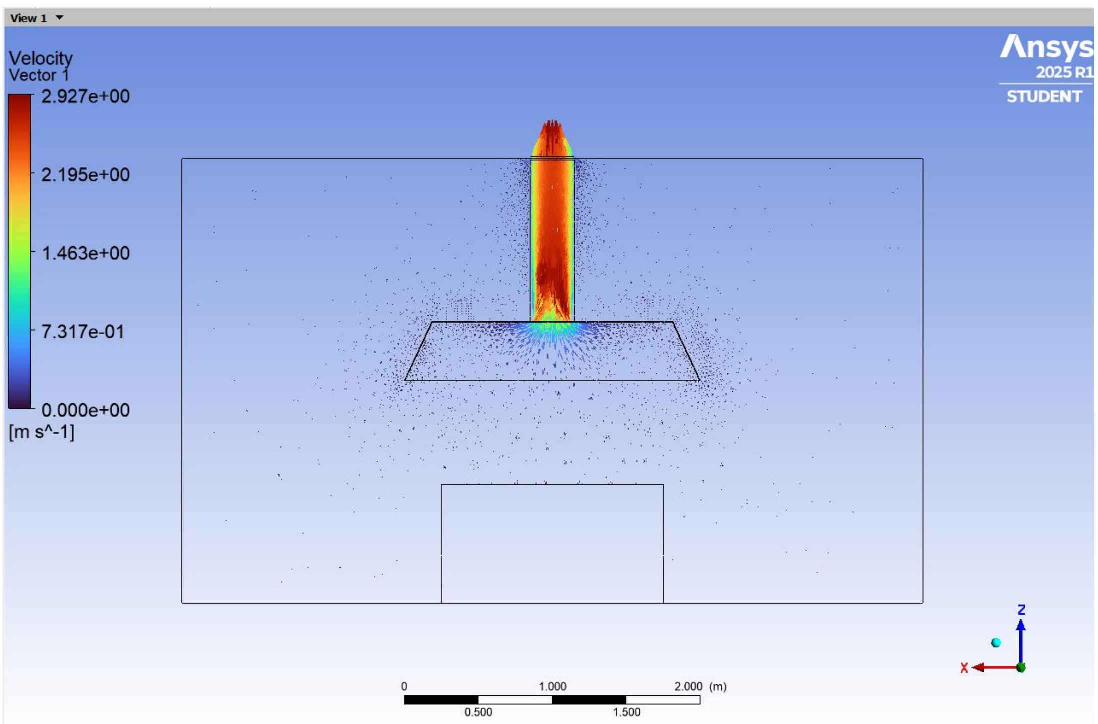

Figure 4.17: Vector plot for case 3

```
Console
Calculation complete.

                  Mass Flow Rate               [kg/s]
-------------------------------- --------------------
                           inlet              0.18375

                  Mass Flow Rate               [kg/s]
-------------------------------- --------------------
                          outlet           -0.1837381
```

Figure 4.18: Mass flow rate for inlet and outlet

In case 3, the mounting distance was kept at 0.7 m while the hood area was doubled to 3.0 m². Unlike the previous two cases, the streamline plot (Figure 4.14) showed a more dispersed jet effect and distinct recirculation zones were formed under and beside the hood. The larger hood area could not fully entrain the plume, resulting in horizontal spreading of hot air. The vector plot (Figure 4.17) revealed strong side flow components and reduced vertical suction power. An increase in the velocity scale was observed compared to case 2. The smoke velocity increased with the increase in hood area. Also an increase in velocity was observed at the tip of the chimney. Compared to the other cases, heat dispersion was more contained and less spread into the room, with minimal leakage beyond the hood area. The mass flow balance was maintained (inlet: 0.18375 kg/s, outlet: –0.18374 kg/s), but the wider geometry introduced more complex flow behavior, which may make convergence difficult in more advanced configurations.

Parameter	Case 1	Case 2	Case 3
Mounting Distance (m)	1	0.7	0.7
Hood Area (m²)	1.5	1.5	3.0
Inlet Velocity(m/s)	0.1	0.1	0.1
Inlet Flow Rate (kg/s)	0.18375	0.18375	0.18375
Outlet Flow Rate (kg/s)	–1.8374688	–1.8376161	–0.1837381
Jet Directionality	Centered	More centered	Diffuse
Recirculation Zones	Prominent	Minimal	Few
Heat Dispersion	Higher	High	Low
Convergence	Stable	Stable	Stable

Table 4.1: Comparative Evaluation

When evaluating all three cases, it can be concluded that Case 2 demonstrates the most stable and efficient extraction performance. The reduced distance between the heat source and the hood enables the jet to remain centered and vertical, minimizing lateral dispersion and suppressing recirculation zones. This configuration ensures effective capture of rising hot air with minimal turbulence near the boundaries.

In Case 1, although the jet remains generally centered, the increased mounting distance creates a larger vertical gap that allows for more air entrainment and the formation of prominent recirculation zones. As a result, the heat and flow fields exhibit higher dispersion compared to Case 2, reducing overall capture efficiency.

Case 3, designed with a doubled hood area, leads to a diffuse jet profile due to the mismatch between the extraction area and the inlet velocity. This causes the flow to weaken and spread laterally, producing few but unstable recirculation regions. On the other hand, the velocity inside the hood and at the outlet increased compared to Case 2, leading to a rise in volumetric flow rate.

5. CONCLUSIONS

In this study, the performance of kitchen hood systems was evaluated through numerical flow simulations conducted for three different configurations with varying mounting heights and surface areas. All simulations were performed in ANSYS Fluent under natural convection conditions, using constant inlet velocity and mass flow rate. For each configuration, flow streamlines, jet directionality, recirculation zones, and heat dispersion were examined in detail.

Among the evaluated configurations, the second case, with a mounting height of 0.7 m and a hood area of 1.5 m², demonstrated the most efficient and stable flow performance. The jet remained well-centered, recirculation zones were minimal, and Heat dispersion remained at an acceptable level, allowing for effective capture of the rising hot air. The smoke speed started to accelerate quickly inside the hood compared to case 1. In the first case, due to the higher mounting height of 1.0 m, air entrainment increased, leading to more prominent recirculation zones and slightly higher heat dispersion. Although the jet directionality remained centered, flow control weakened. In the third case, the hood area was increased to 3.0 m² and mounting height of 0.7 m. As a result, the jet structure became diffuse, directionality weakened, and the flow became less organized. Compared to case 2, it was observed that high-speed velocity vectors increased at the hood exit. Therefore exhaust flow rate slightly increased compared to second case. The heat dispersion remained at the lowest level; however, the weak jet directionality indicated a loss in flow control.

In all simulations, residuals were reduced below 10^{-4}, and mass conservation was successfully maintained. The results are consistent with previous studies in the literature (e.g., Bhatia, 2014), showing that increasing the hood area alone does not guarantee improved performance. Instead, factors such as geometric configuration, jet stability, and flow alignment must be considered together. This study supports such theoretical findings with CFD-based evidence and provides contributions to the design and optimization of kitchen ventilation systems.

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7. APPENDICES

Appendix A - Iterations for case 1

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

1 1.0000e+00 4.1958e-05 3.8899e-05 2.1289e-04 4.3628e-04 5.9094e+01 6.1219e+05 0:03:23 199

2 1.0000e+00 3.7792e-02 3.7413e-02 7.5899e-02 1.3585e-03 2.6555e-01 4.5491e-01 0:03:33 198

3 3.0871e-01 3.0517e-02 3.0250e-02 3.8481e-02 9.6276e-04 1.2042e-01 2.3002e-01 0:03:20 197

Reversed flow on 7 faces (1.8% area) of pressure-outlet 6.

4 1.6734e-01 1.1984e-02 1.1948e-02 1.7275e-02 5.4303e-04 9.3989e-02 1.8111e-01 0:03:09 19

Reversed flow on 25 faces (7.0% area) of pressure-outlet 6.

5 1.1995e-01 5.2651e-03 5.1974e-03 9.9310e-03 3.5070e-04 8.3569e-02 1.6787e-01 0:02:59 195

Reversed flow on 28 faces (7.9% area) of pressure-outlet 6.

6 1.0530e-01 3.2139e-03 3.2623e-03 7.4990e-03 2.7824e-04 7.6127e-02 1.6047e-01 0:02:51 194

Reversed flow on 31 faces (8.8% area) of pressure-outlet 6.

7 9.0219e-02 2.1640e-03 2.1881e-03 6.0088e-03 2.5491e-04 7.2003e-02 1.5182e-01 0:02:45 193

Reversed flow on 29 faces (8.3% area) of pressure-outlet 6.

8 7.4694e-02 1.6490e-03 1.6422e-03 5.0299e-03 2.2926e-04 6.2477e-02 1.4116e-01 0:02:39 192

Reversed flow on 27 faces (7.8% area) of pressure-outlet 6.

9 6.0387e-02 1.5163e-03 1.5220e-03 3.8016e-03 2.0533e-04 5.6177e-02 1.5868e-01 0:02:35 191

Reversed flow on 28 faces (8.1% area) of pressure-outlet 6.

10 5.3601e-02 1.4652e-03 1.4943e-03 2.8706e-03 1.8618e-04 5.6911e-02 1.7870e-01 0:02:36 190

Reversed flow on 30 faces (8.5% area) of pressure-outlet 6.

11 4.5686e-02 1.4731e-03 1.5319e-03 2.0565e-03 1.7830e-04 4.8929e-02 1.5684e-01 0:02:31 189

Reversed flow on 28 faces (7.9% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

12 3.1581e-02 9.2156e-04 9.6925e-04 1.6986e-03 1.5636e-04 4.2696e-02 1.3581e-01 0:02:29 188

Reversed flow on 26 faces (7.2% area) of pressure-outlet 6.

13 2.8658e-02 8.1831e-04 8.4266e-04 1.3571e-03 1.2098e-04 3.6281e-02 1.0997e-01 0:02:27 187

Reversed flow on 27 faces (7.5% area) of pressure-outlet 6.

14 2.1396e-02 6.2313e-04 6.4053e-04 1.1085e-03 1.0006e-04 3.2932e-02 9.5988e-02 0:02:25 186

Reversed flow on 25 faces (6.9% area) of pressure-outlet 6.

15 1.7860e-02 5.0398e-04 5.1774e-04 9.9054e-04 9.6485e-05 3.0450e-02 8.0074e-02 0:02:22 185

Reversed flow on 24 faces (6.6% area) of pressure-outlet 6.

16 1.4836e-02 4.2457e-04 4.3254e-04 9.0576e-04 8.1273e-05 2.9127e-02 7.2974e-02 0:02:20 184

Reversed flow on 23 faces (6.3% area) of pressure-outlet 6.

17 1.2897e-02 4.1453e-04 4.2410e-04 7.6631e-04 7.2546e-05 2.7605e-02 6.5048e-02 0:02:18 183

Reversed flow on 22 faces (6.0% area) of pressure-outlet 6.

18 1.0940e-02 3.4171e-04 3.4688e-04 6.9549e-04 6.5828e-05 2.5663e-02 5.4590e-02 0:02:16 182

Reversed flow on 20 faces (5.4% area) of pressure-outlet 6.

19 9.7191e-03 3.0162e-04 3.0304e-04 6.5024e-04 6.0785e-05 2.4133e-02 4.8627e-02 0:02:15 181

Reversed flow on 18 faces (4.8% area) of pressure-outlet 6.

20 8.8872e-03 2.7210e-04 2.6950e-04 6.0744e-04 5.6288e-05 2.2532e-02 4.2575e-02 0:02:13 180

Reversed flow on 17 faces (4.6% area) of pressure-outlet 6.

21 7.9737e-03 2.4607e-04 2.4241e-04 5.6602e-04 5.2969e-05 2.1012e-02 3.6949e-02 0:02:13 179

Reversed flow on 16 faces (4.2% area) of pressure-outlet 6.

22 7.3206e-03 2.2335e-04 2.1684e-04 5.3200e-04 5.0363e-05 1.9592e-02 3.2226e-02 0:02:12 178

Reversed flow on 16 faces (4.2% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

23 6.7952e-03 2.0353e-04 1.9561e-04 5.0364e-04 4.8184e-05 1.8265e-02 2.8503e-02 0:02:11 177

Reversed flow on 15 faces (3.9% area) of pressure-outlet 6.

24 6.3897e-03 1.8728e-04 1.7901e-04 4.7901e-04 4.6542e-05 1.7075e-02 2.5758e-02 0:02:10 176

Reversed flow on 14 faces (3.7% area) of pressure-outlet 6.

25 6.0888e-03 1.8457e-04 1.7864e-04 4.4992e-04 4.5431e-05 1.5950e-02 2.3634e-02 0:02:10 175

Reversed flow on 14 faces (3.7% area) of pressure-outlet 6.

26 5.6755e-03 1.6557e-04 1.6044e-04 4.2299e-04 4.4184e-05 1.4868e-02 2.1049e-02 0:02:09 174

Reversed flow on 14 faces (3.7% area) of pressure-outlet 6.

27 5.4299e-03 1.5373e-04 1.4935e-04 3.9870e-04 4.3269e-05 1.3912e-02 1.9251e-02 0:02:09 173

Reversed flow on 14 faces (3.7% area) of pressure-outlet 6.

28 5.2279e-03 1.4361e-04 1.4004e-04 3.8206e-04 4.2681e-05 1.3021e-02 1.7547e-02 0:02:13 172

Reversed flow on 14 faces (3.7% area) of pressure-outlet 6.

