Computer Modeling of Temperature Conditions in the System Unit of a Personal Computer

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Abstract: - This work addresses the critical task of computer modeling of temperature conditions inside a personal computer system unit to improve its reliability and efficiency. A structural-parametric model of a PC is formulated and implemented, allowing for the formalization of key system components and their characteristics. Based on this approach, a detailed 3D geometry of the chassis and internal components was created in SolidWorks. The SolidWorks Flow Simulation module was then used to perform a numerical analysis of thermal conditions and airflow within the enclosure under different load scenarios (idle and high load). The simulation revealed areas of overheating and air stagnation in the baseline configuration. To improve thermal performance, a modified case design is proposed featuring additional ventilation openings and an auxiliary fan. A comparative analysis of the simulation results for the baseline and updated designs showed improved airflow uniformity and heat dissipation efficiency under idle conditions. The practical significance of the work lies in the applicability of the developed methodology for optimizing cooling systems in the design of new and the modernization of existing PCs, contributing to increased equipment lifespan and fault tolerance.

Key-Words: - Computer, Modeling, Airflow Simulation, Thermal Analysis, Personal Computer, Temperature, Modes.

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1 Introduction

1.1 Relevance and Purpose of Work

Today, thermal modeling is a relevant and key task in optimizing the design of computer enclosures and cooling systems. The main scientific objective is to model the thermal behavior of a computer system to ensure its reliability and efficiency over a long service life. Computer systems (CS) are defined here as personal computers (PCs), or more specifically, as their system units. Modeling a PC involves addressing technical and engineering challenges arising from the complexity of thermal processes and their interaction with different operating conditions.

This problem is important because it determines service life, which in turn affects the efficiency of computer systems. Modeling the design of a PC and then simulating its temperature conditions can lead to significant improvements in cooling efficiency and system reliability.

The scientific tasks include the development of a structural and parametric model, along with a 3D model of the PC. These are essential for detailed thermal modeling, which is critical to improving the efficiency and reliability of the system.

Practical tasks include developing a functional and reliable system capable of operating under real-world PC conditions.

The topic was chosen based on an analysis of user needs regarding long-term PC operation, as well as existing problems and shortcomings in improving the performance of such systems. The initial data include results from previous studies, technical requirements, and specifications for creating a 3D model of a PC, followed by thermal modeling [1], [2], [3].

This research is critical to addressing existing challenges and achieving new performance levels in computer systems. Computational modeling of PC thermal behavior will not only serve as a prerequisite for improving reliability but will also contribute to industrial development, increased efficiency, and more rational system design.

The scientific novelty of this work lies in the integrated approach that combines a structural-parametric representation of a PC system unit with CFD-based analysis of airflow and temperature fields under both idle conditions and high-load conditions. Unlike existing studies, the proposed approach evaluates the influence of case design modifications (additional perforations and

auxiliary fan placement) on airflow structure and thermal performance across different operating regimes, revealing a trade-off between improved idle cooling and reduced efficiency under high thermal load.

The purpose of this work is to analyze and improve thermal performance and airflow behavior to enhance system reliability and efficiency.

The main tasks are:

1. Development of a structural-parametric model of a personal computer to formalize its key components and their characteristics, which allows for a systematic description of the system's design and functioning.
2. Creating a detailed 3D model of a PC tower.
3. Computer simulation of temperature conditions and air flows inside the hull.
4. Optimization of the housing design and cooling system based on simulation results, including modification of the housing.

1.2 Work-related Analysis

The process of designing and modeling, both the design itself and solving problems of computer networks, and innovative approaches to building sustainable, modern networks are the focus of many scientific works [4], [5], [6], and structural elements of system units of personal computers are presented in detail in [7], [8].

Personal computers are used in many industries, each with its own specific hardware and temperature requirements [9], [10], [11], [12], [13], [14], [15], [16].

For example, the use of PCs in science and technology [9], [10], [11] plays an important role in high-performance computing, simulations, and data analysis. These tasks require powerful processors and graphics cards that generate a large amount of heat.

In a business environment, PCs are used by technicians for database management, financial analysis, and processing large amounts of information [12], [13], [14].

Gaming PCs and media processing computers have high graphics performance requirements, which also affect thermal conditions [15], [16].

Computer modeling of temperature conditions in the system unit of a personal computer is a relevant topic in modern conditions, when performance and energy efficiency of computer systems are becoming increasingly important.

Reference [17] discusses the use of computational fluid dynamics (CFD) using Icepak to develop cooling solutions for a desktop computer with an 80 W processor. The authors provide calculations, with the main focus on minimizing the airflow requirements inside the case. The main drawback of the article is the lack of attention to various configurations and load scenarios that may occur in real-world use.

Work [18] discusses CFD analysis of central processing unit (CPU) cooling systems. The authors describe the process of creating 3D models of a computer case and components, including CPU, radiator, and fan. They describe CFD simulations for analyzing airflow and temperature distribution inside the case. The influence of various factors – such as fan location, heatsink size, and fan speed – on CPU cooling efficiency is investigated. Although the authors present interesting results of CFD analysis, they only consider CPU cooling, while other components, such as GPU, random access memory (RAM), etc., need to be taken into account for a complete assessment of the thermal conditions of the computer.

The search for optimal configurations for passive heat removal from the case is presented in [19]. The authors numerically evaluated the temperature distribution and flow field around various heating elements. The paper explores methods to enhance natural convection and thermal radiation inside the case for more effective heat removal from components without relying on active cooling (fans). However, the study neglects a critical factor: the influence of component layout and placement inside the case. Consequently, the proposed methods may prove insufficient for modern, high-power desktop systems with substantial heat dissipation.

In [20], the three-dimensional heat transfer process in a desktop computer case using an 85-watt processor was analyzed using a CFD software package. The aim is to study the temperature distribution of components and flows to assess the efficiency of the air-cooled cooling system. The authors tuned simulation parameters, such as grid resolution, turbulence model, convergence criteria, and sampling schemes. However, the exact geometry of fans and resistances was not fully modeled in the work, but simplified models were used.

Thermal processes in a PC system unit include several mechanisms, such as heat conduction, convection, and radiation [21].

There are various methodologies for modeling thermal behavior in the literature. Some researchers employ the finite element method (FEM) to simulate thermal processes in detail [22], [23]. Other approaches include using CFD to model convection inside the system unit [17], [18], [24].

In general, these works make an important contribution to the field of computer modeling of temperature conditions in the system unit of a personal computer.

The general tendency of these scientific works is a great interest in the development and modeling of temperature conditions in the system unit. They highlight key aspects such as component placement within the system unit, the impact of cooling element size and speed, and the selection of optimal cooling solutions.

