ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering | e–ISSN: 2067 – 3809
Tome XVIII [2025] | Fascicule 4 [October – December]

[1.] Flavius BUCUR , [2.] Ana SOCALICI , [2.] Corneliu BIRTOK BANEASA

SIMULATION OF THE AIR INTAKE PROCESS THROUGH THE DYNAMIC TRANSFER SYSTEM FOR LARGE–DISPLACEMENT ENGINES

[1.] "Anghel Saligny" Railway Transport Technological High School, Simeria, ROMANIA
[2] Dept. Engineering and Management, Politehnica University of Timisoara, Faculty of Engineering Hunedoara, Hunedora, ROMANIA

Abstract: Large–displacement engines, typically above 4.0 liters, require substantial air volumes for efficient combustion. To optimize this process, dynamic air transfer systems are employed to enhance the airflow characteristics, reduce pressure losses, and maximize volumetric efficiency. This paper presents a detailed 3D modeling and computational fluid dynamics simulation of an aerodynamic air intake system for large–displacement bus engines. Using SolidWorks Flow Simulation, various design iterations were analyzed to identify the most effective intake system configuration. The results demonstrate significant improvements in air intake performance, suggesting that this simulation approach can be used for enhancing engine efficiency in commercial vehicles. Air intake systems are very important for engine performance, especially in large engines like those in buses. Good air flow helps the engine burn fuel better, which improves power, saves fuel, and reduces pollution.
Keywords: research project, simulation, air, dynamic transfer, engines

INTRODUCTION

Air intake systems in internal combustion engines deliver filtered, temperature–controlled air to the combustion chamber for efficient fuel burning and power generation. They optimize airflow volume, density, and distribution to enhance performance, reduce emissions, and improve fuel efficiency.

Air intake systems play a crucial role in the performance of internal combustion engines, particularly those with large displacements. Engines with capacities greater than 4.0 liters, such as those used in buses, require efficient air management to ensure optimal combustion [1–6]. The efficiency of the intake system affects the overall engine performance, including power output, fuel consumption, and emissions.

Air intake systems supply clean, filtered air to internal combustion engines, enabling efficient combustion by mixing oxygen–rich air with fuel. Their design directly influences power output, fuel economy, and emissions through optimized airflow and temperature control. Air filters capture dust and particulates to safeguard engine internals while allowing maximum airflow. Throttle bodies regulate air entry via a butterfly valve linked to the accelerator, working with mass airflow sensors for precise ECU adjustments.

The air intake system's primary function is to deliver the required volume of air to the engine while minimizing pressure losses and turbulence [7–12]. Therefore, the design of these systems must be carefully optimized to balance high airflow with low aerodynamic resistance. In this study, the air intake system of a bus engine was modeled and simulated using SolidWorks Flow Simulation, aiming to improve the aerodynamic characteristics and, consequently, the overall engine efficiency [13–15].

The main objectives of this study are:

- To design and simulate an optimized dynamic air intake system for a large–displacement bus engine using SolidWorks;
- To analyse the impact of different intake system configurations on airflow characteristics, such as pressure distribution, turbulence, and velocity profiles;
- To identify the most effective design that minimizes pressure losses, reduces turbulence, and ensures uniform airflow to the engine.

METHODOLOGIES

Design of the Air Intake System

Design principles for air intake systems in internal combustion engines prioritize maximizing airflow velocity, density, and uniformity while minimizing restrictions, turbulence, and heat build–up to optimize combustion efficiency.

Variable–length manifolds switch runner paths for low/high–speed performance, while patents emphasize incremental pipe sizing for continuous flow from plenum to ports. Computational modeling predicts intake rates and valve timing for minimal pressure drops. These designs reduce emissions and enhance torque across operating conditions.

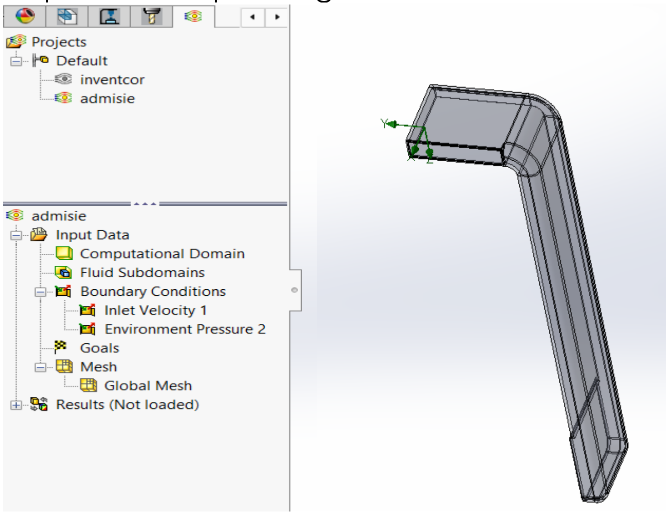

Figure 1. The modeling process started with the creation of the air intake system in SolidWorks

The modeling process (figure 1) started with the creation of the air intake system in SolidWorks, where the geometric constraints and design parameters of a typical bus engine compartment were incorporated. The intake system was designed to facilitate the smooth flow of air from the external environment into the engine, passing through ducts, filters, and manifolds. Computational Fluid Dynamics (CFD) simulations model unsteady airflow in air intake systems of internal combustion engines, predicting pressure distributions, velocities, and swirl to optimize design before prototyping.