29 5.0307e-03 1.3479e-04 1.3146e-04 3.6607e-04 4.1855e-05 1.2202e-02 1.6131e-02 0:02:11 171

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

30 4.9009e-03 1.2811e-04 1.2595e-04 3.5244e-04 4.0976e-05 1.1484e-02 1.5053e-02 0:02:11 170

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

31 4.7374e-03 1.2495e-04 1.2389e-04 3.3641e-04 4.0382e-05 1.0778e-02 1.3782e-02 0:02:14 169

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

32 4.6385e-03 1.1792e-04 1.1771e-04 3.2368e-04 3.9830e-05 1.0165e-02 1.2783e-02 0:02:14 168

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

33 4.5797e-03 1.1346e-04 1.1330e-04 3.1142e-04 3.8520e-05 9.6011e-03 1.1947e-02 0:02:14 167

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

34 4.4273e-03 1.0759e-04 1.0758e-04 2.9987e-04 3.7464e-05 9.0787e-03 1.1229e-02 0:02:14 166

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

35 4.3552e-03 1.0374e-04 1.0432e-04 2.9023e-04 3.6471e-05 8.5755e-03 1.0500e-02 0:02:13 165

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

36 4.2498e-03 9.9869e-05 1.0098e-04 2.8164e-04 3.5399e-05 8.1222e-03 1.0028e-02 0:02:12 164

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

37 4.1736e-03 9.6752e-05 9.8233e-05 2.7348e-04 3.4354e-05 7.6802e-03 9.3704e-03 0:02:10 163

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

38 4.0968e-03 9.4195e-05 9.5880e-05 2.6493e-04 3.3286e-05 7.2773e-03 8.8658e-03 0:02:14 162

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

39 4.0393e-03 9.1085e-05 9.2754e-05 2.5785e-04 3.2202e-05 6.8989e-03 8.2493e-03 0:02:15 161

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

40 4.0134e-03 8.8805e-05 8.9961e-05 2.5068e-04 3.1323e-05 6.5549e-03 7.8111e-03 0:02:13 160

Reversed flow on 13 faces (3.4% area) of pressure-outlet 6.

41 3.9720e-03 8.6566e-05 8.7392e-05 2.4410e-04 3.0342e-05 6.2402e-03 7.3776e-03 0:02:16 159

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

42 3.9658e-03 8.4798e-05 8.4974e-05 2.3761e-04 2.9709e-05 5.9467e-03 7.0421e-03 0:02:18 158

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

43 3.9309e-03 8.2962e-05 8.2952e-05 2.3210e-04 2.8937e-05 5.6748e-03 6.6137e-03 0:02:17 157

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

44 3.9166e-03 8.1530e-05 8.1409e-05 2.2589e-04 2.8333e-05 5.4237e-03 6.3355e-03 0:02:16 156

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

45 3.8678e-03 7.9595e-05 7.9350e-05 2.2010e-04 2.7659e-05 5.1942e-03 6.0093e-03 0:02:16 155

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

46 3.8241e-03 7.7785e-05 7.7307e-05 2.1503e-04 2.7075e-05 4.9766e-03 5.7197e-03 0:02:16 154

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

47 3.7814e-03 7.6176e-05 7.5515e-05 2.0980e-04 2.6470e-05 4.7851e-03 5.5459e-03 0:02:12 153

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

48 3.7141e-03 7.4559e-05 7.3866e-05 2.0531e-04 2.6052e-05 4.5990e-03 5.3619e-03 0:02:12 152

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

49 3.6674e-03 7.3269e-05 7.2004e-05 2.0079e-04 2.5571e-05 4.4366e-03 5.3946e-03 0:02:10 151

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

50 3.6068e-03 7.1784e-05 7.0123e-05 1.9600e-04 2.5188e-05 4.2538e-03 4.8262e-03 0:02:06 150

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

51 3.5278e-03 7.0352e-05 6.8247e-05 1.9158e-04 2.4869e-05 4.1042e-03 4.6943e-03 0:02:04 149

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

52 3.4466e-03 6.8771e-05 6.6277e-05 1.8730e-04 2.4527e-05 3.9516e-03 4.4138e-03 0:02:02 148

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

53 3.3872e-03 6.7683e-05 6.4527e-05 1.8373e-04 2.4209e-05 3.8150e-03 4.2712e-03 0:01:59 147

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

54 3.3243e-03 6.6290e-05 6.2860e-05 1.7960e-04 2.3752e-05 3.6796e-03 4.0724e-03 0:01:58 146

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

55 3.2504e-03 6.4922e-05 6.1353e-05 1.7574e-04 2.3301e-05 3.5501e-03 3.8708e-03 0:01:58 145

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

56 3.2115e-03 6.3805e-05 5.9853e-05 1.7218e-04 2.2949e-05 3.4276e-03 3.7219e-03 0:01:58 144

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

57 3.1458e-03 6.2371e-05 5.8127e-05 1.6874e-04 2.2603e-05 3.3069e-03 3.5648e-03 0:01:57 143

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

58 3.0922e-03 6.1313e-05 5.6598e-05 1.6541e-04 2.2292e-05 3.1891e-03 3.4217e-03 0:01:57 142

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

59 3.0414e-03 6.0229e-05 5.5154e-05 1.6224e-04 2.2053e-05 3.0750e-03 3.3056e-03 0:01:58 141

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

60 3.0036e-03 5.9367e-05 5.4264e-05 1.5917e-04 2.1620e-05 2.9587e-03 3.1523e-03 0:01:58 140

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

61 2.9525e-03 5.8036e-05 5.2959e-05 1.5623e-04 2.1277e-05 2.8470e-03 3.0216e-03 0:01:58 139

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

62 2.8901e-03 5.6976e-05 5.1519e-05 1.5292e-04 2.1057e-05 2.7388e-03 2.9131e-03 0:01:59 138

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

63 2.8714e-03 5.5736e-05 5.0060e-05 1.4995e-04 2.0766e-05 2.6321e-03 2.8013e-03 0:01:59 137

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

64 2.8615e-03 5.4757e-05 4.8952e-05 1.4701e-04 2.0387e-05 2.5271e-03 2.6850e-03 0:01:56 136

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

65 2.8404e-03 5.3430e-05 4.7556e-05 1.4417e-04 2.0028e-05 2.4223e-03 2.5494e-03 0:01:54 135

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

66 2.7960e-03 5.2445e-05 4.6384e-05 1.4102e-04 1.9651e-05 2.3218e-03 2.4515e-03 0:01:51 134

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

67 2.7596e-03 5.1415e-05 4.5142e-05 1.3793e-04 1.9381e-05 2.2224e-03 2.3318e-03 0:01:50 133

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

68 2.7401e-03 5.0288e-05 4.3794e-05 1.3497e-04 1.9067e-05 2.1278e-03 2.2528e-03 0:01:52 132

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

69 2.7116e-03 4.9377e-05 4.2762e-05 1.3243e-04 1.8870e-05 2.0333e-03 2.1496e-03 0:01:53 131

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

70 2.6504e-03 4.8271e-05 4.1860e-05 1.2958e-04 1.8664e-05 1.9410e-03 2.0693e-03 0:01:52 130

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

71 2.6054e-03 4.7167e-05 4.0592e-05 1.2676e-04 1.8479e-05 1.8501e-03 1.9617e-03 0:01:52 129

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

72 2.5595e-03 4.6020e-05 3.9413e-05 1.2443e-04 1.8326e-05 1.7619e-03 1.8692e-03 0:01:49 128

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

73 2.5172e-03 4.5275e-05 3.8417e-05 1.2151e-04 1.7982e-05 1.6755e-03 1.7814e-03 0:01:47 127

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

74 2.4617e-03 4.4126e-05 3.7311e-05 1.1873e-04 1.7826e-05 1.5926e-03 1.7102e-03 0:01:46 126

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

75 2.4298e-03 4.3082e-05 3.6289e-05 1.1607e-04 1.7577e-05 1.5105e-03 1.6228e-03 0:01:44 125

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

76 2.3835e-03 4.2407e-05 3.5529e-05 1.1356e-04 1.7450e-05 1.4330e-03 1.5665e-03 0:01:44 124

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

77 2.3293e-03 4.1498e-05 3.4544e-05 1.1136e-04 1.7229e-05 1.3565e-03 1.4914e-03 0:01:45 123

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

78 2.2926e-03 4.1036e-05 3.3839e-05 1.0826e-04 1.7153e-05 1.2827e-03 1.4285e-03 0:01:46 122

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

79 2.2379e-03 3.9752e-05 3.2610e-05 1.0574e-04 1.7007e-05 1.2114e-03 1.3682e-03 0:01:46 121

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

80 2.1942e-03 3.9082e-05 3.1971e-05 1.0344e-04 1.6933e-05 1.1398e-03 1.2943e-03 0:01:47 120

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

81 2.1296e-03 3.8429e-05 3.1325e-05 1.0084e-04 1.6814e-05 1.0718e-03 1.2361e-03 0:01:48 119

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

82 2.0849e-03 3.7513e-05 3.0399e-05 9.8097e-05 1.6743e-05 1.0060e-03 1.1700e-03 0:01:47 118

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

83 2.0593e-03 3.6752e-05 2.9583e-05 9.5724e-05 1.6576e-05 9.4192e-04 1.1130e-03 0:01:46 117

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

84 2.0248e-03 3.6070e-05 2.9099e-05 9.3408e-05 1.6426e-05 8.8145e-04 1.0539e-03 0:02:02 116

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

85 1.9750e-03 3.5097e-05 2.8179e-05 9.0902e-05 1.6226e-05 8.2390e-04 1.0022e-03 0:01:57 115

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

86 1.9555e-03 3.4652e-05 2.7750e-05 8.8526e-05 1.5974e-05 7.6968e-04 9.5288e-04 0:01:53 114

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

87 1.9117e-03 3.4009e-05 2.7159e-05 8.6097e-05 1.5978e-05 7.1693e-04 9.0218e-04 0:01:49 113

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

88 1.8893e-03 3.3335e-05 2.6707e-05 8.3833e-05 1.5805e-05 6.6838e-04 8.5890e-04 0:01:46 112

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

89 1.8406e-03 3.2876e-05 2.6277e-05 8.2226e-05 1.5647e-05 6.2063e-04 8.0561e-04 0:01:41 111

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

90 1.8206e-03 3.2449e-05 2.6063e-05 8.0065e-05 1.5559e-05 5.7817e-04 7.7367e-04 0:01:40 110

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

91 1.7813e-03 3.1538e-05 2.5191e-05 7.7956e-05 1.5362e-05 5.4246e-04 7.5916e-04 0:01:40 109

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

92 1.7668e-03 3.1452e-05 2.5015e-05 7.5238e-05 1.5136e-05 5.0637e-04 7.3915e-04 0:01:38 108

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

93 1.7242e-03 3.0804e-05 2.4583e-05 7.3253e-05 1.4821e-05 4.7080e-04 7.0961e-04 0:01:37 10

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

94 1.7381e-03 3.0192e-05 2.4137e-05 7.1270e-05 1.5007e-05 4.3812e-04 6.7370e-04 0:01:36 106

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

95 1.7388e-03 2.9754e-05 2.3665e-05 6.9339e-05 1.4820e-05 4.0698e-04 6.2762e-04 0:01:35 105

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

96 1.7197e-03 2.9130e-05 2.3289e-05 6.7406e-05 1.4912e-05 3.7914e-04 5.9000e-04 0:01:34 104

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

97 1.7153e-03 2.8597e-05 2.2868e-05 6.5712e-05 1.4780e-05 3.5375e-04 5.6096e-04 0:01:33 103

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

98 1.7108e-03 2.8100e-05 2.2493e-05 6.4083e-05 1.4827e-05 3.3131e-04 5.3363e-04 0:01:33 102

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

99 1.6927e-03 2.7862e-05 2.2191e-05 6.2560e-05 1.4736e-05 3.1238e-04 5.1707e-04 0:01:32 101

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

100 1.6733e-03 2.7267e-05 2.1761e-05 6.1115e-05 1.4557e-05 2.9552e-04 4.9580e-04 0:01:31 100

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

101 1.6811e-03 2.7259e-05 2.1917e-05 5.9185e-05 1.4554e-05 2.8236e-04 5.0869e-04 0:01:30 99

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

102 1.6544e-03 2.6492e-05 2.1247e-05 5.7576e-05 1.4568e-05 2.6785e-04 4.6904e-04 0:01:29 98

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

103 1.6547e-03 2.5975e-05 2.0780e-05 5.6160e-05 1.4701e-05 2.5552e-04 4.5069e-04 0:01:29 97

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

104 1.6638e-03 2.5527e-05 2.0544e-05 5.5059e-05 1.4712e-05 2.4585e-04 4.4842e-04 0:01:27 96

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

105 1.6617e-03 2.5267e-05 2.0370e-05 5.4020e-05 1.4759e-05 2.3809e-04 4.4380e-04 0:01:26 95

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

106 1.6694e-03 2.4764e-05 2.0171e-05 5.3014e-05 1.5127e-05 2.2846e-04 4.0713e-04 0:01:25 94

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

107 1.6898e-03 2.4454e-05 2.0195e-05 5.1379e-05 1.4960e-05 2.2303e-04 4.2276e-04 0:01:24 93

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

108 1.6702e-03 2.3882e-05 1.9641e-05 5.0325e-05 1.4959e-05 2.1662e-04 3.9798e-04 0:01:21 92

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

109 1.7094e-03 2.3364e-05 1.9413e-05 4.9484e-05 1.4776e-05 2.1162e-04 3.8501e-04 0:01:23 91

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

110 1.7199e-03 2.2985e-05 1.9087e-05 4.8775e-05 1.4893e-05 2.0943e-04 3.8921e-04 0:01:22 90

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

111 1.7225e-03 2.2698e-05 1.9109e-05 4.8018e-05 1.4994e-05 2.0791e-04 3.9895e-04 0:01:20 89

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

112 1.6899e-03 2.1982e-05 1.8673e-05 4.7175e-05 1.4746e-05 2.0364e-04 3.6890e-04 0:01:18 88

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

113 1.6930e-03 2.1544e-05 1.8481e-05 4.6090e-05 1.4782e-05 2.0264e-04 3.7936e-04 0:01:18 87

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

114 1.6818e-03 2.1095e-05 1.8212e-05 4.5289e-05 1.4769e-05 2.0250e-04 3.8679e-04 0:01:18 86

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

115 1.6430e-03 2.0620e-05 1.7921e-05 4.4613e-05 1.4830e-05 2.0140e-04 3.7853e-04 0:01:17 85

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

116 1.6382e-03 2.0644e-05 1.8173e-05 4.3831e-05 1.4856e-05 2.0127e-04 3.9792e-04 0:01:16 84

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

117 1.6074e-03 1.9957e-05 1.7475e-05 4.2872e-05 1.4947e-05 1.9930e-04 3.7608e-04 0:01:16 83

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

118 1.5861e-03 1.9572e-05 1.7291e-05 4.2141e-05 1.4888e-05 1.9811e-04 3.6694e-04 0:01:15 82