Thus, this work focuses on the design and composition of system unit components, the primary parameters of which are formalized using a structural-parametric model. This approach is essential for enhancing cooling system efficiency and the overall reliability of a personal computer.

2 Formalization of the Problem

This study investigates the thermal performance and reliability of a personal computer system unit using CFD-based numerical simulation. The mathematical formulation includes the creation of a structural-parametric model that accounts for the design features and operation of PC structural elements to improve operational reliability.

Input data for the system includes design parameters and configurations for both new and existing PCs.

Determining optimal parameters will guarantee improved system reliability.

Let's assume that the proposed structural-parametric model is necessary to determine key parameters for a particular PC and their formalization, which is necessary both when designing new computer systems and for already operating ones to optimize the functioning process.

Input parameters when creating a 3D model of a PC are represented by models:

$$CS^i_{PC} = <SZ^i_{CS}\, M^i_t, N^i_{PC}, VT^i_{PC}>,\ i = 1, ..., I, \quad (1)$$

where
CS^i_{PC} – case of a personal computer system unit;
SZ^i_{CS} – size of a personal computer;
M^i_t – material;
N^i_{PC} – number of compartments;
VT^i_{PC} – ventilation.

Power supply (PS^i_{PC}) can be represented as:

$$PS^i_{PC} = <SZ^i_{PS}, PW_{PS}, MD_{PS}>,\ i = 1, ..., I, \quad (2)$$

where
SZ^i_{PS} – dimensions of power supply;
PW_{PS} – power supply unit;
MD_{PS} – modularity of power supply.

Motherboard (MB^i_{PC}) can be represented as:

$$MB^i_{PC} = <SZ^i_{MB}, CH^i_{MB}, SC^i_{MB}, RS^i_{MB}, ES^i_{MB}>, \quad (3)$$

$$i = 1, ..., I,$$

where
SZ^i_{MB} – dimensions of the motherboard;
CH^i_{MB} – motherboard chipset;
SC^i_{MB} – motherboard socket;
RS^i_{MB} – motherboard RAM slots;
ES^i_{MB} – motherboard expansion slots.
CPU (CPU^i_{PC}) can be described as:

$$CPU^i_{PC} = <M^i_{CPU}, CS^i_{CPU}, N^i_{CPU}, PC^i_{CPU}>, \quad (4)$$

$$i = 1, ..., I,$$

where
M^i_{CPU} – CPU model;
CS^i_{CPU} – CPU clock frequency;
N^i_{CPU} – number of CPU cores/threads;
PC^i_{CPU} – power consumption of the central processor.

RAM memory (RAM^i_{PC}) can be formalized as:

$$RAM^i_{PC} = <T^i_{RAM}, V^i_{RAM}, F^i_{RAM}>,\ i = 1, ..., I, \quad (5)$$

where
T^i_{RAM} – type of RAM;
V^i_{RAM} – amount of RAM;
F^i_{RAM} – RAM frequency.

Data storage devices (DS^i_{PC}) are represented by models:

$$DS^i_{PC} = <SZ^i_{DS}, T^i_{DS}, V^i_{DS}, S^i_{DS}>, \quad (6)$$

$$i = 1, ..., I,$$

where
SZ^i_{DS} – size of data storage device;
T^i_{DS} – type of data storage device;
V^i_{DS} – data storage capacity;
S^i_{DS} – read/write speed of data storage device.

Active and passive cooling components (APC^i_{PC}) can be described as:

$$APC^i_{PC} = <SZ^i_{APC}, T^i_{APC}, RS^i_m, CN^i_t,$$

$$BR^i_t, \lambda_k, q, \alpha>,\ i = 1, ..., I, \quad (7)$$

where
SZ^i_{APC} – dimensions of active and passive cooling components;
T^i_{APC} – type of cooling components;
RS^i_m – maximum rotation speed of cooling component;
CN^i_t – type of cooling component connector;

BR^i_t – bearing type of cooling component;
λ_k – thermal conductivity coefficient, W/m·K;
q – heat flux, W/m^2;
α – heat transfer coefficient.

Dimensions of active and passive cooling components (SZ^i_{APC}) are represented by models:

$$SZ^i_{APC} = <D_{APC}, Dm_{APC}, H_{APC}, W_{APC}>, \quad (8)$$

where D_{APC} – depth of cooling component, mm;
Dm_{APC} – diameter of cooling component, mm;
H_{APC} – height of cooling component, mm;
W_{APC} – width of cooling component, mm.

Thus, the proposed structural-parametric model enables formalization of the key components and characteristics of a PC system unit, which serve as the foundation for subsequent 3D modeling and thermal analysis.

3 Materials and Methods

3.1 Development of Structural and Parametric Model

Since key parameters of PC (system unit) were defined above, they are written in the form of a structural and parametric model as follows:

$$PC = <M_{GI}, M_S>, \quad (9)$$

where
M_{GI} – general information about a personal computer;
M_S – structure of a personal computer.

Then, the set of M_{GI} general information can be described by the following dependencies:

$$M_{GI} = <S_{PC}, M_{PC}, T^i_{PC}, TG^i_{PC}>, \quad (10)$$

where S_{PC} – personal computer series;
M_{PC} – model of a personal computer;
T^i_{PC} – type of a personal computer;
TG^i_{PC} – purpose of a personal computer.

At the same time T^i_{PC} type of a personal computer.

The purpose of a TG^i_{PC} can also be of three levels: consumer, gaming, or business (e.g., manufacturing).

The structure of a personal computer (system unit) is defined as a hierarchical set of components:

$$M_S = <CS^i_{PC}, PS^i_{PC}, MB^i_{PC}, CPU^i_{PC}, RAM^i_{PC},$$

$$DS^i_{PC}, APC^i_{PC}>, \quad (11)$$

where
CS^i_{PC} – case of personal computer system unit;
PS^i_{PC} – power supply;
MB^i_{PC} – motherboard;
CPU^i_{PC} – CPU;
RAM^i_{PC} – RAM memory;
DS^i_{PC} – data storage device;
APC^i_{PC} – active and passive cooling components.

The result is a sequence of PC element parameters that will be used for structural modeling and subsequent temperature analysis.

3.2 Selecting Cooling Elements for Basic Design of Personal Computer

Before modeling, cooling components were selected to ensure the developed personal computer does not overheat.

Among cooling elements, you can distinguish between active and passive ones. Passive cooling works on the principle of direct heat transfer from the heated element to the radiator.

Using heat-conducting material or heat tubes, the radiator removes heat to the environment by thermal radiation and heat transfer through heat-conducting materials surrounded by air. This results in natural convection of surrounding air.