Computational Fluid Dynamics Simulation

After the geometry was finalized, SolidWorks Flow Simulation was used to conduct CFD simulations. SolidWorks Flow Simulation enables embedded CFD analysis directly within CAD models for air intake systems, simulating airflow, pressure drops, and velocities to refine designs like manifolds and ports. It uses finite volume methods to solve incompressible/compressible flows, ideal for steady–state or transient engine intake studies with minimal meshing effort.

The simulations aimed to replicate real–world operating conditions, such as:

- ambient temperature: 298 K
- atmospheric pressure: 101,325 Pa
- inlet air velocity: 10 m/s
- engine operating speeds: 1,000 to 3,500 RPM

Boundary conditions were defined at the air intake and engine inlet to represent realistic airflow behaviour. The primary objectives of the CFD analysis were to determine the airflow velocity, pressure distribution, and turbulence levels within the intake system.

Design Iterations

Design iterations for air intake systems leverage SolidWorks Flow Simulation's parametric study tool to automate testing of geometry variations like runner lengths, plenum volumes, and valve angles, rapidly identifying optimal configurations for uniform flow and peak volumetric efficiency.

Multiple intake designs were tested, each featuring variations in duct geometry, flow–straightening elements, and surface profiles. Key performance indicators (KPIs) such as:

- pressure loss across the system
- flow velocity uniformity
- turbulence intensity
- airflow distribution at the manifold inlet

were evaluated to identify the most aerodynamically efficient configuration. Key performance indicators for air intake systems in internal combustion engines, evaluated via CFD simulations like SolidWorks Flow Simulation, quantify flow efficiency, uniformity, and losses to guide design iterations.

RESULTS

CFD simulation results for air intake systems using SolidWorks Flow Simulation reveal critical airflow patterns, pressure losses, and distribution imbalances that drive design improvements. The CFD simulation results highlighted several key findings (figures 2–5):

- Pressure Loss: The optimized intake design reduced pressure losses by 12% compared to the baseline configuration. This improvement was achieved through smoother transitions in the duct geometry, which minimized flow resistance;
- Velocity Distribution: The optimized intake configuration resulted in a more uniform airflow distribution at the engine manifold. The velocity profile showed less variation across the intake cross–section, reducing the risk of uneven combustion and enhancing engine efficiency;
- Turbulence Reduction: Incorporating flow–straightening elements significantly reduced turbulence within the ducts. This improvement contributed to a more stable and controlled air intake process, promoting better combustion conditions;
- Volumetric Efficiency: The improved design increased the volumetric efficiency of the intake system, ensuring that more air was available for combustion. This directly contributed to enhanced engine power and fuel economy.

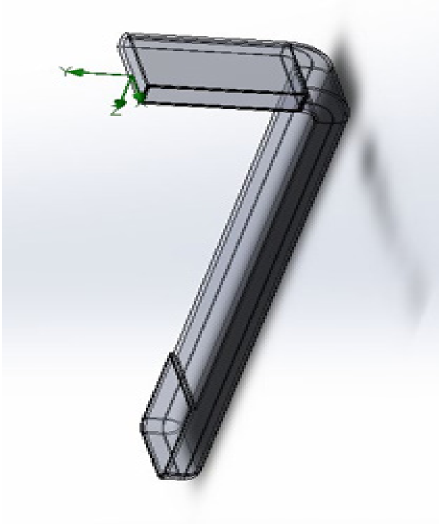

Figure 2. Model system transfer

The results of the CFD simulations demonstrate the significant impact of intake system design on engine performance. By reducing pressure losses and minimizing turbulence, the intake system becomes more efficient, allowing for better air delivery to the engine. The flow–straightening elements and smooth duct transitions played a crucial role in achieving these improvements.