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

119 1.5467e-03 1.8950e-05 1.6765e-05 4.1407e-05 1.4887e-05 1.9609e-04 3.4837e-04 0:01:14 81

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

120 1.5420e-03 1.8494e-05 1.6559e-05 4.0528e-05 1.4817e-05 1.9448e-04 3.4838e-04 0:01:13 80

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

121 1.5341e-03 1.8092e-05 1.6328e-05 3.9972e-05 1.4784e-05 1.9378e-04 3.5011e-04 0:01:11 79

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

122 1.5065e-03 1.7953e-05 1.6388e-05 3.9280e-05 1.4668e-05 1.9262e-04 3.5390e-04 0:01:09 78

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

123 1.4929e-03 1.7412e-05 1.6034e-05 3.8479e-05 1.4589e-05 1.9061e-04 3.4326e-04 0:01:07 77

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

124 1.4646e-03 1.7133e-05 1.5723e-05 3.7833e-05 1.4319e-05 1.8573e-04 3.2468e-04 0:01:05 76

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

125 1.4453e-03 1.6737e-05 1.5348e-05 3.6844e-05 1.4331e-05 1.8311e-04 3.3037e-04 0:01:06 75

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

126 1.4106e-03 1.6238e-05 1.4996e-05 3.6185e-05 1.4173e-05 1.7987e-04 3.1972e-04 0:01:05 74

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

127 1.3893e-03 1.5974e-05 1.4780e-05 3.5624e-05 1.4199e-05 1.7754e-04 3.2413e-04 0:01:03 73

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

128 1.3653e-03 1.5907e-05 1.4975e-05 3.5202e-05 1.4071e-05 1.7387e-04 3.2083e-04 0:01:01 72

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

129 1.3381e-03 1.5456e-05 1.4451e-05 3.4418e-05 1.4098e-05 1.6779e-04 2.9611e-04 0:00:59 71

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

130 1.3087e-03 1.5076e-05 1.3999e-05 3.3499e-05 1.4037e-05 1.6224e-04 2.7738e-04 0:00:58 70

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

131 1.2800e-03 1.4709e-05 1.3556e-05 3.3054e-05 1.4152e-05 1.5992e-04 2.8583e-04 0:00:56 69

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

132 1.2605e-03 1.4494e-05 1.3378e-05 3.2395e-05 1.4050e-05 1.5186e-04 2.4814e-04 0:00:55 68

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

133 1.2455e-03 1.4227e-05 1.3234e-05 3.1870e-05 1.4126e-05 1.4749e-04 2.5209e-04 0:00:54 67

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

134 1.2224e-03 1.3910e-05 1.2815e-05 3.1264e-05 1.4228e-05 1.4277e-04 2.4104e-04 0:00:52 66

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

135 1.2054e-03 1.3612e-05 1.2406e-05 3.0763e-05 1.4317e-05 1.3780e-04 2.2293e-04 0:00:52 65

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

136 1.1920e-03 1.3354e-05 1.2185e-05 3.0309e-05 1.4306e-05 1.3366e-04 2.2228e-04 0:00:51 64

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

137 1.1901e-03 1.3209e-05 1.1985e-05 2.9900e-05 1.4395e-05 1.2972e-04 2.1063e-04 0:00:50 63

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

138 1.1781e-03 1.3156e-05 1.1998e-05 2.9652e-05 1.4416e-05 1.2637e-04 2.0906e-04 0:00:50 62

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

139 1.1732e-03 1.2793e-05 1.1595e-05 2.8990e-05 1.4505e-05 1.2276e-04 1.9666e-04 0:00:48 61

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

140 1.1731e-03 1.2623e-05 1.1297e-05 2.8584e-05 1.4576e-05 1.1786e-04 1.8918e-04 0:00:47 60

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

141 1.1898e-03 1.2310e-05 1.1030e-05 2.8141e-05 1.4671e-05 1.1795e-04 2.1357e-04 0:00:46 59

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

142 1.1912e-03 1.2302e-05 1.1207e-05 2.8173e-05 1.4656e-05 1.1230e-04 1.8070e-04 0:00:45 58

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

143 1.1862e-03 1.2115e-05 1.1161e-05 2.7818e-05 1.4714e-05 1.0942e-04 1.8291e-04 0:00:44 57

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

144 1.1818e-03 1.1817e-05 1.0775e-05 2.7416e-05 1.4827e-05 1.0658e-04 1.7294e-04 0:00:43 56

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

145 1.1865e-03 1.1640e-05 1.0498e-05 2.7065e-05 1.4861e-05 1.0385e-04 1.6506e-04 0:00:42 55

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

146 1.1736e-03 1.1482e-05 1.0300e-05 2.6658e-05 1.4755e-05 1.0120e-04 1.6490e-04 0:00:41 54

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

147 1.1640e-03 1.1623e-05 1.0327e-05 2.6394e-05 1.4705e-05 1.0002e-04 1.6697e-04 0:00:40 53

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

148 1.1477e-03 1.1410e-05 1.0145e-05 2.5947e-05 1.4606e-05 9.8448e-05 1.6343e-04 0:00:39 52

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

149 1.1435e-03 1.1106e-05 9.8119e-06 2.5397e-05 1.4552e-05 9.6217e-05 1.5159e-04 0:00:38 51

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

150 1.1381e-03 1.0916e-05 9.6167e-06 2.5134e-05 1.4568e-05 9.5016e-05 1.5118e-04 0:00:38 50

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

151 1.1383e-03 1.0724e-05 9.4234e-06 2.4817e-05 1.4575e-05 9.3206e-05 1.4726e-04 0:00:37 49

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

152 1.1341e-03 1.0498e-05 9.2833e-06 2.4219e-05 1.4565e-05 9.0774e-05 1.3648e-04 0:00:36 48

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

153 1.1319e-03 1.0578e-05 9.2734e-06 2.4089e-05 1.4681e-05 9.0308e-05 1.4231e-04 0:00:35 47

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

154 1.1090e-03 1.0358e-05 9.1219e-06 2.3600e-05 1.4674e-05 9.1269e-05 1.5398e-04 0:00:35 46

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

155 1.0956e-03 1.0191e-05 8.9539e-06 2.3339e-05 1.4646e-05 9.0768e-05 1.4952e-04 0:00:34 45

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

156 1.0892e-03 1.0247e-05 9.1368e-06 2.2819e-05 1.4650e-05 8.9153e-05 1.5178e-04 0:00:33 44

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

157 1.0775e-03 9.8932e-06 8.6933e-06 2.2151e-05 1.4680e-05 8.7861e-05 1.4257e-04 0:00:32 43

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

158 1.0726e-03 9.6826e-06 8.5039e-06 2.1837e-05 1.4661e-05 8.6253e-05 1.3263e-04 0:00:31 42

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

159 1.0644e-03 9.5786e-06 8.3936e-06 2.1561e-05 1.4655e-05 8.6697e-05 1.4199e-04 0:00:31 41

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

160 1.0644e-03 9.7176e-06 8.6416e-06 2.1145e-05 1.4694e-05 8.6265e-05 1.4670e-04 0:00:30 40

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

161 1.0469e-03 9.3542e-06 8.2993e-06 2.0761e-05 1.4669e-05 8.4345e-05 1.2849e-04 0:00:29 39

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

162 1.0481e-03 9.1900e-06 8.1147e-06 2.0401e-05 1.4428e-05 8.3756e-05 1.3505e-04 0:00:29 38

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

163 1.0379e-03 9.0186e-06 7.9561e-06 2.0044e-05 1.4342e-05 8.2192e-05 1.2473e-04 0:00:28 37

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

164 1.0223e-03 8.8426e-06 7.8128e-06 1.9736e-05 1.4213e-05 8.1465e-05 1.2486e-04 0:00:27 36

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

165 1.0114e-03 8.8208e-06 7.7849e-06 1.9466e-05 1.4221e-05 8.1481e-05 1.2875e-04 0:00:27 35

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

166 9.9299e-04 8.9240e-06 7.9717e-06 1.9327e-05 1.4080e-05 8.2437e-05 1.3935e-04 0:00:26 34

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

167 9.8871e-04 8.7835e-06 7.8152e-06 1.9102e-05 1.4079e-05 8.0196e-05 1.2252e-04 0:00:25 33

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

168 9.7933e-04 8.6725e-06 7.7852e-06 1.8616e-05 1.4002e-05 7.9130e-05 1.2836e-04 0:00:24 32

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

169 9.6724e-04 8.4196e-06 7.4928e-06 1.8055e-05 1.3976e-05 7.7614e-05 1.1810e-04 0:00:24 31

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

170 9.6140e-04 8.2908e-06 7.3764e-06 1.7774e-05 1.3949e-05 7.6561e-05 1.1219e-04 0:00:23 30

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

171 9.6766e-04 8.4967e-06 7.4693e-06 1.7557e-05 1.4001e-05 7.6511e-05 1.2014e-04 0:00:22 29

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

172 9.4411e-04 8.4574e-06 7.4442e-06 1.7297e-05 1.3941e-05 7.6181e-05 1.2373e-04 0:00:21 28

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

173 9.4314e-04 8.2540e-06 7.3100e-06 1.7062e-05 1.3932e-05 7.3706e-05 1.0680e-04 0:00:20 27

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

174 9.4221e-04 8.1509e-06 7.2397e-06 1.6809e-05 1.3988e-05 7.2941e-05 1.1674e-04 0:00:20 26

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

175 9.3952e-04 7.9524e-06 6.9852e-06 1.6577e-05 1.3938e-05 7.4242e-05 1.3186e-04 0:00:19 25

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

176 9.3648e-04 8.2011e-06 7.3443e-06 1.6558e-05 1.3926e-05 7.0970e-05 1.0694e-04 0:00:18 24

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

177 9.3031e-04 8.2062e-06 7.5241e-06 1.6361e-05 1.3834e-05 6.9734e-05 1.1131e-04 0:00:18 23

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

178 9.2191e-04 8.0609e-06 7.2906e-06 1.6013e-05 1.3903e-05 6.8079e-05 1.0412e-04 0:00:17 22

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

179 9.1642e-04 7.9172e-06 6.9950e-06 1.5770e-05 1.3713e-05 6.6345e-05 9.7213e-05 0:00:16 21

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

180 9.0604e-04 7.7780e-06 6.8794e-06 1.5406e-05 1.3740e-05 6.4999e-05 9.9654e-05 0:00:16 20

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

181 8.9926e-04 7.6434e-06 6.7473e-06 1.5094e-05 1.3707e-05 6.3592e-05 9.9457e-05 0:00:15 19

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

182 9.0086e-04 7.5568e-06 6.6333e-06 1.4909e-05 1.3877e-05 6.3414e-05 1.0496e-04 0:00:15 18

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

183 8.9214e-04 7.7504e-06 6.7505e-06 1.4717e-05 1.3802e-05 6.3078e-05 1.0871e-04 0:00:14 17

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

184 8.8613e-04 7.4832e-06 6.4881e-06 1.4475e-05 1.3990e-05 6.5858e-05 1.3751e-04 0:00:13 16

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

185 8.8724e-04 7.9949e-06 7.2269e-06 1.4952e-05 1.3832e-05 6.2479e-05 1.1690e-04 0:00:12 15

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

186 8.8060e-04 7.8823e-06 7.3838e-06 1.4874e-05 1.3817e-05 6.1042e-05 1.3055e-04 0:00:12 14

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

187 8.7488e-04 7.5531e-06 6.8699e-06 1.4244e-05 1.3606e-05 5.9355e-05 1.1591e-04 0:00:12 13

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

188 8.7194e-04 7.3633e-06 6.7445e-06 1.3999e-05 1.3597e-05 5.7934e-05 1.1553e-04 0:00:11 12

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

189 8.7063e-04 7.2896e-06 6.6103e-06 1.3734e-05 1.3426e-05 5.7238e-05 1.2866e-04 0:00:11 11

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

190 8.6050e-04 7.2585e-06 6.6010e-06 1.3334e-05 1.3413e-05 5.5529e-05 1.1721e-04 0:00:10 10

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

191 8.5094e-04 6.9874e-06 6.2405e-06 1.2918e-05 1.3266e-05 5.2816e-05 9.1741e-05 0:00:09 9

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

192 8.4486e-04 6.8242e-06 6.0576e-06 1.2803e-05 1.3274e-05 5.7279e-05 1.3524e-04 0:00:08 8

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

193 8.3437e-04 7.3693e-06 6.5545e-06 1.3395e-05 1.3130e-05 5.4242e-05 1.2065e-04 0:00:07 7

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

194 8.2696e-04 7.2443e-06 6.7533e-06 1.3370e-05 1.3058e-05 5.3153e-05 1.4011e-04 0:00:06 6

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

195 8.1440e-04 6.9000e-06 6.2636e-06 1.2724e-05 1.2997e-05 5.0652e-05 1.1138e-04 0:00:05 5

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

196 8.0836e-04 6.7304e-06 6.1194e-06 1.2454e-05 1.3014e-05 4.8283e-05 1.0219e-04 0:00:04 4

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

197 8.0690e-04 6.6659e-06 5.9852e-06 1.2223e-05 1.3073e-05 4.7406e-05 1.1079e-04 0:00:03 3

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

198 7.9112e-04 6.6655e-06 6.0605e-06 1.1881e-05 1.3136e-05 4.5637e-05 9.9941e-05 0:00:02 2

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

199 7.8266e-04 6.3899e-06 5.7614e-06 1.1528e-05 1.3267e-05 4.3393e-05 8.1518e-05 0:00:01 1

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

200 7.7185e-04 6.2862e-06 5.5781e-06 1.1262e-05 1.3335e-05 4.4936e-05 1.0444e-04 0:00:00 0

Appendix B - Iterations for case 2

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

1 1.0000e+00 4.6050e-05 4.2968e-05 2.1936e-04 4.4828e-04 9.3052e+01 1.4494e+06 0:03:40 199

2 1.0000e+00 3.9823e-02 3.9020e-02 6.5326e-02 1.1896e-03 3.1290e-01 5.5495e-01 0:03:50 198

Reversed flow on 2 faces (0.5% area) of pressure-outlet 6.

3 2.9947e-01 3.1353e-02 3.0384e-02 3.7002e-02 8.9050e-04 1.4466e-01 2.5719e-01 0:03:36 197

Reversed flow on 19 faces (4.5% area) of pressure-outlet 6.