The surface of the heating component and the radiator has a roughness that does not allow them to fit closely together, resulting in a thin layer of air with low thermal conductivity. To avoid this problem, a special heat-conducting paste is used.

An active cooling system includes a radiator to which a fan is added to increase the volume of air that passes through the radiator and cools it. This combination of heatsink and fan is known as a cooler.

To cool the processor in this work, we chose a standard cooler from Intel (Figure 1) for a 1151 socket processor [21].

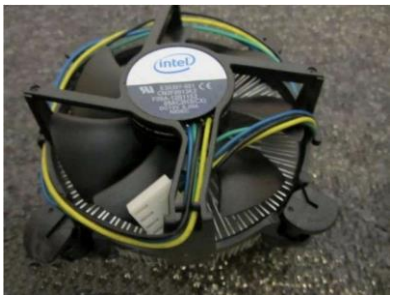


Fig. 1: Intel cooler for the central processor
Source: [25]

The fan in this assembly has a diameter of 90 mm and 2200 rpm, radiator material is aluminum.

Figure 2 shows the XFAN 120 fan (Table 1), which was selected for the DeepCool power supply unit.



Fig. 2: XFAN 120 cooler for power supply unit
Source: [26]

Table 1. Features of the DeepCool XFAN 120 fan

Fan parameters	Meaning
Cooling system (T^i_{APC})	Active (cooler)
Maximum rotation speed, rpm (RS^i_m)	1300 ± 10 %
Fan diameter, mm	120
Depth, mm (D_{APC})	25
Width, mm (W_{APC})	120
Height, mm (H_{APC})	120
Bearing type (BR^i_t)	Hydrodynamic
Number of coolers (N^i_C)	1
Connector type (CN^i_t)	Molex

Source: created by the author.

The XFAN 120 cooler is inexpensive and provides good cooling for the passive cooling element.

This cooler is built into the power supply by the manufacturer.

3.3 Modeling Basic Personal Computer

The concept of basic case refers to the basic configuration and case of a PC with an Intel cooler for the central processor and XFAN 120 cooler for the power supply (Figure 3).

The modeling process will begin with the creation of drawings of the first object, which will be called the case. Design is the first stage in the product manufacturing chain, and this applies not only to the enclosure, but also to any component or product, or even something bigger. At this stage, 3D models and drawings (design documentation) are developed.

The computer-aided design (CAD) process is implemented using SolidWorks software. This platform was selected due to its intuitive user interface, robust 3D modeling capabilities for complex geometries, extensive industrial adoption, and compatibility with various formats and standards.

Figure 3 presents the baseline personal computer case used for airflow and thermal simulations.



Fig. 3: The baseline personal computer case used for airflow and thermal simulations
Source: created by the author.

The general sequence of actions for developing a 3D model of a personal computer case (system unit) and components in SolidWorks was as follows:

- creating a sketch of a «rectangle» according to case dimensions;
- shaping the case into a parallelepiped using the «Elongated boss» function (Figure 4);
- selecting the side with the main hole for placing internal components and creating a sketch and cutout on the back side;
- add cutouts on other sides of the case as needed. To create an array of holes, you need to create a sketch of one hole, use the Linear Array function, and set direction and distance between holes;
- create motherboard slots by creating a hole sketch and using the «Elongated Cutout» function;

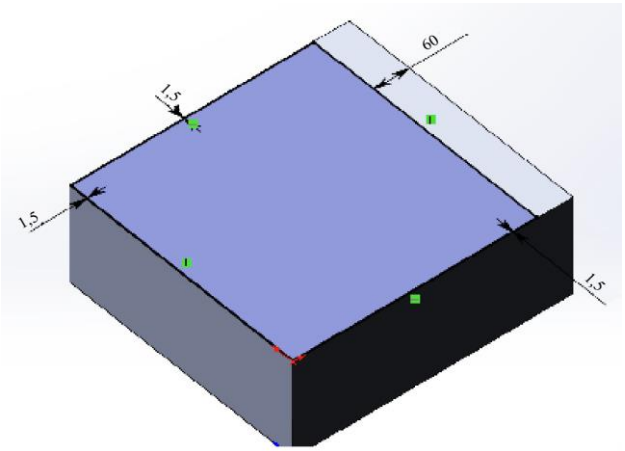


Fig. 4: SolidWorks modeling process of the PC case showing the step-by-step creation of the 3D geometry, including extrusion operations and basic shaping procedures
Source: created by the author.

- creating a cutout for rear exits, and for this purpose, pull the «hollow» inside the case, create a sketch of exit holes, and cut a cavity inside the elongated element;

- adding holes for air circulation (Figure 5), and to do this, create sketches of holes on the surface of the model and determine their diameter and position;

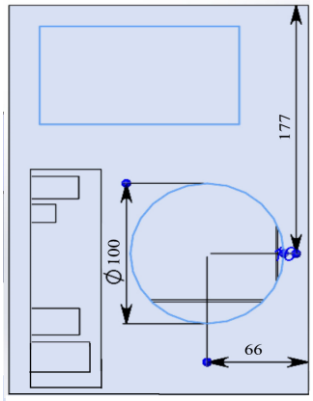
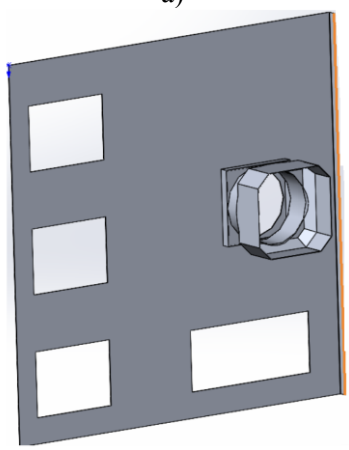


Fig. 5: Ventilation openings and cutouts created in the PC case model during the design process to define airflow pathways
Source: created by the author.

- further model internal components: motherboard, processor, memory, hard disk, power supply, video card, and place internal components according to seats and lead «wires» from the power supply (Figure 6, a, b).



a)



b)

Fig. 6: Personal computer case: placement of components in case and case cover
Source: created by the author.

So, in this subsection, a three-dimensional model of personal computer design was developed. This model includes all key elements necessary for further realization of the project. The next step will be temperature analysis and testing of the model.

3.4 Experiments

To analyze the internal temperature of the system unit, the SolidWorks Flow Simulation module was selected.

SolidWorks Flow Simulation is software for numerical modeling and analysis of hydraulic and thermal processes in the SolidWorks CAD environment. It is a SolidWorks add-on module that enables engineers to predict various physical phenomena, including heat transfer, fluid dynamics, aerodynamics, and fluid resistance.

The experiments involve modeling heat transfer to analyze thermal processes within the PC structure and determine temperature conditions.