4 1.5326e-01 1.3486e-02 1.3494e-02 1.6602e-02 5.2084e-04 1.2320e-01 3.9616e-01 0:03:39 196

Reversed flow on 44 faces (11.7% area) of pressure-outlet 6.

5 1.2358e-01 7.6790e-03 7.6410e-03 1.1274e-02 3.7542e-04 1.1018e-01 2.5804e-01 0:03:29 195

Reversed flow on 44 faces (11.7% area) of pressure-outlet 6.

6 1.0977e-01 5.2344e-03 5.1944e-03 1.0550e-02 3.3316e-04 1.0184e-01 1.9538e-01 0:03:18 194

Reversed flow on 44 faces (11.6% area) of pressure-outlet 6.

7 9.1337e-02 3.0529e-03 2.9950e-03 8.1065e-03 3.0309e-04 8.8416e-02 1.5990e-01 0:03:07 193

Reversed flow on 45 faces (12.0% area) of pressure-outlet 6.

8 7.3704e-02 1.9738e-03 1.9228e-03 6.5592e-03 2.7312e-04 7.7878e-02 1.4351e-01 0:03:00 192

Reversed flow on 30 faces (7.6% area) of pressure-outlet 6.

9 5.8246e-02 1.4867e-03 1.4569e-03 5.4799e-03 2.4135e-04 6.8773e-02 1.3473e-01 0:02:55 191

Reversed flow on 29 faces (7.3% area) of pressure-outlet 6.

10 4.5505e-02 1.2944e-03 1.3075e-03 4.4674e-03 2.1286e-04 6.0789e-02 1.3093e-01 0:02:49 190

Reversed flow on 30 faces (7.6% area) of pressure-outlet 6.

11 3.5019e-02 1.0075e-03 1.0281e-03 3.8820e-03 1.8361e-04 5.0469e-02 1.3230e-01 0:02:45 189

Reversed flow on 30 faces (7.5% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

12 2.7704e-02 7.8641e-04 8.0619e-04 3.3554e-03 1.7485e-04 7.6217e-02 2.4310e-01 0:02:43 188

Reversed flow on 44 faces (11.2% area) of pressure-outlet 6.

13 3.2974e-02 2.4508e-03 2.5044e-03 2.4508e-03 1.6127e-04 6.4338e-02 1.9664e-01 0:02:39 187

Reversed flow on 48 faces (12.5% area) of pressure-outlet 6.

14 2.3993e-02 1.3543e-03 1.4394e-03 1.6324e-03 1.4740e-04 6.1158e-02 2.0247e-01 0:02:37 186

Reversed flow on 44 faces (11.5% area) of pressure-outlet 6.

15 2.0407e-02 1.0022e-03 1.0344e-03 1.3796e-03 1.3572e-04 5.3093e-02 1.7382e-01 0:02:37 185

Reversed flow on 29 faces (7.7% area) of pressure-outlet 6.

16 1.8282e-02 8.9402e-04 9.0403e-04 1.2821e-03 1.1335e-04 4.1914e-02 1.4759e-01 0:02:35 184

Reversed flow on 21 faces (5.6% area) of pressure-outlet 6.

17 1.3907e-02 6.0764e-04 6.1909e-04 1.0602e-03 1.0326e-04 3.4291e-02 1.1520e-01 0:02:32 183

Reversed flow on 17 faces (4.5% area) of pressure-outlet 6.

18 1.1786e-02 4.7991e-04 4.7751e-04 9.4239e-04 8.9894e-05 3.2572e-02 1.0145e-01 0:02:33 182

Reversed flow on 23 faces (6.0% area) of pressure-outlet 6.

19 1.2071e-02 4.9034e-04 5.0348e-04 7.8055e-04 8.2497e-05 2.9869e-02 8.4797e-02 0:02:31 18

Reversed flow on 24 faces (6.3% area) of pressure-outlet 6.

20 9.7744e-03 3.4875e-04 3.6514e-04 6.5906e-04 7.4107e-05 2.6746e-02 7.0928e-02 0:02:30 180

Reversed flow on 25 faces (6.5% area) of pressure-outlet 6.

21 8.6347e-03 2.8534e-04 2.9563e-04 5.9837e-04 6.5645e-05 2.3929e-02 5.7945e-02 0:02:29 179

Reversed flow on 24 faces (6.2% area) of pressure-outlet 6.

22 8.0347e-03 2.4973e-04 2.5336e-04 5.5871e-04 5.9382e-05 2.1455e-02 4.7598e-02 0:02:26 178

Reversed flow on 23 faces (6.0% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

23 7.5345e-03 2.2313e-04 2.2124e-04 5.2816e-04 5.4991e-05 1.9416e-02 3.8430e-02 0:02:25 177

Reversed flow on 20 faces (5.1% area) of pressure-outlet 6.

24 6.9365e-03 2.0124e-04 1.9451e-04 5.0225e-04 5.1775e-05 1.7886e-02 3.3306e-02 0:02:24 176

Reversed flow on 18 faces (4.6% area) of pressure-outlet 6.

25 6.3963e-03 1.8355e-04 1.7372e-04 4.7829e-04 4.8731e-05 1.6677e-02 2.9765e-02 0:02:22 175

Reversed flow on 18 faces (4.6% area) of pressure-outlet 6.

26 5.9884e-03 1.6906e-04 1.5809e-04 4.5649e-04 4.5893e-05 1.5595e-02 2.6830e-02 0:02:20 174

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

27 5.7671e-03 1.6257e-04 1.5225e-04 4.3130e-04 4.4051e-05 1.4543e-02 2.3359e-02 0:02:22 173

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

28 5.3822e-03 1.5031e-04 1.4164e-04 4.1085e-04 4.2567e-05 1.3698e-02 2.1293e-02 0:02:22 172

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

29 5.1772e-03 1.4346e-04 1.3475e-04 3.8004e-04 4.0920e-05 1.2938e-02 1.9548e-02 0:02:22 171

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

30 4.9591e-03 1.3552e-04 1.2801e-04 3.5515e-04 3.9567e-05 1.2207e-02 1.7984e-02 0:02:21 170

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

31 4.7501e-03 1.2316e-04 1.1525e-04 3.3964e-04 3.8265e-05 1.1547e-02 1.6965e-02 0:02:22 169

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

32 4.6139e-03 1.1928e-04 1.1281e-04 3.1842e-04 3.7523e-05 1.1065e-02 1.9737e-02 0:02:22 168

Reversed flow on 18 faces (4.5% area) of pressure-outlet 6.

33 4.3949e-03 1.1133e-04 1.0484e-04 3.0683e-04 3.6601e-05 1.0736e-02 1.9850e-02 0:02:21 167

Reversed flow on 18 faces (4.5% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

34 4.3046e-03 1.0764e-04 1.0264e-04 2.9524e-04 3.5803e-05 9.8791e-03 1.3966e-02 0:02:19 166

Reversed flow on 18 faces (4.5% area) of pressure-outlet 6.

35 4.1061e-03 1.0118e-04 9.6976e-05 2.7675e-04 3.4744e-05 9.3699e-03 1.2764e-02 0:02:18 165

Reversed flow on 18 faces (4.5% area) of pressure-outlet 6.

36 3.9622e-03 9.4553e-05 9.1302e-05 2.6732e-04 3.3746e-05 8.8988e-03 1.1642e-02 0:02:15 164

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

37 3.8662e-03 8.9981e-05 8.7949e-05 2.5887e-04 3.2746e-05 8.4854e-03 1.0863e-02 0:02:13 163

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

38 3.8240e-03 9.1535e-05 9.0951e-05 2.4669e-04 3.2056e-05 8.1029e-03 1.0298e-02 0:02:11 162

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

39 3.7140e-03 8.4433e-05 8.4325e-05 2.3823e-04 3.1447e-05 7.7200e-03 9.4720e-03 0:02:09 161

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

40 3.6716e-03 8.0537e-05 8.0761e-05 2.3112e-04 3.0470e-05 7.2562e-03 8.5120e-03 0:02:08 160

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

41 3.6220e-03 7.7685e-05 7.8446e-05 2.2443e-04 2.9519e-05 6.8504e-03 7.6421e-03 0:02:07 159

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

42 3.5732e-03 7.5015e-05 7.5999e-05 2.1815e-04 2.8472e-05 6.5039e-03 7.0657e-03 0:02:06 158

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

43 3.5528e-03 7.5231e-05 7.6555e-05 2.1003e-04 2.7887e-05 6.1846e-03 6.5973e-03 0:02:05 157

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

44 3.4997e-03 7.1199e-05 7.2601e-05 2.0384e-04 2.7065e-05 5.8932e-03 6.1100e-03 0:02:04 156

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

45 3.4726e-03 6.8612e-05 6.9640e-05 1.9832e-04 2.6641e-05 5.6285e-03 5.7039e-03 0:02:03 155

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

46 3.4397e-03 6.7478e-05 6.8002e-05 1.9220e-04 2.6173e-05 5.3871e-03 5.3501e-03 0:02:03 154

Reversed flow on 17 faces (4.3% area) of pressure-outlet 6.

47 3.3741e-03 6.5676e-05 6.5940e-05 1.8735e-04 2.5979e-05 5.1651e-03 5.0589e-03 0:02:02 153

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

48 3.3353e-03 6.3986e-05 6.3823e-05 1.8302e-04 2.5372e-05 4.9575e-03 4.8068e-03 0:02:02 152

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

49 3.3137e-03 6.3431e-05 6.2836e-05 1.7815e-04 2.5094e-05 4.7585e-03 4.5878e-03 0:02:00 151

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

50 3.2703e-03 6.1873e-05 6.1039e-05 1.7398e-04 2.4517e-05 4.5688e-03 4.3563e-03 0:01:59 150

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

51 3.2275e-03 6.0935e-05 5.9530e-05 1.6953e-04 2.4162e-05 4.3865e-03 4.1352e-03 0:01:59 149

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

52 3.1759e-03 5.9832e-05 5.7950e-05 1.6561e-04 2.3819e-05 4.2173e-03 3.9393e-03 0:01:59 148

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

53 3.1296e-03 5.8494e-05 5.6344e-05 1.6184e-04 2.3580e-05 4.0556e-03 3.7516e-03 0:01:59 147

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

54 3.0884e-03 5.7314e-05 5.4904e-05 1.5813e-04 2.3240e-05 3.9016e-03 3.5811e-03 0:01:58 146

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

55 3.0588e-03 5.6518e-05 5.3666e-05 1.5423e-04 2.2995e-05 3.7533e-03 3.4358e-03 0:01:57 145

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

56 3.0264e-03 5.5144e-05 5.2137e-05 1.5067e-04 2.2586e-05 3.6104e-03 3.2972e-03 0:01:55 144

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

57 2.9942e-03 5.3856e-05 5.0721e-05 1.4738e-04 2.2327e-05 3.4738e-03 3.1756e-03 0:01:55 143

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

58 2.9700e-03 5.2709e-05 4.9395e-05 1.4410e-04 2.1866e-05 3.3422e-03 3.0639e-03 0:01:54 142

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

59 2.9357e-03 5.1792e-05 4.8223e-05 1.4086e-04 2.1567e-05 3.2152e-03 2.9607e-03 0:01:52 141

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

60 2.8940e-03 5.0747e-05 4.7086e-05 1.3782e-04 2.1067e-05 3.0913e-03 2.8519e-03 0:01:51 140

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

61 2.8571e-03 4.9669e-05 4.5885e-05 1.3489e-04 2.0605e-05 2.9715e-03 2.7192e-03 0:01:50 139

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

62 2.8072e-03 4.8661e-05 4.4750e-05 1.3179e-04 2.0135e-05 2.8574e-03 2.6096e-03 0:01:49 138

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

63 2.7577e-03 4.7609e-05 4.3723e-05 1.2870e-04 1.9849e-05 2.7449e-03 2.4950e-03 0:01:49 137

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

64 2.7257e-03 4.6539e-05 4.2678e-05 1.2590e-04 1.9523e-05 2.6378e-03 2.3956e-03 0:01:47 136

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

65 2.7162e-03 4.5545e-05 4.1707e-05 1.2309e-04 1.9386e-05 2.5332e-03 2.2974e-03 0:01:47 135

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

66 2.6745e-03 4.4441e-05 4.0662e-05 1.2051e-04 1.9147e-05 2.4336e-03 2.2079e-03 0:01:46 134

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

67 2.6296e-03 4.3473e-05 3.9798e-05 1.1789e-04 1.9037e-05 2.3371e-03 2.1224e-03 0:01:44 133

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

68 2.5810e-03 4.2429e-05 3.8888e-05 1.1549e-04 1.8691e-05 2.2441e-03 2.0448e-03 0:01:44 132

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

69 2.5358e-03 4.1412e-05 3.8045e-05 1.1307e-04 1.8566e-05 2.1542e-03 1.9618e-03 0:01:43 131

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

70 2.4939e-03 4.0522e-05 3.7156e-05 1.1064e-04 1.8328e-05 2.0674e-03 1.8860e-03 0:01:42 130

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

71 2.4547e-03 3.9593e-05 3.6422e-05 1.0840e-04 1.8125e-05 1.9831e-03 1.8057e-03 0:01:41 129

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

72 2.4159e-03 3.8786e-05 3.5672e-05 1.0602e-04 1.7789e-05 1.9014e-03 1.7291e-03 0:01:41 128

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

73 2.3643e-03 3.7865e-05 3.4897e-05 1.0395e-04 1.7594e-05 1.8220e-03 1.6502e-03 0:01:40 127

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

74 2.3265e-03 3.7057e-05 3.4176e-05 1.0177e-04 1.7365e-05 1.7461e-03 1.5813e-03 0:01:39 126

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

75 2.3017e-03 3.6337e-05 3.3423e-05 9.9715e-05 1.7218e-05 1.6728e-03 1.5125e-03 0:01:38 125

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

76 2.2597e-03 3.5510e-05 3.2659e-05 9.7599e-05 1.7063e-05 1.6028e-03 1.4517e-03 0:01:37 124

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

77 2.2397e-03 3.4763e-05 3.1924e-05 9.5590e-05 1.6879e-05 1.5342e-03 1.3890e-03 0:01:37 123