The numerical simulation of thermal processes begins with the integration of the SolidWorks Flow Simulation module into the CAD environment. The initial stage involves configuring the pre-developed 3D model within the simulation interface to establish the boundary conditions and physical parameters required for thermal analysis.

In Flow Simulation, you can set values of boundary conditions, enter and monitor parameters, and analyze results to understand the behavior of the PC structure under various conditions.

After setting the initial environmental parameters, the computational domain and component parameters are defined, followed by mesh generation. The main ventilation openings (intake and exhaust) were explicitly modeled and remained open in the computational domain.

To simplify the computational model and ensure numerical stability, some minor geometric openings were closed. These features do not significantly affect the main airflow pathways, which are governed by the primary intake and exhaust regions. Therefore, their influence on the overall thermal and aerodynamic behavior is considered negligible. Boundary conditions were defined based on typical operating conditions of a personal computer. The inlet air temperature was set to 25 °C, corresponding to standard room conditions. Ambient pressure was assumed to be 1 atm. Heat sources were defined based on the typical power consumption of components:

- CPU – 65 W;
- GPU – 120 W;
- PSU – 50 W.

A grid independence study was performed using three mesh densities (coarse, medium, and fine). The variation in maximum temperature between the medium and fine meshes did not exceed 3 %, indicating mesh convergence. Therefore, the medium mesh was selected for further simulations as a compromise between accuracy and computational cost. To simulate turbulent airflow within the PC enclosure, the standard k-ε turbulence model was employed, as it offers an optimal trade-off between computational efficiency and predictive accuracy for internal flow simulations.

The simulation is based on the steady-state solution of the Navier-Stokes equations and the energy equation for incompressible flow. The governing equations include conservation of mass, momentum, and energy. The convergence criterion was set such that residuals of all governing equations were below 10^{-3}, which is commonly accepted for engineering-level CFD simulations.

Next, the airflow region is defined; in this study, it corresponds to a single flow domain (Figure 7).

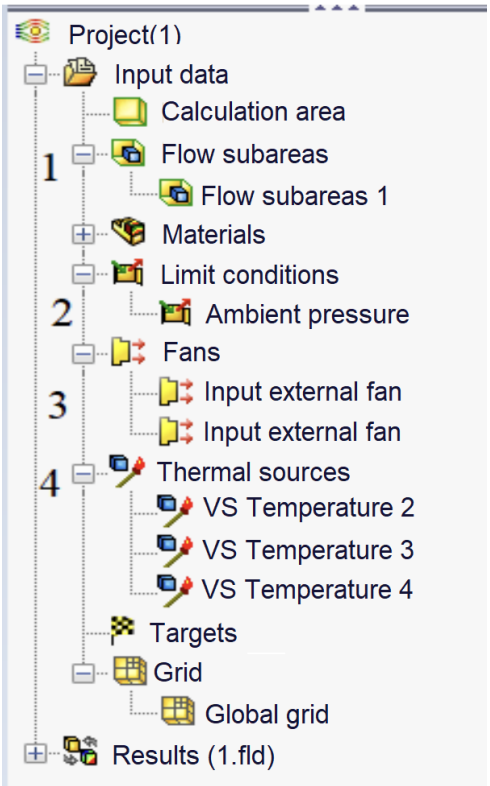


Fig. 7: Flow Simulation analysis tree
Source: created by the author.

Figure 7 shows the following: 1 – air flow zone; 2 – boundary conditions; 3 – fans; 4 – heat sources.

The material for elements under study (3D models of PC components) can be selected during the design of an individual element or in the analysis tree in the «Materials» section.

The main ventilation openings (intake and exhaust) were explicitly modeled and remained open in the computational domain.

To simplify the computational model and ensure numerical stability, some minor geometric features were simplified. These elements do not significantly affect the main airflow pathways, which are governed by the primary intake and exhaust regions.

Such simplifications are commonly used in CFD modeling of electronic cooling systems.

Figure 8 shows the process of adding boundary conditions, which can only be realized after all openings are closed. This is done to indicate to the system where air (or other substance) enters the designed system.

The «Fans» tab in SolidWorks Flow Simulation is used to configure fan parameters in numerical fluid or gas flow simulations.

In the «Fans» tab, you set fan parameters:
- fan speed;
- fan location;
- air or liquid flow direction.

Fan performance curves and operational parameters were specified according to the manufacturer's technical data and integrated within the SolidWorks Flow Simulation environment.

These parameters are important for accurate modeling of aerodynamic and hydrodynamic processes in cooling, ventilation, and other technical systems.

Figure 8 shows the airflow distribution in the baseline PC case under idle conditions.

The «idle» condition refers to the system's idle state, where the model disregards workloads and processes associated with standard operation. Specifically, this involves excluding heat generation from the processor and other key components from the thermal simulation.

Consequently, the «idle conditions» model focuses exclusively on the airflow dynamics within the case, disregarding internal thermal loads and heat generation from components.

Analyzing data from the first simulation, we can conclude that the internal air temperature reaches approximately 45 °C when it is not in loaded mode.

Specifically, the temperature of internal components during operation ranges from 30 °C to 50 °C (Figure 8).

To analyze the cooling of components, the temperature of internal components was increased to approximately 75 °C, which depends on the specific component.

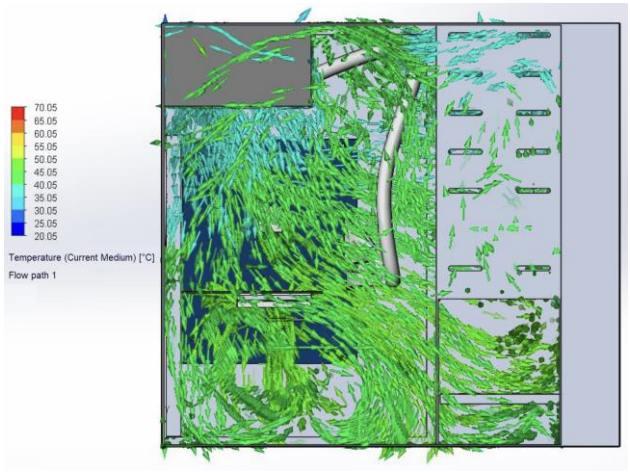


Fig. 8: Airflow simulation in the baseline PC case under idle conditions, showing general airflow distribution and regions of low-velocity circulation without significant thermally driven flow effects
Source: created by the author.

Figure 9 (Appendix) shows airflow simulation in the baseline PC case under high-load conditions.

The «loaded» state represents the system under full-load conditions, accounting for the active thermal dissipation of its internal components. This includes heat generated by the CPU and GPU operations, which directly influence the internal thermal environment of the chassis. Consequently, the «loaded» model evaluates airflow dynamics under realistic operational scenarios.