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

78 2.2185e-03 3.4054e-05 3.1163e-05 9.3652e-05 1.6807e-05 1.4703e-03 1.3649e-03 0:01:36 122

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

79 2.1980e-03 3.3380e-05 3.0506e-05 9.1940e-05 1.6745e-05 1.4069e-03 1.3017e-03 0:01:35 121

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

80 2.1754e-03 3.2815e-05 2.9929e-05 9.0089e-05 1.6608e-05 1.3452e-03 1.2425e-03 0:01:34 120

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

81 2.1347e-03 3.2127e-05 2.9207e-05 8.8259e-05 1.6468e-05 1.2867e-03 1.1952e-03 0:01:34 119

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

82 2.1064e-03 3.1508e-05 2.8520e-05 8.6492e-05 1.6322e-05 1.2309e-03 1.1632e-03 0:01:33 118

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

83 2.0798e-03 3.0919e-05 2.7857e-05 8.4758e-05 1.6219e-05 1.1752e-03 1.1051e-03 0:01:32 117

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

84 2.0509e-03 3.0335e-05 2.7216e-05 8.3158e-05 1.5952e-05 1.1219e-03 1.0494e-03 0:01:31 116

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

85 2.0156e-03 2.9825e-05 2.6591e-05 8.1374e-05 1.5823e-05 1.0713e-03 1.0122e-03 0:01:30 115

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

86 1.9752e-03 2.9256e-05 2.6016e-05 7.9744e-05 1.5632e-05 1.0234e-03 9.8274e-04 0:01:30 114

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

87 1.9365e-03 2.8707e-05 2.5447e-05 7.8222e-05 1.5510e-05 9.7685e-04 9.4227e-04 0:01:30 113

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

88 1.8999e-03 2.8209e-05 2.4878e-05 7.6478e-05 1.5365e-05 9.3181e-04 9.0181e-04 0:01:29 112

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

89 1.8643e-03 2.7651e-05 2.4324e-05 7.5134e-05 1.5243e-05 8.8926e-04 8.6639e-04 0:01:28 111

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

90 1.8237e-03 2.7240e-05 2.3838e-05 7.3470e-05 1.5185e-05 8.5023e-04 8.4360e-04 0:01:28 110

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

91 1.7699e-03 2.6984e-05 2.3450e-05 7.2173e-05 1.5068e-05 8.1236e-04 8.1925e-04 0:01:29 109

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

92 1.7618e-03 2.6488e-05 2.2936e-05 7.0727e-05 1.4918e-05 7.7580e-04 7.9761e-04 0:01:28 108

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

93 1.7386e-03 2.5962e-05 2.2463e-05 6.9139e-05 1.4866e-05 7.3998e-04 7.6691e-04 0:01:27 107

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

94 1.7161e-03 2.5512e-05 2.2054e-05 6.7721e-05 1.4774e-05 7.0593e-04 7.3794e-04 0:01:25 106

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

95 1.6988e-03 2.5082e-05 2.1695e-05 6.6418e-05 1.4626e-05 6.7363e-04 7.0986e-04 0:01:24 105

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

96 1.6829e-03 2.4724e-05 2.1344e-05 6.5050e-05 1.4549e-05 6.4845e-04 7.0419e-04 0:01:23 104

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

97 1.6663e-03 2.4341e-05 2.0953e-05 6.3945e-05 1.4424e-05 6.1750e-04 6.7311e-04 0:01:21 103

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

98 1.6696e-03 2.4018e-05 2.0643e-05 6.2726e-05 1.4310e-05 5.9359e-04 6.6300e-04 0:01:21 102

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

99 1.6527e-03 2.3696e-05 2.0365e-05 6.1651e-05 1.4295e-05 5.6455e-04 6.3302e-04 0:01:20 101

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

100 1.6369e-03 2.3505e-05 2.0146e-05 6.0536e-05 1.4185e-05 5.4412e-04 6.3318e-04 0:01:19 100

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

101 1.6201e-03 2.3292e-05 2.0007e-05 5.9313e-05 1.4260e-05 5.2358e-04 6.2974e-04 0:01:18 99

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

102 1.6109e-03 2.2752e-05 1.9595e-05 5.8239e-05 1.4171e-05 5.0262e-04 6.2655e-04 0:01:18 98

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

103 1.5941e-03 2.2652e-05 1.9491e-05 5.7057e-05 1.4127e-05 4.8101e-04 6.0688e-04 0:01:17 97

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

104 1.5687e-03 2.2076e-05 1.9025e-05 5.5983e-05 1.4084e-05 4.5999e-04 5.9190e-04 0:01:17 96

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

105 1.5643e-03 2.1828e-05 1.8869e-05 5.4933e-05 1.4048e-05 4.3949e-04 5.7159e-04 0:01:16 95

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

106 1.5575e-03 2.1483e-05 1.8595e-05 5.3862e-05 1.3964e-05 4.1952e-04 5.5325e-04 0:01:15 94

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

107 1.5543e-03 2.1177e-05 1.8361e-05 5.2837e-05 1.3951e-05 4.0105e-04 5.4023e-04 0:01:15 93

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

108 1.5349e-03 2.0957e-05 1.8133e-05 5.1761e-05 1.3881e-05 3.8289e-04 5.2818e-04 0:01:14 92

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

109 1.5213e-03 2.0570e-05 1.7879e-05 5.0749e-05 1.3913e-05 3.6553e-04 5.1777e-04 0:01:13 91

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

110 1.5168e-03 2.0241e-05 1.7607e-05 4.9756e-05 1.4055e-05 3.4833e-04 4.9868e-04 0:01:14 90

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

111 1.5102e-03 1.9950e-05 1.7360e-05 4.8795e-05 1.3997e-05 3.3165e-04 4.7322e-04 0:01:14 89

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

112 1.5013e-03 1.9668e-05 1.7054e-05 4.7816e-05 1.3994e-05 3.1641e-04 4.6289e-04 0:01:13 88

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

113 1.4970e-03 1.9348e-05 1.6768e-05 4.6870e-05 1.3871e-05 3.0259e-04 4.5732e-04 0:01:20 87

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

114 1.4876e-03 1.9074e-05 1.6629e-05 4.5969e-05 1.3830e-05 2.8911e-04 4.4704e-04 0:01:18 86

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

115 1.4614e-03 1.8758e-05 1.6392e-05 4.5067e-05 1.3785e-05 2.7652e-04 4.3993e-04 0:01:15 85

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

116 1.4351e-03 1.8489e-05 1.6137e-05 4.4265e-05 1.3886e-05 2.6484e-04 4.3280e-04 0:01:13 84

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

117 1.4210e-03 1.8235e-05 1.5954e-05 4.3194e-05 1.3958e-05 2.5322e-04 4.1298e-04 0:01:11 83

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

118 1.4102e-03 1.7895e-05 1.5643e-05 4.2353e-05 1.3845e-05 2.4240e-04 4.0536e-04 0:01:09 82

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

119 1.3875e-03 1.7548e-05 1.5350e-05 4.1506e-05 1.3860e-05 2.3243e-04 3.9819e-04 0:01:08 81

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

120 1.3639e-03 1.7267e-05 1.5140e-05 4.0708e-05 1.3796e-05 2.2279e-04 3.8659e-04 0:01:07 80

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

121 1.3387e-03 1.7061e-05 1.4924e-05 3.9797e-05 1.3934e-05 2.1319e-04 3.7103e-04 0:01:05 79

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

122 1.3230e-03 1.6652e-05 1.4534e-05 3.8973e-05 1.3963e-05 2.0445e-04 3.5176e-04 0:01:04 78

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

123 1.3098e-03 1.6366e-05 1.4252e-05 3.8067e-05 1.4014e-05 1.9689e-04 3.4483e-04 0:01:03 77

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

124 1.2877e-03 1.6176e-05 1.4082e-05 3.7251e-05 1.3957e-05 1.9011e-04 3.4110e-04 0:01:01 76

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

125 1.2660e-03 1.5840e-05 1.3850e-05 3.6584e-05 1.4024e-05 1.8328e-04 3.3152e-04 0:01:01 75

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

126 1.2428e-03 1.5500e-05 1.3580e-05 3.5977e-05 1.4112e-05 1.7776e-04 3.2489e-04 0:00:59 74

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

127 1.2369e-03 1.5278e-05 1.3397e-05 3.5094e-05 1.4254e-05 1.7283e-04 3.1341e-04 0:00:59 73

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

128 1.2348e-03 1.5390e-05 1.3484e-05 3.4766e-05 1.4110e-05 1.6889e-04 3.1673e-04 0:00:58 72

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

129 1.2098e-03 1.4939e-05 1.3041e-05 3.3698e-05 1.4164e-05 1.6501e-04 3.1670e-04 0:00:57 71

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

130 1.1981e-03 1.4624e-05 1.2791e-05 3.3023e-05 1.4094e-05 1.6066e-04 3.0683e-04 0:00:56 70

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

131 1.1949e-03 1.4249e-05 1.2465e-05 3.2477e-05 1.4104e-05 1.5668e-04 2.8747e-04 0:00:55 69

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

132 1.1810e-03 1.4158e-05 1.2332e-05 3.1723e-05 1.4033e-05 1.5332e-04 2.7016e-04 0:00:55 68

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

133 1.1683e-03 1.3857e-05 1.2096e-05 3.1230e-05 1.4012e-05 1.5067e-04 2.6669e-04 0:00:54 67

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

134 1.1625e-03 1.3617e-05 1.1922e-05 3.0637e-05 1.4063e-05 1.4872e-04 2.6747e-04 0:00:54 66

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

135 1.1536e-03 1.3256e-05 1.1651e-05 3.0071e-05 1.4096e-05 1.4683e-04 2.6406e-04 0:00:52 65

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

136 1.1515e-03 1.3035e-05 1.1462e-05 2.9695e-05 1.4070e-05 1.4565e-04 2.6377e-04 0:00:52 64

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

137 1.1363e-03 1.2938e-05 1.1417e-05 2.9203e-05 1.3960e-05 1.4317e-04 2.4805e-04 0:00:50 63

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

138 1.1315e-03 1.2592e-05 1.1086e-05 2.8726e-05 1.3968e-05 1.4231e-04 2.3853e-04 0:00:49 62

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

139 1.1215e-03 1.2440e-05 1.0945e-05 2.8220e-05 1.3917e-05 1.4268e-04 2.5920e-04 0:00:49 61

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

140 1.1110e-03 1.2194e-05 1.0731e-05 2.7782e-05 1.3973e-05 1.4202e-04 2.6246e-04 0:00:48 60

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

141 1.1058e-03 1.1936e-05 1.0596e-05 2.7507e-05 1.3891e-05 1.4022e-04 2.4922e-04 0:00:47 59

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

142 1.0986e-03 1.1701e-05 1.0384e-05 2.7149e-05 1.3913e-05 1.3803e-04 2.2726e-04 0:00:47 58

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

143 1.0906e-03 1.1457e-05 1.0194e-05 2.6874e-05 1.3793e-05 1.3673e-04 2.1648e-04 0:00:46 57

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

144 1.0813e-03 1.1279e-05 1.0000e-05 2.6503e-05 1.3696e-05 1.3574e-04 2.1971e-04 0:00:45 56

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

145 1.0781e-03 1.1105e-05 9.8650e-06 2.6159e-05 1.3634e-05 1.3517e-04 2.3030e-04 0:00:44 55

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

146 1.0758e-03 1.1230e-05 1.0094e-05 2.5800e-05 1.3622e-05 1.3460e-04 2.4015e-04 0:00:43 54

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

147 1.0686e-03 1.0893e-05 9.7930e-06 2.5505e-05 1.3644e-05 1.3230e-04 2.3087e-04 0:00:43 53

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

148 1.0619e-03 1.0634e-05 9.5227e-06 2.5266e-05 1.3559e-05 1.2998e-04 2.2325e-04 0:00:42 52

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

149 1.0425e-03 1.0394e-05 9.3293e-06 2.4922e-05 1.3462e-05 1.2703e-04 2.0641e-04 0:00:42 51

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

150 1.0354e-03 1.0160e-05 9.1255e-06 2.4592e-05 1.3491e-05 1.2552e-04 2.0565e-04 0:00:41 50

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

151 1.0294e-03 1.0045e-05 9.0153e-06 2.4367e-05 1.3575e-05 1.2484e-04 2.2542e-04 0:00:40 49

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

152 1.0235e-03 9.9222e-06 8.8944e-06 2.4046e-05 1.3634e-05 1.2259e-04 2.2341e-04 0:00:39 48

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

153 1.0157e-03 9.7152e-06 8.7392e-06 2.3827e-05 1.3674e-05 1.2025e-04 2.1932e-04 0:00:38 47

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

154 1.0024e-03 9.5516e-06 8.5589e-06 2.3558e-05 1.3607e-05 1.1557e-04 1.8099e-04 0:00:37 46

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

155 9.9356e-04 9.3633e-06 8.4069e-06 2.3276e-05 1.3666e-05 1.1307e-04 1.7165e-04 0:00:37 45

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

156 9.8645e-04 9.2809e-06 8.2675e-06 2.3017e-05 1.3689e-05 1.1146e-04 1.7950e-04 0:00:36 44

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

157 9.8452e-04 9.2437e-06 8.2414e-06 2.2698e-05 1.3748e-05 1.0924e-04 1.7674e-04 0:00:35 43

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

158 9.8125e-04 9.0525e-06 8.1717e-06 2.2519e-05 1.3840e-05 1.0799e-04 1.8707e-04 0:00:34 42

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

159 9.8106e-04 9.0383e-06 8.1348e-06 2.2409e-05 1.3824e-05 1.0598e-04 1.9014e-04 0:00:33 41

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

160 9.7497e-04 8.8118e-06 7.9329e-06 2.2142e-05 1.3858e-05 1.0341e-04 1.8866e-04 0:00:32 40

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

161 9.7854e-04 8.6899e-06 7.7935e-06 2.1878e-05 1.3859e-05 1.0058e-04 1.7973e-04 0:00:32 39

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

162 9.7481e-04 8.6468e-06 7.7248e-06 2.1471e-05 1.3883e-05 9.7275e-05 1.5420e-04 0:00:31 38

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

163 9.6982e-04 8.5462e-06 7.6376e-06 2.1253e-05 1.3892e-05 9.7392e-05 1.8777e-04 0:00:30 37