As you can see from Figure 9 (Appendix), the air temperature mostly reaches 65 °C.

Continuous air circulation within a closed chassis without adequate exchange with the external environment results in heat accumulation. This leads to inadequate component cooling, which may trigger thermal throttling or cause system instability during intensive data processing and computational tasks.

Therefore, to solve this problem, additional ventilation openings were introduced in the case, and an attached fan with an internal diameter of 80 mm was attached to the bottom hole.

4 Research Results and Discussion

As a result of experiments, it was determined that with a constant flow of cold air, hot air will exit through the opening on top of the system unit case, and thus hot air will not be trapped inside the case.

Now, the DeepCool XFAN 80 fan was selected for air cooling (Figure 10, Appendix).

This fan was chosen because:
1. Suitable size.
2. Reasonable price.
3. Compact version that is suitable for small cases and narrow spaces.

Therefore, a standard 80 mm fan was selected for its market availability and demonstrated cooling effectiveness.

Parameters of DeepCool XFAN 80 fan (Table 2).

Table 2. Features of DeepCool XFAN 80 fan

Fan parameters	Meaning
Cooling system (T^i_{APC})	Active (cooler)
Maximum rotation speed, rpm (RS^i_m)	1800 ± 10 %
Depth, mm (D_{APC})	25
Width, mm (W_{APC})	80
Height, mm (H_{APC})	80
Bearing type (BR^i_t)	Hydrodynamic
Number of coolers (N^i_C)	1
Connector type (CN^i_t)	Molex

Source: created by the author.

The maximum rotational speed of the active cooler (fan) directly affects the heating of components in the PC. The fan is designed to cool components such as the processor, graphics card, and motherboard.

Increasing the speed of the fan improves heat dissipation from these components, which helps maintain their optimal operating temperature.

Several holes were added to the PC design, and a DeepCool XFAN 80 fan was attached to the bottom hole. This solution should help to displace warm air by supplying cold air from below into the computer case and removing warm air with a fan.

Figure 10 (Appendix) presents airflow simulation in the modified PC case under idle conditions. The side view (Figure 10a in Appendix) illustrates the upward movement of incoming air, while the top view (Figure 10b in Appendix) demonstrates relatively uniform airflow distribution and the absence of significant turbulence or stagnation zones.

Figure 10a and Figure 10b (Appendix) shows modeling of air flow inside the updated PC case without load or at rest.

In Figure 10a (Appendix), one can see:
- relatively small amount of air flow inside the case;
- cold air flows (blue lines) enter through front openings and move upward;
- a small vortex of hot air (green lines) is generated by the video card cooler.
- air flows are mainly concentrated on the right side of the case.

Figure 10b (Appendix), shows:

- relatively uniform air movement inside the case without sharp flows;
- green and light green trajectories predominate, indicating moderate speed of air masses;
- cold air enters through openings at the bottom and spreads evenly inside;
- no significant turbulent structures or stagnation zones are observed.

Figure 11 (Appendix) shows airflow simulation in the modified PC case under high load conditions.

A side view (Figure 11a, Appendix) showing the formation of recirculation zones and upward movement of heated o n air near the CPU/GPU.

A top view (Figure 11b, Appendix) illustrates turbulent flow patterns, stagnation regions, and interaction between intake and exhaust streams.

Figure 11a (Appendix), you can see the following features:

1. Hot air flow (green lines) from the CPU and video card rises and circulates inside the case.
2. Cooler (black part) creates a powerful vortex flow of hot air.
3. Blue lines show a slower flow of cold air in the lower part of the case.

Figure 11 b (Appendix) shows:

1. General chaotic movement of air masses inside the case in different directions.
2. Areas with higher airflow rates are marked in green/yellow.
3. Blue lines show a slower flow of cold air in the lower part of the case.

Therefore, based on the simulation results for the baseline (manufacturer's) case (Figure 3, Appendix) equipped with a DeepCool XFAN 120 fan and an Intel CPU cooler, it can be concluded that air circulation is less effective compared to the updated design under idle conditions. Air stagnation zones and temperature levels in the range of 60-73 °C are observed. In these conditions, the temperature of passive cooling components approaches that of the heat sources (approximately 70 °C), which reduces heat dissipation efficiency, since the temperature difference between the cooling air (~60 °C) and the components is insufficient.

Consequently, an improvement was proposed that would not entail high initial economic costs and would not require unique properties from machine tools or production machines.

Thus, when defining the context of this work, its main goal was established: computer modeling of a personal computer to ensure its reliability and efficiency. As a result of this work, this goal has been achieved because:

- analysis of modern PC designs;
- spheres of PC application are analyzed;
- a structural and parametric model was created;
- cooling elements for the basic design of a personal computer are selected;
- a sequence of actions for developing a 3D model of the system unit case and its components is described;
- creation of a 3D model of the basic design of the system unit using the SolidWorks system;
- computer modeling of temperature conditions without load and during high load;
- determination of internal air temperature and direction of its movement;
- creating a 3D model of the design of the updated version of the system unit using the SolidWorks system;
- results comparison of the modeling temperature conditions of the updated and basic versions of the system unit.

Studying airflow and heat transfer is essential to evaluate cooling efficiency.

Moreover, the influence of component layout and its positioning inside the case must be taken into
account.

Table 3. Comparative analysis of thermal and airflow parameters under idle conditions

Parameter	Figure 8 (basic PC case)	Figure 10 (updated PC case)
Maximum local temperature (°C)	~70	~50
Dominant temperature range (°C)	25–45	20–35
Airflow characteristics	More turbulent airflow with pronounced recirculation zones	Less intense and more uniform airflow
Flow distribution	Localized circulation near CPU cooler	More evenly distributed airflow
Thermal pattern	Presence of elevated temperature zones (35-45 °C) with local peaks near heat sources	Predominantly lower temperature zones (20-35 °C) with significantly reduced local peak values

Source: created by the author.

The results of temperature field modeling and airflow behavior for the baseline (Figure 8) and updated (Figure 10, Appendix) PC cases under idle

conditions are presented in Table 3. In this study, idle conditions correspond to reduced but non-zero heat generation of components, reflecting realistic operating conditions.

The reported maximum temperatures correspond to localized regions near heat-generating components, while the majority of the enclosure volume remains within the dominant temperature range. In addition to the reduction in maximum temperature, the updated configuration demonstrates a shift of the temperature field toward lower values (20-35 °C), compared to 25-45 °C in the baseline case.

Beyond temperature reduction, the updated design also exhibits a more uniform airflow distribution with fewer stagnation zones.