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

164 9.6536e-04 8.5167e-06 7.5783e-06 2.1057e-05 1.3997e-05 9.5318e-05 1.8490e-04 0:00:29 36

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

165 9.5506e-04 8.3469e-06 7.4677e-06 2.0825e-05 1.4160e-05 9.2900e-05 1.8112e-04 0:00:28 35

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

166 9.5479e-04 8.2131e-06 7.3472e-06 2.0713e-05 1.4214e-05 9.0768e-05 1.7569e-04 0:00:27 34

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

167 9.4002e-04 8.1289e-06 7.2502e-06 2.0487e-05 1.4259e-05 8.6874e-05 1.3709e-04 0:00:26 33

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

168 9.3724e-04 7.9495e-06 7.1047e-06 2.0275e-05 1.4347e-05 8.5154e-05 1.4307e-04 0:00:25 32

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

169 9.3344e-04 7.8873e-06 7.0108e-06 2.0007e-05 1.4300e-05 8.3231e-05 1.4199e-04 0:00:25 31

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

170 9.3503e-04 7.7732e-06 6.9806e-06 1.9789e-05 1.4208e-05 8.1860e-05 1.4606e-04 0:00:24 30

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

171 9.2226e-04 7.6633e-06 6.9421e-06 1.9598e-05 1.4185e-05 8.1292e-05 1.5840e-04 0:00:23 29

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

172 9.1411e-04 7.6368e-06 6.8729e-06 1.9388e-05 1.4216e-05 7.9798e-05 1.6103e-04 0:00:23 28

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

173 8.9927e-04 7.4781e-06 6.7456e-06 1.9210e-05 1.4173e-05 7.7628e-05 1.6076e-04 0:00:22 27

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

174 8.9231e-04 7.4087e-06 6.6604e-06 1.8943e-05 1.4196e-05 7.4255e-05 1.3111e-04 0:00:22 26

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

175 8.7971e-04 7.3214e-06 6.5570e-06 1.8634e-05 1.4268e-05 7.4339e-05 1.5184e-04 0:00:21 25

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

176 8.7596e-04 7.2666e-06 6.5508e-06 1.8496e-05 1.4242e-05 7.4132e-05 1.6416e-04 0:00:20 24

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

177 8.6764e-04 7.2712e-06 6.5328e-06 1.8120e-05 1.4251e-05 7.2695e-05 1.6301e-04 0:00:19 23

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

178 8.6634e-04 7.0842e-06 6.3998e-06 1.7885e-05 1.4271e-05 7.1845e-05 1.6904e-04 0:00:18 22

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

179 8.6327e-04 6.9855e-06 6.2915e-06 1.7548e-05 1.4287e-05 6.7730e-05 1.2644e-04 0:00:17 21

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

180 8.5602e-04 6.8550e-06 6.1301e-06 1.7236e-05 1.4337e-05 6.6437e-05 1.2238e-04 0:00:16 20

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

181 8.5464e-04 6.7587e-06 6.0735e-06 1.7105e-05 1.4374e-05 6.5682e-05 1.2850e-04 0:00:15 19

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

182 8.4855e-04 6.7479e-06 6.0427e-06 1.6773e-05 1.4351e-05 6.4572e-05 1.2942e-04 0:00:15 18

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

183 8.4149e-04 6.6544e-06 6.0282e-06 1.6510e-05 1.4400e-05 6.4555e-05 1.4329e-04 0:00:14 17

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

184 8.3359e-04 6.6064e-06 5.9825e-06 1.6226e-05 1.4368e-05 6.3604e-05 1.4609e-04 0:00:13 16

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

185 8.3110e-04 6.4388e-06 5.8299e-06 1.5936e-05 1.4354e-05 6.1630e-05 1.4452e-04 0:00:13 15

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

186 8.3179e-04 6.3255e-06 5.7457e-06 1.5803e-05 1.4315e-05 5.9852e-05 1.2985e-04 0:00:12 1

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

187 8.3412e-04 6.3568e-06 5.7082e-06 1.5510e-05 1.4249e-05 5.9577e-05 1.3574e-04 0:00:11 13

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

188 8.2056e-04 6.3604e-06 5.7491e-06 1.5287e-05 1.4225e-05 5.9869e-05 1.5202e-04 0:00:10 12

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

189 8.2108e-04 6.3667e-06 5.6647e-06 1.4895e-05 1.4121e-05 5.8685e-05 1.4859e-04 0:00:09 11

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

190 8.2626e-04 6.2006e-06 5.5511e-06 1.4508e-05 1.4168e-05 5.8215e-05 1.5220e-04 0:00:08 10

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

191 8.2027e-04 6.1983e-06 5.5352e-06 1.4288e-05 1.4064e-05 5.5888e-05 1.2718e-04 0:00:08 9

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

192 8.1804e-04 6.0892e-06 5.3983e-06 1.4046e-05 1.4129e-05 5.4083e-05 1.0981e-04 0:00:07 8

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

193 8.1899e-04 6.0017e-06 5.3291e-06 1.3864e-05 1.4031e-05 5.3502e-05 1.1887e-04 0:00:06 7

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

194 8.2091e-04 5.9726e-06 5.2966e-06 1.3532e-05 1.4031e-05 5.2441e-05 1.1681e-04 0:00:05 6

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

195 8.1939e-04 5.8528e-06 5.2345e-06 1.3167e-05 1.3961e-05 5.1862e-05 1.2427e-04 0:00:04

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

196 8.2044e-04 5.7537e-06 5.2155e-06 1.3072e-05 1.3965e-05 5.1984e-05 1.3358e-04 0:00:03 4

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

197 8.1446e-04 5.6917e-06 5.1378e-06 1.2814e-05 1.3921e-05 5.0442e-05 1.3422e-04 0:00:03 3

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

198 8.0849e-04 5.6060e-06 5.0860e-06 1.2660e-05 1.3911e-05 4.8825e-05 1.2186e-04 0:00:02 2

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

199 8.0389e-04 5.6456e-06 5.0372e-06 1.2396e-05 1.3948e-05 4.7711e-05 1.1152e-04 0:00:01 1

Reversed flow on 16 faces (4.1% area) of pressure-outlet 6.

200 7.9672e-04 5.6005e-06 5.0299e-06 1.2142e-05 1.3968e-05 4.7848e-05 1.3011e-04 0:00:00 0

Appendix C - Iterations for case 3

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

1 1.0000e+00 1.1134e-04 8.5995e-05 5.2600e-04 5.1542e-04 1.1501e+02 3.4001e+05 0:05:55 199

2 1.0000e+00 3.8897e-02 3.7949e-02 7.0543e-02 9.5857e-04 2.0299e-01 3.7880e-01 0:06:00 198

Reversed flow on 1 face (0.2% area) of pressure-outlet 6.

3 2.7183e-01 2.9411e-02 2.9027e-02 3.5754e-02 7.0709e-04 1.0383e-01 1.5522e-01 0:05:48 197

Reversed flow on 15 faces (4.0% area) of pressure-outlet 6.

4 1.2783e-01 1.4323e-02 1.4397e-02 1.9179e-02 4.0256e-04 7.9729e-02 1.5231e-01 0:05:25 196

Revrsed flow on 34 faces (9.4% area) of pressure-outlet 6.

5 6.1726e-02 5.9066e-03 5.8812e-03 9.9763e-03 2.1935e-04 6.7606e-02 1.4805e-01 0:05:06 195

Reversed flow on 41 faces (11.5% area) of pressure-outlet 6.

6 4.4643e-02 3.2756e-03 3.2850e-03 7.5239e-03 1.3602e-04 4.4308e-02 1.2392e-01 0:04:50 194

Reversed flow on 44 faces (12.3% area) of pressure-outlet 6.

7 3.1561e-02 1.7400e-03 1.7337e-03 5.4476e-03 7.7371e-05 3.1839e-02 1.0781e-01 0:04:37 193

Reversed flow on 47 faces (13.2% area) of pressure-outlet 6.

8 2.5434e-02 1.4523e-03 1.4496e-03 3.8402e-03 4.7706e-05 2.6584e-02 1.1458e-01 0:04:27 19

Reversed flow on 51 faces (14.3% area) of pressure-outlet 6.

9 2.1394e-02 1.3454e-03 1.3598e-03 2.6726e-03 3.4952e-05 2.4186e-02 1.3334e-01 0:04:17 191

Reversed flow on 48 faces (13.3% area) of pressure-outlet 6.

10 1.6101e-02 9.0322e-04 9.1767e-04 2.1925e-03 2.4343e-05 1.9255e-02 1.2003e-01 0:04:10 190

Reversed flow on 42 faces (11.6% area) of pressure-outlet 6.

11 1.2873e-02 6.9620e-04 6.9478e-04 1.8309e-03 1.8250e-05 1.6040e-02 1.1446e-01 0:04:05 18

Reversed flow on 38 faces (10.6% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

12 1.0456e-02 5.7409e-04 5.6792e-04 1.5678e-03 1.5038e-05 1.2738e-02 9.8748e-02 0:03:59 188

Reversed flow on 36 faces (10.1% area) of pressure-outlet 6.

13 8.8224e-03 4.9119e-04 4.8322e-04 1.2692e-03 1.2462e-05 1.0603e-02 9.5175e-02 0:03:56 187

Reversed flow on 34 faces (9.5% area) of pressure-outlet 6.

14 7.4133e-03 4.1315e-04 4.0682e-04 1.0816e-03 1.0555e-05 9.2274e-03 1.0161e-01 0:03:52 186

Reversed flow on 33 faces (9.1% area) of pressure-outlet 6.

15 6.6830e-03 3.7870e-04 3.7726e-04 8.8528e-04 9.2555e-06 7.9471e-03 9.5503e-02 0:03:49 185

Reversed flow on 32 faces (8.9% area) of pressure-outlet 6.

16 5.5864e-03 3.0084e-04 3.0044e-04 8.1059e-04 8.6128e-06 6.7001e-03 8.3026e-02 0:03:48 184

Reversed flow on 27 faces (7.5% area) of pressure-outlet 6.

17 4.9405e-03 2.5899e-04 2.5805e-04 7.3566e-04 7.9245e-06 5.9176e-03 7.2746e-02 0:03:47 183

Reversed flow on 25 faces (7.0% area) of pressure-outlet 6.

18 4.4298e-03 2.2460e-04 2.2282e-04 6.9856e-04 6.7952e-06 5.3676e-03 6.6586e-02 0:03:45 182

Reversed flow on 25 faces (7.0% area) of pressure-outlet 6.

19 4.1228e-03 2.1689e-04 2.1368e-04 6.2514e-04 6.8202e-06 4.9807e-03 6.2693e-02 0:03:43 181

Reversed flow on 23 faces (6.4% area) of pressure-outlet 6.

20 3.6646e-03 1.9546e-04 1.9395e-04 5.6847e-04 6.3151e-06 4.6628e-03 5.7633e-02 0:03:43 180

Reversed flow on 21 faces (5.8% area) of pressure-outlet 6.

21 3.2753e-03 1.7209e-04 1.7120e-04 5.2804e-04 6.1590e-06 4.4157e-03 5.2751e-02 0:03:39 179

Reversed flow on 20 faces (5.4% area) of pressure-outlet 6.

22 2.9966e-03 1.5768e-04 1.5599e-04 5.0037e-04 5.2595e-06 4.1655e-03 4.6537e-02 0:03:39 178

Reversed flow on 20 faces (5.4% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

23 2.7809e-03 1.4888e-04 1.4787e-04 4.6445e-04 5.3294e-06 4.0539e-03 4.4580e-02 0:03:37 177

Reversed flow on 19 faces (5.1% area) of pressure-outlet 6.

24 2.5866e-03 1.3985e-04 1.3824e-04 4.4099e-04 4.8127e-06 4.0603e-03 4.4488e-02 0:03:36 176

Reversed flow on 19 faces (5.1% area) of pressure-outlet 6.

25 2.4129e-03 1.3216e-04 1.3044e-04 4.1890e-04 4.8423e-06 3.7676e-03 3.6357e-02 0:03:33 175

Reversed flow on 19 faces (5.1% area) of pressure-outlet 6.

26 2.2604e-03 1.2512e-04 1.2341e-04 3.9654e-04 4.3334e-06 3.6453e-03 3.2477e-02 0:03:32 174

Reversed flow on 19 faces (5.1% area) of pressure-outlet 6.

27 2.1240e-03 1.1853e-04 1.1714e-04 3.7819e-04 4.4436e-06 3.5415e-03 2.9243e-02 0:03:30 173

Reversed flow on 18 faces (4.8% area) of pressure-outlet 6.

28 2.0179e-03 1.1326e-04 1.1180e-04 3.6295e-04 3.9990e-06 3.4625e-03 2.6677e-02 0:03:30 172

Reversed flow on 19 faces (5.1% area) of pressure-outlet 6.

29 1.8878e-03 1.0838e-04 1.0751e-04 3.4651e-04 4.1135e-06 3.3770e-03 2.4130e-02 0:03:29 171

Reversed flow on 19 faces (5.1% area) of pressure-outlet 6.

30 1.7725e-03 1.0339e-04 1.0262e-04 3.3331e-04 3.6938e-06 3.2998e-03 2.1415e-02 0:03:27 170

Reversed flow on 19 faces (5.1% area) of pressure-outlet 6.

31 1.6780e-03 9.9013e-05 9.8585e-05 3.2073e-04 3.8099e-06 3.2305e-03 1.9174e-02 0:03:26 169

Reversed flow on 18 faces (4.8% area) of pressure-outlet 6.

32 1.5940e-03 9.4996e-05 9.4800e-05 3.1015e-04 3.4392e-06 3.1743e-03 1.7374e-02 0:03:25 168

Reversed flow on 18 faces (4.8% area) of pressure-outlet 6.

33 1.5228e-03 9.2135e-05 9.1952e-05 3.0014e-04 3.5547e-06 3.1195e-03 1.5899e-02 0:03:24 167

Reversed flow on 18 faces (4.8% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

34 1.4493e-03 8.8521e-05 8.8545e-05 2.9054e-04 3.2231e-06 3.0789e-03 1.4752e-02 0:03:25 166

Reversed flow on 18 faces (4.8% area) of pressure-outlet 6.

35 1.3828e-03 8.5546e-05 8.5847e-05 2.8225e-04 3.3597e-06 3.0360e-03 1.3721e-02 0:03:21 165

Reversed flow on 18 faces (4.8% area) of pressure-outlet 6.

36 1.3189e-03 8.2761e-05 8.2966e-05 2.7428e-04 3.0461e-06 2.9905e-03 1.2748e-02 0:03:21 164

Reversed flow on 18 faces (4.8% area) of pressure-outlet 6.

37 1.2610e-03 8.0476e-05 8.0677e-05 2.6697e-04 3.1662e-06 2.9547e-03 1.2364e-02 0:03:17 163

Reversed flow on 17 faces (4.5% area) of pressure-outlet 6.

38 1.2179e-03 7.8451e-05 7.8415e-05 2.6015e-04 2.9119e-06 2.9173e-03 1.1627e-02 0:03:17 162

Reversed flow on 17 faces (4.5% area) of pressure-outlet 6.

39 1.1584e-03 7.6756e-05 7.6682e-05 2.5461e-04 3.0159e-06 2.8796e-03 1.1182e-02 0:03:17 161

Reversed flow on 17 faces (4.5% area) of pressure-outlet 6.

40 1.1086e-03 7.4847e-05 7.4626e-05 2.4874e-04 2.7785e-06 2.8434e-03 1.0679e-02 0:03:17 160

Reversed flow on 17 faces (4.5% area) of pressure-outlet 6.

41 1.0633e-03 7.2839e-05 7.2906e-05 2.4356e-04 2.8984e-06 2.7820e-03 1.0004e-02 0:03:15 159

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

42 1.0116e-03 7.1196e-05 7.1138e-05 2.3830e-04 2.6637e-06 2.7213e-03 9.3771e-03 0:03:15 158

Reversed flow on 15 faces (3.8% area) of pressure-outlet 6.

43 9.6434e-04 7.0026e-05 6.9605e-05 2.3355e-04 2.7301e-06 2.6575e-03 8.7363e-03 0:03:13 157

Reversed flow on 14 faces (3.5% area) of pressure-outlet 6.

44 9.2550e-04 6.8865e-05 6.8269e-05 2.2892e-04 2.5126e-06 2.6086e-03 8.4179e-03 0:03:11 156

Reversed flow on 14 faces (3.5% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

45 8.8347e-04 6.7464e-05 6.6760e-05 2.2456e-04 2.5083e-06 2.5530e-03 7.9455e-03 0:03:10 155

Reversed flow on 14 faces (3.5% area) of pressure-outlet 6.

46 8.5217e-04 6.6181e-05 6.5261e-05 2.2044e-04 2.5596e-06 2.4936e-03 7.3955e-03 0:03:08 154

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

47 8.1920e-04 6.5018e-05 6.3577e-05 2.1636e-04 2.3437e-06 2.4403e-03 7.1161e-03 0:03:09 153

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

48 7.9382e-04 6.3761e-05 6.2111e-05 2.1249e-04 2.3326e-06 2.3844e-03 6.6519e-03 0:03:07 152

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

49 7.6545e-04 6.2592e-05 6.0663e-05 2.0875e-04 2.3678e-06 2.3295e-03 6.3298e-03 0:03:06 151

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

50 7.4337e-04 6.1340e-05 5.9337e-05 2.0523e-04 2.1692e-06 2.2741e-03 5.9308e-03 0:03:03 150

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

51 7.2103e-04 6.0062e-05 5.7988e-05 2.0163e-04 2.1745e-06 2.2229e-03 5.6480e-03 0:03:02 149

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

52 7.0226e-04 5.8763e-05 5.6715e-05 1.9823e-04 2.1398e-06 2.1687e-03 5.2947e-03 0:03:01 148

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

53 6.8255e-04 5.7614e-05 5.5515e-05 1.9497e-04 2.1108e-06 2.1182e-03 5.0012e-03 0:03:01 147

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

54 6.6290e-04 5.6346e-05 5.4347e-05 1.9188e-04 2.0663e-06 2.0675e-03 4.7237e-03 0:03:02 146

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

55 6.4861e-04 5.5316e-05 5.3337e-05 1.8874e-04 2.0380e-06 2.0203e-03 4.4922e-03 0:03:00 145

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

56 6.3329e-04 5.4133e-05 5.2257e-05 1.8575e-04 1.9954e-06 1.9741e-03 4.3038e-03 0:02:58 144

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

57 6.1792e-04 5.3164e-05 5.1277e-05 1.8284e-04 1.9515e-06 1.9302e-03 4.1301e-03 0:02:56 143

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

58 6.0198e-04 5.2129e-05 5.0325e-05 1.8024e-04 1.9243e-06 1.8884e-03 3.9976e-03 0:02:54 142

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

59 5.9219e-04 5.1243e-05 4.9437e-05 1.7758e-04 1.8930e-06 1.8478e-03 3.8552e-03 0:02:51 141

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

60 5.8264e-04 5.0449e-05 4.8679e-05 1.7508e-04 1.8555e-06 1.8043e-03 3.7050e-03 0:02:50 140

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

61 5.6956e-04 4.9760e-05 4.7970e-05 1.7246e-04 1.8271e-06 1.7616e-03 3.5438e-03 0:02:48 139

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

62 5.5565e-04 4.8866e-05 4.7107e-05 1.7011e-04 1.8028e-06 1.7185e-03 3.4053e-03 0:02:46 138

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

63 5.4483e-04 4.7889e-05 4.6295e-05 1.6786e-04 1.7752e-06 1.6770e-03 3.2766e-03 0:02:46 137

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

64 5.3188e-04 4.7142e-05 4.5433e-05 1.6578e-04 1.7526e-06 1.6343e-03 3.1231e-03 0:02:45 136

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

65 5.2291e-04 4.6301e-05 4.4653e-05 1.6372e-04 1.7300e-06 1.5938e-03 3.0112e-03 0:02:45 135

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

66 5.1702e-04 4.5790e-05 4.3950e-05 1.6165e-04 1.7078e-06 1.5528e-03 2.8975e-03 0:02:43 134

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

67 5.0889e-04 4.4933e-05 4.3203e-05 1.5979e-04 1.6856e-06 1.5141e-03 2.8068e-03 0:02:42 133

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

68 5.0060e-04 4.4376e-05 4.2591e-05 1.5781e-04 1.6614e-06 1.4762e-03 2.7256e-03 0:02:42 132

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

69 4.9383e-04 4.3626e-05 4.1849e-05 1.5636e-04 1.6484e-06 1.4384e-03 2.6332e-03 0:02:40 131

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

70 4.8717e-04 4.3202e-05 4.1346e-05 1.5448e-04 1.6274e-06 1.3974e-03 2.5075e-03 0:02:39 130

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

71 4.8343e-04 4.2249e-05 4.0403e-05 1.5274e-04 1.6169e-06 1.3613e-03 2.4304e-03 0:02:38 129

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

72 4.8352e-04 4.1818e-05 3.9995e-05 1.5083e-04 1.5951e-06 1.3239e-03 2.3214e-03 0:02:37 128

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

73 4.7154e-04 4.1002e-05 3.9281e-05 1.4906e-04 1.5728e-06 1.2869e-03 2.2352e-03 0:02:36 127

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

74 4.6856e-04 4.0295e-05 3.8489e-05 1.4727e-04 1.5505e-06 1.2519e-03 2.1538e-03 0:02:35 126

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

75 4.6134e-04 3.9548e-05 3.7855e-05 1.4564e-04 1.5359e-06 1.2166e-03 2.0595e-03 0:02:33 125

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

76 4.5339e-04 3.8972e-05 3.7292e-05 1.4393e-04 1.5175e-06 1.1831e-03 1.9825e-03 0:02:33 124

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

77 4.4805e-04 3.8290e-05 3.6654e-05 1.4240e-04 1.5028e-06 1.1507e-03 1.9026e-03 0:02:30 123

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

78 4.4524e-04 3.7789e-05 3.6110e-05 1.4080e-04 1.4938e-06 1.1197e-03 1.8380e-03 0:02:28 122

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

79 4.4430e-04 3.7064e-05 3.5486e-05 1.3947e-04 1.4900e-06 1.0915e-03 1.7749e-03 0:02:26 121

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

80 4.4150e-04 3.6567e-05 3.5081e-05 1.3794e-04 1.4776e-06 1.0641e-03 1.7032e-03 0:02:24 120

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

81 4.3696e-04 3.5885e-05 3.4437e-05 1.3664e-04 1.4625e-06 1.0397e-03 1.6506e-03 0:02:23 119

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

82 4.3307e-04 3.5390e-05 3.4053e-05 1.3505e-04 1.4496e-06 1.0177e-03 1.5866e-03 0:02:20 118

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

83 4.2449e-04 3.4742e-05 3.3432e-05 1.3375e-04 1.4464e-06 9.9762e-04 1.5295e-03 0:02:19 117

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

84 4.2276e-04 3.4250e-05 3.3017e-05 1.3218e-04 1.4412e-06 9.8193e-04 1.4811e-03 0:02:17 116

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

85 4.1852e-04 3.3700e-05 3.2488e-05 1.3084e-04 1.4353e-06 9.6693e-04 1.4262e-03 0:02:15 115

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

86 4.1726e-04 3.3247e-05 3.2043e-05 1.2936e-04 1.4308e-06 9.5616e-04 1.3842e-03 0:02:14 114

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

87 4.1254e-04 3.2711e-05 3.1579e-05 1.2801e-04 1.4253e-06 9.4689e-04 1.3356e-03 0:02:13 113

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

88 4.0971e-04 3.2301e-05 3.1114e-05 1.2665e-04 1.4173e-06 9.4037e-04 1.2865e-03 0:02:11 112

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

89 4.0620e-04 3.1730e-05 3.0622e-05 1.2535e-04 1.4159e-06 9.3651e-04 1.2568e-03 0:02:10 111

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

90 4.0141e-04 3.1360e-05 3.0222e-05 1.2399e-04 1.4038e-06 9.3291e-04 1.2167e-03 0:02:09 110

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

91 3.9490e-04 3.0827e-05 2.9737e-05 1.2284e-04 1.4057e-06 9.2872e-04 1.1790e-03 0:02:09 109

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

92 3.9342e-04 3.0329e-05 2.9421e-05 1.2152e-04 1.4070e-06 9.2583e-04 1.1525e-03 0:02:08 10

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

93 3.8781e-04 2.9897e-05 2.9011e-05 1.2033e-04 1.4153e-06 9.2124e-04 1.1165e-03 0:02:06 107

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

94 3.8784e-04 2.9401e-05 2.8639e-05 1.1908e-04 1.4095e-06 9.1875e-04 1.1012e-03 0:02:05 106

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

95 3.8391e-04 2.9008e-05 2.8321e-05 1.1798e-04 1.4042e-06 9.1578e-04 1.0801e-03 0:02:04 105

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

96 3.8518e-04 2.8626e-05 2.8040e-05 1.1688e-04 1.3914e-06 9.1279e-04 1.0565e-03 0:02:02 104

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

97 3.7927e-04 2.8228e-05 2.7704e-05 1.1584e-04 1.3882e-06 9.1046e-04 1.0444e-03 0:02:01 103

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

98 3.8240e-04 2.7950e-05 2.7437e-05 1.1474e-04 1.3937e-06 9.0719e-04 1.0130e-03 0:02:00 102

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

99 3.8088e-04 2.7592e-05 2.7137e-05 1.1370e-04 1.4009e-06 9.0468e-04 9.9385e-04 0:01:59 101

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

100 3.7805e-04 2.7267e-05 2.6829e-05 1.1257e-04 1.3974e-06 9.0341e-04 9.8145e-04 0:01:58 100

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

101 3.7767e-04 2.6956e-05 2.6566e-05 1.1159e-04 1.3932e-06 9.0131e-04 9.6149e-04 0:01:56 99

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

102 3.7377e-04 2.6681e-05 2.6279e-05 1.1055e-04 1.3848e-06 9.0054e-04 9.4828e-04 0:01:55 98

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

103 3.7329e-04 2.6415e-05 2.6045e-05 1.0965e-04 1.3949e-06 9.0004e-04 9.3846e-04 0:01:55 97

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

104 3.7553e-04 2.6254e-05 2.5881e-05 1.0871e-04 1.4043e-06 9.0014e-04 9.3003e-04 0:01:54 96

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

105 3.7205e-04 2.5984e-05 2.5599e-05 1.0783e-04 1.4048e-06 9.0051e-04 9.3236e-04 0:01:52 95

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

106 3.6796e-04 2.5804e-05 2.5453e-05 1.0682e-04 1.4113e-06 9.0122e-04 9.2245e-04 0:01:51 94

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

107 3.7279e-04 2.5586e-05 2.5170e-05 1.0595e-04 1.4250e-06 9.0511e-04 9.4595e-04 0:01:52 93

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

108 3.7343e-04 2.5342e-05 2.4998e-05 1.0493e-04 1.4212e-06 9.0936e-04 9.5998e-04 0:01:51 92

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

109 3.7148e-04 2.5174e-05 2.4831e-05 1.0399e-04 1.4153e-06 9.1354e-04 9.8411e-04 0:01:51 91

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

110 3.7269e-04 2.4979e-05 2.4714e-05 1.0292e-04 1.4108e-06 9.1697e-04 9.8495e-04 0:01:51 90

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

111 3.7085e-04 2.4804e-05 2.4533e-05 1.0203e-04 1.4157e-06 9.2025e-04 9.9297e-04 0:01:55 89

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

112 3.7043e-04 2.4633e-05 2.4345e-05 1.0107e-04 1.4180e-06 9.2319e-04 9.8621e-04 0:01:52 88

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

113 3.7009e-04 2.4441e-05 2.4122e-05 1.0027e-04 1.4199e-06 9.2690e-04 1.0120e-03 0:01:49 87

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

114 3.7142e-04 2.4260e-05 2.4035e-05 9.9213e-05 1.4331e-06 9.2977e-04 1.0010e-03 0:01:47 86

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

115 3.6767e-04 2.4082e-05 2.3862e-05 9.8441e-05 1.4298e-06 9.3241e-04 1.0088e-03 0:01:49 85

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

116 3.6659e-04 2.3892e-05 2.3785e-05 9.7451e-05 1.4275e-06 9.3690e-04 1.0211e-03 0:01:46 84