The results indicate that the baseline configuration (Figure 8) exhibits a higher maximum temperature (~70 °C), while the average internal air temperature remains in the range of 25-45 °C. The airflow in this case shows a turbulent structure with significant recirculation zones, particularly near the CPU cooler. These flow characteristics impede uniform heat removal, leading to localized thermal accumulation and reduced cooling efficiency.

In contrast, the updated configuration reduces the maximum temperature to ~50 °C (approximately 28% reduction) and improves flow uniformity under idle conditions. The updated PC case (Figure 10, Appendix) also maintains a narrower temperature range (20-35 °C). The airflow pattern becomes more organized and uniform, with minimized recirculation. The airflow pattern becomes more organized and uniform, with minimized recirculation. This improved flow distribution facilitates more effective heat dissipation and ensures a more homogeneous thermal field.

The obtained results are consistent with previously reported CFD-based studies [27], where similar airflow patterns, including recirculation zones and temperature gradients, were observed in desktop PC enclosures under comparable thermal loads.

While airflow behavior is evaluated indirectly through temperature gradients and flow visualization, the reduction of stagnant zones in the updated configuration indicates enhanced cooling performance under idle conditions. Consequently, the modified design demonstrates improved thermal stability compared to the baseline configuration during low-load operation. The updated design reduces maximum temperature by ~20 °C under idle conditions (from ~70 °C to ~50 °C), corresponding to a ~28 % improvement.

The subsequent section presents the results of temperature field modeling under load conditions for the baseline configuration (Figure 9, Appendix) and the updated case under high load (Figure 11, Appendix), as summarized in Table 4.

Table 4. Results of temperature field modeling of PC under load conditions

Parameter	Figure 9 (basic PC case)	Figure 11 (updated PC case)
Maximum temperature (°C)	~85	~80
Dominant temperature range (°C)	45–70	40–65
Overheating zones	Less localized, more evenly distributed high-temperature regions	Localized high-temperature regions near CPU/GPU
Airflow characteristics	More uniform compared to Figure 11, moderate turbulence	More turbulent and chaotic
Flow distribution	More organized flow with stable intake streams and limited recirculation	Presence of recirculation and stagnation zones
Thermal pattern	More evenly distributed temperature field without strong localization of hot spots	Presence of localized high-temperature regions near CPU/GPU

Source: created by the author.

The maximum temperature in the updated configuration under high-load conditions is approximately 80 °C, compared to about 85 °C in the baseline case.

Although the updated configuration demonstrates a lower maximum temperature under high-load conditions, the airflow structure becomes less uniform.

Specifically, the interaction of multiple airflow streams leads to the formation of recirculation zones and localized stagnation regions. These effects reduce the overall flow stability and may negatively impact long-term cooling efficiency, despite the observed reduction in peak temperature. This corresponds to an approximate reduction of 5-6 % in peak temperature.

Thus, despite the load effect, the airflow at the inlet in the baseline configuration (Figure 9, Appendix) appears more balanced and organized compared to the more chaotic and turbulent flow

observed inside the case under peak load conditions (Figure 11, Appendix). This behavior is associated with the formation of localized overheating regions and airflow stagnation zones, which may reduce heat dissipation efficiency.

The following physical interpretation explains the airflow patterns and the observed behavior. The reduction in thermal performance of the updated design under high-load conditions stems from structural modifications in the airflow. While the auxiliary fan and additional perforations enhance airflow distribution under idle conditions (Figure 10, Appendix), they trigger flow interference and increased turbulence under high thermal loads (Figure 11, Appendix).

Specifically, the interaction between the intake flow from the bottom fan and the exhaust streams of the CPU and GPU coolers triggers the formation of recirculation zones. As illustrated in Figure 11 (Appendix), these vortical structures trap heated air near critical components, thereby impairing heat removal efficiency.

Furthermore, the supplementary intake airflow disrupts the established pressure-driven front-to-top path observed in the baseline configuration (Figure 9, Appendix). This disruption induces complex flow trajectories and localized hotspots, partially negating the advantages of an increased ventilation area and diminishing overall cooling performance under high-load conditions.

In Figure 11a (Appendix), the airflow vectors and vortex structures indicate the formation of recirculation zones, where the interaction of opposing flows traps heated air near critical components.

Figure 11b (Appendix) presents a top view of airflow trajectories. Low-velocity vectors in the corner regions indicate stagnation zones, while irregular flow patterns highlight increased turbulence and flow interaction caused by the auxiliary bottom fan.

Based on the above analysis, the following general conclusions can be drawn regarding the comparison of airflow behavior in the basic and updated PC case designs.

Idle conditions:

- the updated case design (Figure 10, Appendix) demonstrates improved airflow organization at idle, characterized by more uniform and stable flow patterns;
- in the basic design (Figure 8), the airflow is more chaotic and turbulent, with localized circulation zones that may negatively affect heat dissipation.

Under load conditions:

- under high load, the updated design (Figure 11, Appendix) exhibits localized flow and thermal limitations, including the formation of hot air vortices near cooling components, localized high-temperature regions, and stagnation zones;
- the basic design (Figure 9, Appendix) demonstrates more stable and organized airflow under load, with more uniform flow distribution, no strongly localized overheating zones, and stable intake airflow.

In summary, the updated PC case design (Figure 10 and Figure 11 in Appendix) enhances airflow distribution under idle conditions; however, under high thermal loads, it exhibits reduced heat dissipation efficiency in critical areas.

In contrast, the baseline design (Figure 8 and Figure 9), despite exhibiting less uniform airflow under idle conditions, maintains more effective heat dissipation characteristics under load due to its more organized airflow patterns.

Therefore, achieving optimal thermal performance for the updated design necessitates further optimization to enhance heat dissipation under high-load conditions. Cooling primarily relies on intake airflow from the lower part of the enclosure, which facilitates continuous air circulation throughout the system.

5 Conclusion

This study addresses the problem of computer modeling of temperature conditions in a personal computer system unit to improve its reliability and thermal performance.

The scientific novelty of this research lies in the development of a structural-parametric model of a personal computer, integrated with a comprehensive full-system CFD simulation. Unlike conventional approaches that primarily address isolated components (e.g., CPU cooling), the proposed methodology treats the entire system unit as a coupled thermo-aerodynamic environment. The model incorporates the spatial configuration of components, their specific thermal properties, and complex airflow pathways, thereby facilitating a holistic analysis of heat transfer processes.

A key scientific contribution of this study is the identification of a non-intuitive effect. Although the modified design improves airflow distribution and reduces temperature under idle conditions, it leads to reduced cooling efficiency under high-load conditions. This behaviour is explained by airflow interference, increased turbulence, and the formation of recirculation zones near heat-generating components, which negatively affect

heat dissipation. Under high-load conditions, the updated design reduces peak temperature but introduces airflow non-uniformity due to recirculation effects.

The results demonstrate that increasing ventilation or adding cooling elements does not necessarily improve thermal performance. Therefore, effective cooling system design requires a system-level approach that considers complex airflow interactions within the enclosure.

The practical significance of the work is that the proposed model and simulation approach can be used. They help optimise the design of computer system units, improve cooling efficiency, and extend equipment service life.

On the basis of a structural and parametric model, key parameters of PC design are formalized and described, including size, type, and technical characteristics of all major components.

The practical value of the results obtained is that:

1. The proposed structural and parametric model of a personal computer allows optimizing the design of system units and cooling systems, increasing reliability and efficiency of computer systems. This is of great practical importance for computer manufacturers.

2. Developed a 3D model of a PC and a computer simulation of temperature conditions, demonstrating the possibility of thorough analysis and optimization of air circulation and heat dissipation from components without the need for expensive physical experiments.

3. Modeling results allow us to identify «problem areas» in existing PC case designs and offer solutions to improve air circulation and cooling by making minor design changes.

4. Data obtained can be used by computer manufacturers to develop more efficient and reliable cooling systems, increasing productivity and the lifespan of equipment.

The proposed design improves airflow uniformity and thermal performance under idle conditions; however, under high-load conditions, its effectiveness decreases due to flow interference, increased turbulence, and the formation of recirculation zones, which reduce heat dissipation efficiency relative to the baseline design.

Consequently, the proposed solution is effective under idle conditions, while further optimization is required to ensure stable thermal performance under high-load scenarios.

The obtained results highlight the importance of considering airflow interaction effects when introducing additional cooling elements. The results of the numerical simulation are consistent with previously published CFD and experimental studies of desktop computer systems, which support the validity of the proposed modeling approach. A limitation of this study is the absence of experimental validation.

The results are based on numerical simulations and should be further confirmed through physical measurements or comparison with benchmark experimental data.

Prospects for further research are to further optimize the design of the system unit to improve its thermal characteristics. Experimental validation is considered a direction for future work. Particular attention will be paid to taking into account the effect of dust accumulation on overheating of system unit components. It is planned to study various design solutions that will minimize the formation of dust deposits and ensure effective cooling even under conditions of long-term operation.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the author(s) utilized artificial intelligence (AI) technologies solely for the purpose of linguistic refinement and grammatical correction. Following the application of these tools, the author(s) comprehensively reviewed, verified, and edited the resulting text. The author(s) maintain full accountability and responsibility for the accuracy, integrity, and final content of the publication.

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APPENDIX

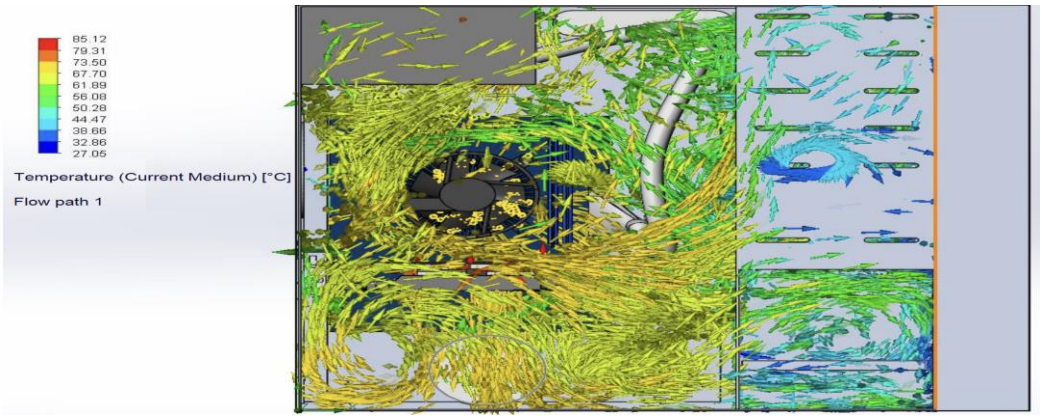
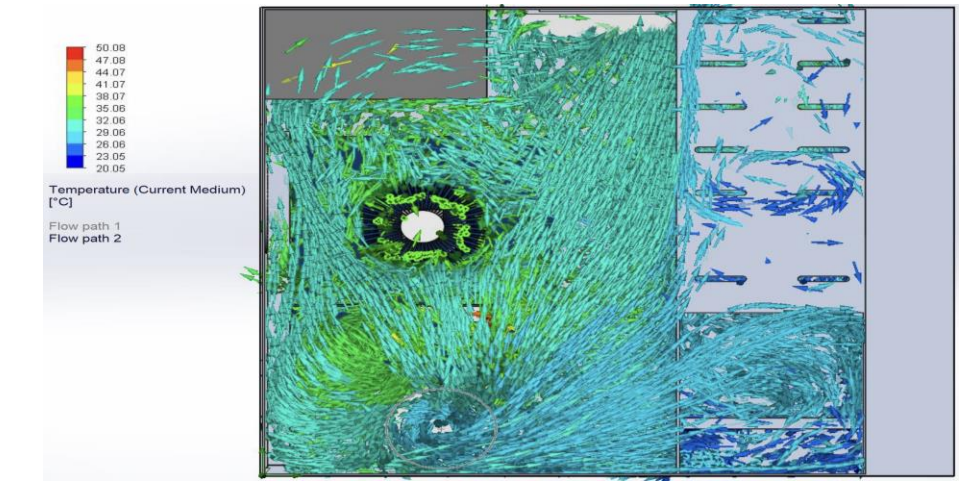
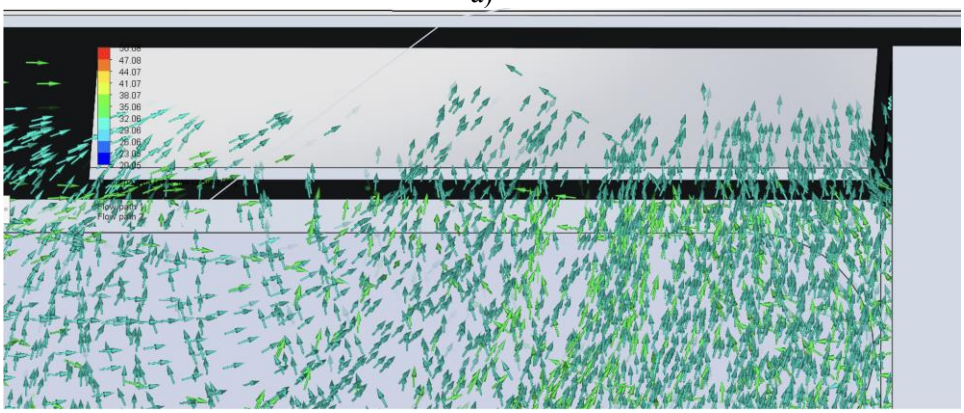


Fig. 9: Airflow simulation in the baseline PC case under high-load conditions. The visualization demonstrates relatively uniform flow distribution, stable intake streams, and the absence of pronounced recirculation zones.
Source: created by the author.