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

117 3.6646e-04 2.3835e-05 2.3756e-05 9.6749e-05 1.4363e-06 9.3987e-04 1.0312e-03 0:01:44 83

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

118 3.6259e-04 2.3669e-05 2.3656e-05 9.5860e-05 1.4389e-06 9.4615e-04 1.0615e-03 0:01:42 82

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

119 3.6089e-04 2.3704e-05 2.3661e-05 9.5321e-05 1.4401e-06 9.5052e-04 1.0740e-03 0:01:40 81

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

120 3.6298e-04 2.3753e-05 2.3770e-05 9.4464e-05 1.4449e-06 9.5257e-04 1.0552e-03 0:01:37 80

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

121 3.5980e-04 2.3490e-05 2.3523e-05 9.3725e-05 1.4623e-06 9.5599e-04 1.0702e-03 0:01:36 79

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

122 3.5982e-04 2.3314e-05 2.3435e-05 9.2922e-05 1.4728e-06 9.6101e-04 1.0782e-03 0:01:35 78

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

123 3.5709e-04 2.3305e-05 2.3444e-05 9.2544e-05 1.4839e-06 9.6529e-04 1.0977e-03 0:01:33 77

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

124 3.5823e-04 2.3175e-05 2.3365e-05 9.1762e-05 1.4940e-06 9.6829e-04 1.0583e-03 0:01:32 76

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

125 3.5520e-04 2.3017e-05 2.3212e-05 9.1122e-05 1.4853e-06 9.7056e-04 1.0649e-03 0:01:32 75

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

126 3.5350e-04 2.2783e-05 2.3071e-05 9.0376e-05 1.4900e-06 9.7487e-04 1.0650e-03 0:01:30 7

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

127 3.5142e-04 2.2744e-05 2.3028e-05 8.9823e-05 1.4997e-06 9.7743e-04 1.0470e-03 0:01:29 73

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

128 3.5417e-04 2.2606e-05 2.2871e-05 8.9257e-05 1.5269e-06 9.8368e-04 1.0717e-03 0:01:28 72

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

129 3.6080e-04 2.2591e-05 2.2840e-05 8.8911e-05 1.5085e-06 9.8709e-04 1.0720e-03 0:01:27 71

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

130 3.5690e-04 2.2604e-05 2.2963e-05 8.8480e-05 1.5100e-06 9.9020e-04 1.0583e-03 0:01:26 7

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

131 3.4884e-04 2.2273e-05 2.2658e-05 8.7968e-05 1.5225e-06 9.9380e-04 1.0677e-03 0:01:26 69

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

132 3.4559e-04 2.2186e-05 2.2701e-05 8.7382e-05 1.5217e-06 9.9930e-04 1.0865e-03 0:01:25 68

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

133 3.4546e-04 2.2189e-05 2.2681e-05 8.7351e-05 1.5230e-06 1.0036e-03 1.0750e-03 0:01:23 67

Reversed flow on 12 faces (3.1% area) of pressure-outlet 6.

134 3.4297e-04 2.2147e-05 2.2668e-05 8.6863e-05 1.5380e-06 1.0081e-03 1.0309e-03 0:01:21 66

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

135 3.4622e-04 2.1957e-05 2.2539e-05 8.6550e-05 1.5489e-06 1.0146e-03 1.0598e-03 0:01:20 65

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

136 3.4711e-04 2.1898e-05 2.2516e-05 8.6158e-05 1.5753e-06 1.0206e-03 1.0679e-03 0:01:18 64

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

137 3.4316e-04 2.1784e-05 2.2453e-05 8.6002e-05 1.5697e-06 1.0256e-03 1.0558e-03 0:01:17 63

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

138 3.4332e-04 2.1758e-05 2.2387e-05 8.5662e-05 1.5978e-06 1.0308e-03 1.0513e-03 0:01:16 62

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

139 3.4152e-04 2.1670e-05 2.2396e-05 8.5512e-05 1.5895e-06 1.0364e-03 1.0517e-03 0:01:14 61

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

140 3.4299e-04 2.1587e-05 2.2332e-05 8.5184e-05 1.6142e-06 1.0436e-03 1.0735e-03 0:01:12 60

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

141 3.450e-04 2.1494e-05 2.2243e-05 8.5073e-05 1.6043e-06 1.0491e-03 1.0774e-03 0:01:12 59

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

142 3.3982e-04 2.1534e-05 2.2312e-05 8.4878e-05 1.6308e-06 1.0551e-03 1.0754e-03 0:01:10 58

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

143 3.4236e-04 2.1458e-05 2.2256e-05 8.4751e-05 1.6269e-06 1.0615e-03 1.0736e-03 0:01:10 57

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

144 3.4221e-04 2.1406e-05 2.2271e-05 8.4572e-05 1.6548e-06 1.0689e-03 1.0808e-03 0:01:09 56

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

145 3.4677e-04 2.1354e-05 2.2224e-05 8.4507e-05 1.6646e-06 1.0748e-03 1.0809e-03 0:01:08 55

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

146 3.4696e-04 2.1375e-05 2.2243e-05 8.4256e-05 1.6835e-06 1.0804e-03 1.0676e-03 0:01:06 54

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

147 3.4696e-04 2.1348e-05 2.2258e-05 8.4118e-05 1.6648e-06 1.0855e-03 1.0565e-03 0:01:05 53

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

148 3.4863e-04 2.1280e-05 2.2205e-05 8.3955e-05 1.6874e-06 1.0932e-03 1.0616e-03 0:01:04 52

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

149 3.4935e-04 2.1350e-05 2.2303e-05 8.3866e-05 1.6830e-06 1.1010e-03 1.0669e-03 0:01:03 51

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

150 3.4704e-04 2.1409e-05 2.2362e-05 8.3748e-05 1.7205e-06 1.1068e-03 1.0523e-03 0:01:01 50

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

151 3.5006e-04 2.1344e-05 2.2336e-05 8.3547e-05 1.7095e-06 1.1111e-03 1.0463e-03 0:01:00 49

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

152 3.5000e-04 2.1288e-05 2.2285e-05 8.3315e-05 1.7430e-06 1.1204e-03 1.0831e-03 0:00:58 48

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

153 3.5207e-04 2.1435e-05 2.2431e-05 8.3342e-05 1.7357e-06 1.1260e-03 1.0756e-03 0:00:57 47

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

154 3.4845e-04 2.1410e-05 2.2463e-05 8.3286e-05 1.7614e-06 1.1324e-03 1.0768e-03 0:00:56 46

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

155 3.4719e-04 2.1329e-05 2.2415e-05 8.3095e-05 1.7452e-06 1.1370e-03 1.0743e-03 0:00:54 45

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

156 3.4856e-04 2.1334e-05 2.2452e-05 8.2980e-05 1.7852e-06 1.1447e-03 1.0858e-03 0:00:53 44

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

157 3.5393e-04 2.1431e-05 2.2613e-05 8.2820e-05 1.7655e-06 1.1499e-03 1.0916e-03 0:00:51 43

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

158 3.4996e-04 2.1412e-05 2.2550e-05 8.2513e-05 1.7987e-06 1.1530e-03 1.0622e-03 0:00:50 42

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

159 3.5593e-04 2.1350e-05 2.2445e-05 8.2314e-05 1.8013e-06 1.1576e-03 1.0586e-03 0:00:49 41

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

160 3.5179e-04 2.1299e-05 2.2310e-05 8.2078e-05 1.8312e-06 1.1651e-03 1.0791e-03 0:00:49 40

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

161 3.5978e-04 2.1356e-05 2.2364e-05 8.2066e-05 1.8093e-06 1.1690e-03 1.0731e-03 0:00:49 39

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

162 3.6093e-04 2.1343e-05 2.2322e-05 8.1688e-05 1.8604e-06 1.1722e-03 1.0556e-03 0:00:48 38

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

163 3.6383e-04 2.1215e-05 2.2247e-05 8.1402e-05 1.8501e-06 1.1768e-03 1.0578e-03 0:00:47 37

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

164 3.6414e-04 2.1197e-05 2.2137e-05 8.1040e-05 1.9010e-06 1.1834e-03 1.0673e-03 0:00:46 36

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

165 3.6032e-04 2.1177e-05 2.2153e-05 8.1018e-05 1.8704e-06 1.1887e-03 1.0737e-03 0:00:44 35

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

166 3.5955e-04 2.1154e-05 2.2159e-05 8.0843e-05 1.9207e-06 1.1921e-03 1.0534e-03 0:00:43 34

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

167 3.6156e-04 2.1078e-05 2.2075e-05 8.0625e-05 1.9140e-06 1.1950e-03 1.0504e-03 0:00:41 33

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

168 3.5862e-04 2.1060e-05 2.2032e-05 8.0380e-05 1.9525e-06 1.2021e-03 1.0694e-03 0:00:40 32

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

169 3.5616e-04 2.1094e-05 2.2011e-05 8.0240e-05 1.9165e-06 1.2050e-03 1.0677e-03 0:00:38 31

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

170 3.6163e-04 2.1099e-05 2.1908e-05 8.0061e-05 1.9802e-06 1.2101e-03 1.0762e-03 0:00:37 30

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

171 3.6228e-04 2.1083e-05 2.1902e-05 7.9952e-05 1.9496e-06 1.2135e-03 1.0780e-03 0:00:35 29

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

172 3.6391e-04 2.1082e-05 2.1868e-05 7.9801e-05 2.0070e-06 1.2170e-03 1.0724e-03 0:00:34 28

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

173 3.5938e-04 2.1084e-05 2.1865e-05 7.9727e-05 1.9671e-06 1.2193e-03 1.0721e-03 0:00:33 27

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

174 3.5674e-04 2.1008e-05 2.1833e-05 7.9510e-05 2.0185e-06 1.2237e-03 1.0815e-03 0:00:31 26

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

175 3.5638e-04 2.1037e-05 2.1862e-05 7.9580e-05 1.9782e-06 1.2265e-03 1.0825e-03 0:00:30 25

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

176 3.5599e-04 2.1024e-05 2.1821e-05 7.9425e-05 2.0339e-06 1.2286e-03 1.0720e-03 0:00:29 24

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

177 3.5882e-04 2.0934e-05 2.1749e-05 7.9490e-05 1.9985e-06 1.2303e-03 1.0758e-03 0:00:28 23

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

178 3.6367e-04 2.0999e-05 2.1807e-05 7.9403e-05 2.1167e-06 1.2349e-03 1.0889e-03 0:00:26 22

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

179 3.6773e-04 2.0974e-05 2.1759e-05 7.9531e-05 1.9715e-06 1.2371e-03 1.0915e-03 0:00:25 21

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

180 3.7288e-04 2.1042e-05 2.1790e-05 7.9383e-05 2.0768e-06 1.2377e-03 1.0740e-03 0:00:24 20

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

181 3.7854e-04 2.0962e-05 2.1705e-05 7.9330e-05 2.0387e-06 1.2386e-03 1.0794e-03 0:00:22 19

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

182 3.7587e-04 2.0983e-05 2.1722e-05 7.9115e-05 2.0976e-06 1.2434e-03 1.1011e-03 0:00:21 18

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

183 3.7771e-04 2.0978e-05 2.1701e-05 7.9401e-05 2.0641e-06 1.2450e-03 1.1074e-03 0:00:20 17

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

184 3.7502e-04 2.1015e-05 2.1758e-05 7.9364e-05 2.1125e-06 1.2442e-03 1.0835e-03 0:00:19 16

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

185 3.6801e-04 2.0932e-05 2.1687e-05 7.9376e-05 2.0675e-06 1.2446e-03 1.0861e-03 0:00:18 15

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

186 3.7816e-04 2.1031e-05 2.1824e-05 7.9265e-05 2.1837e-06 1.2495e-03 1.1120e-03 0:00:17 14

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

187 3.7405e-04 2.1039e-05 2.1779e-05 7.9593e-05 2.0294e-06 1.2496e-03 1.1071e-03 0:00:16 13

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

188 3.7174e-04 2.1058e-05 2.1793e-05 7.9497e-05 2.1579e-06 1.2499e-03 1.0889e-03 0:00:14 12

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

189 3.7368e-04 2.0988e-05 2.1718e-05 7.9544e-05 2.1268e-06 1.2493e-03 1.0891e-03 0:00:13 11

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

190 3.7356e-04 2.1071e-05 2.1847e-05 7.9451e-05 2.2526e-06 1.2529e-03 1.1134e-03 0:00:12 10

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

191 3.6898e-04 2.1146e-05 2.1822e-05 7.9729e-05 2.0903e-06 1.2539e-03 1.1192e-03 0:00:11 9

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

192 3.7840e-04 2.1207e-05 2.1885e-05 7.9734e-05 2.2084e-06 1.2521e-03 1.0908e-03 0:00:10 8

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

193 3.8448e-04 2.1084e-05 2.1716e-05 7.9736e-05 2.1742e-06 1.2517e-03 1.0896e-03 0:00:08 7

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

194 3.8616e-04 2.1133e-05 2.1736e-05 7.9600e-05 2.2615e-06 1.2569e-03 1.1254e-03 0:00:07 6

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

195 3.8645e-04 2.1249e-05 2.1751e-05 7.9956e-05 2.2282e-06 1.2569e-03 1.1305e-03 0:00:06 5

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

196 3.8544e-04 2.1301e-05 2.1811e-05 7.9920e-05 2.2674e-06 1.2566e-03 1.1209e-03 0:00:05 4

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

197 3.7730e-04 2.1225e-05 2.1712e-05 7.9918e-05 2.2296e-06 1.2566e-03 1.1440e-03 0:00:04 3

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

198 3.7655e-04 2.1198e-05 2.1717e-05 7.9839e-05 2.3524e-06 1.2605e-03 1.1673e-03 0:00:03 2

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

iter continuity x-velocity y-velocity z-velocity energy k epsilon time/iter

199 3.7693e-04 2.1358e-05 2.1772e-05 8.0139e-05 2.2016e-06 1.2595e-03 1.1233e-03 0:00:01 1

Reversed flow on 13 faces (3.3% area) of pressure-outlet 6.

200 3.8166e-04 2.1447e-05 2.1857e-05 8.0031e-05 2.3200e-06 1.2590e-03 1.1363e-03 0:00:00 0