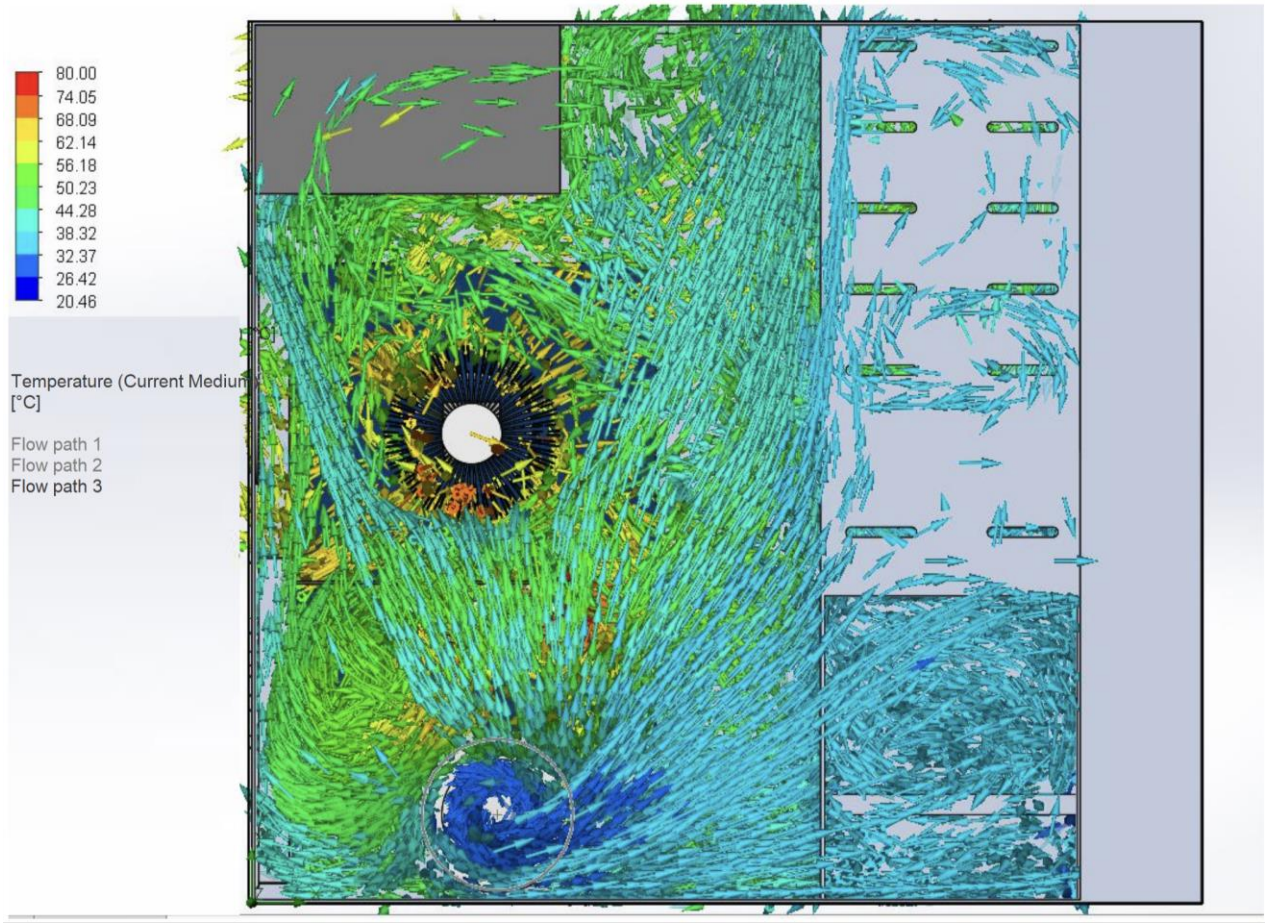


a)

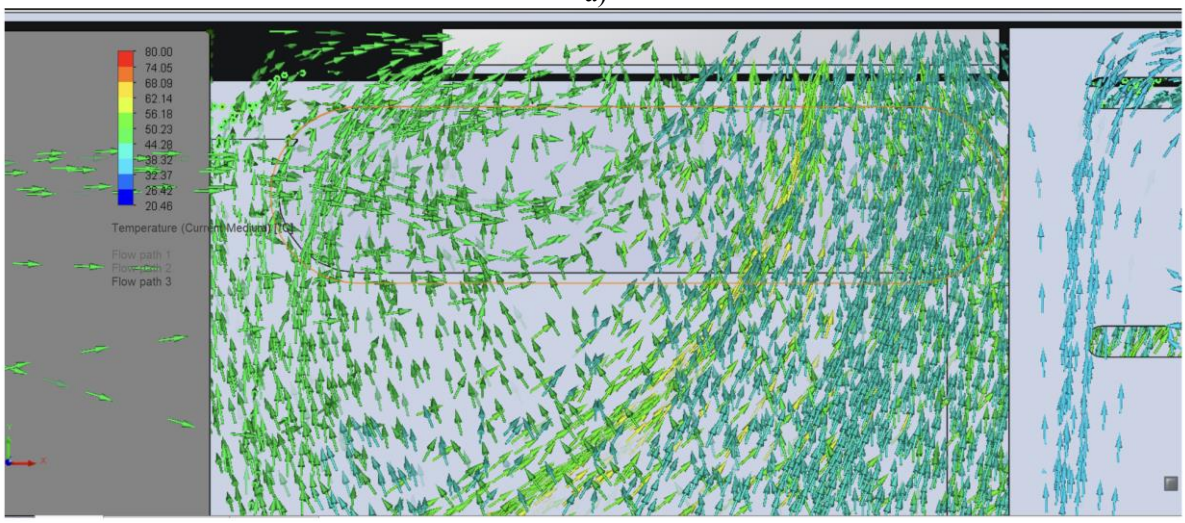


b)

Fig. 10: Airflow simulation in the modified PC case under idle conditions
Source: created by the author.



a)



b)

Fig. 11: Airflow simulation in the modified PC case under high load conditions
Source: created by the author.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in present research, at all stages from the formulation of problem to final findings and solution.

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Conflict of Interest

No conflicts of interest in this research.

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