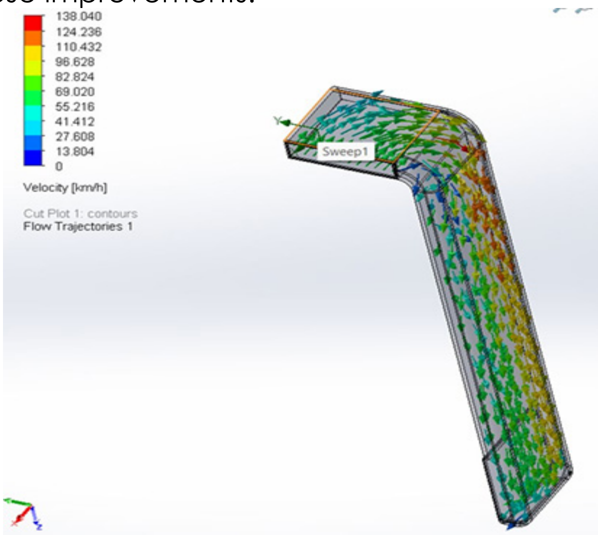

Figure 3. Airflow simulation and speed variation

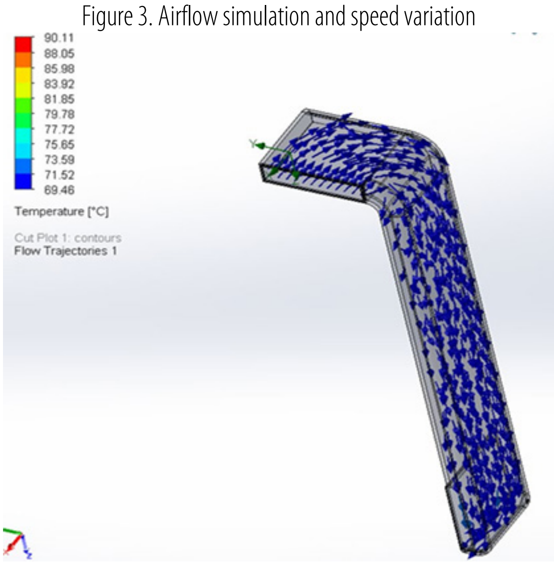

Figure 4. Airflow simulation and temperature variation

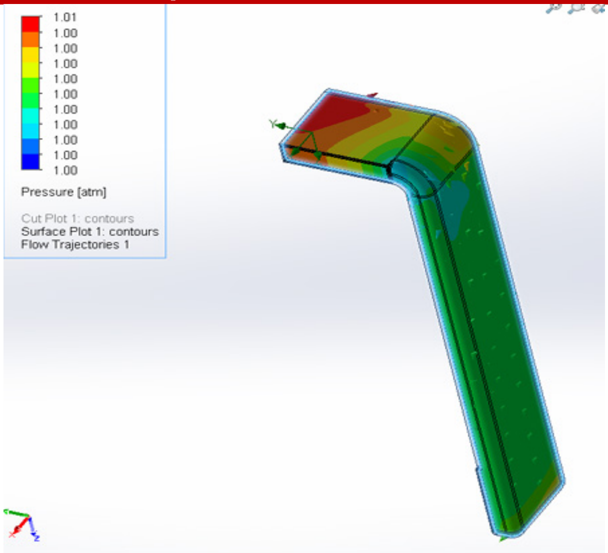

Figure 5. Airflow simulation and pressure variation

Moreover, the use of SolidWorks Flow Simulation allowed for the rapid evaluation of different intake configurations, enabling the identification of an optimal design without the need for physical prototyping. This approach can be extended to other engine systems and vehicle types to further optimize their performance.

While the simulation results are promising, they should be validated experimentally through wind tunnel testing and on–road performance evaluations. Future research could also focus on the impact of intake temperature and humidity variations on engine performance.

CONCLUSIONS

This study demonstrated the successful application of 3D modeling and CFD simulation in optimizing the aerodynamic performance of air intake systems for large–displacement bus engines. The optimized design achieved significant reductions in pressure losses, turbulence, and flow irregularities, resulting in improved engine efficiency.

The use of SolidWorks Flow Simulation in this context highlights the value of computational tools in designing high–performance automotive systems. Future work will focus on experimental validation of the simulation results and the refinement of the intake design to adapt to different operating conditions.

References

[1] Cengel, Y.A., & Boles, M.A. Thermodynamics: An Engineering Approach. McGraw–Hill
[2] White, F.M. (2011). Fluid Mechanics (7th ed.). McGraw–Hill, 2015
[3] SolidWorks Corporation. SolidWorks Flow Simulation User Guide. SolidWorks, 2021
[4] Bartos, D. & Santos, F. Optimization of Engine Intake System Using Computational Fluid Dynamics. International Journal of Engine Research, 10(2), 35–42, 2019

[5] Lee, J. & Kim, H. The Effect of Air Intake System Design on Engine Performance and Emissions. Journal of Mechanical Engineering, 62(4), 215–223, 2016
[6] Zheng, J.Q.; Dai, Y.H.; Liang, Y.T.; Liao, Q.; Zhang, H.R. An online real–time estimation tool of leakage parameters for hazardous liquid pipelines. Int. J. Crit. Infrastruct. Prot. 2020, 31, 100389
[7] Vasileiou, C.; Smyrli, A.; Drogosis, A.; Papadopoulos, E. Development of a passive biped robot digital twin using analysis, experiments, and a multibody simulation environment. Mech. Mach. Theory 2021, 163, 104346
[8] Bossard, J.; Reich, A.; DiMeo, A. Dynamic analysis of a high–pressure relief valve during opening. J. Press. Vessel. Technol. 2021, 143, 01140
[9] Zhou, X.M.; Wang, Z.K.; Zhang, Y.F. A simple method for high–precision evaluation of valve flow coefficient by computational fluid dynamics simulation. Adv. Mech. Eng. 2017, 9, 1–7
[10] Wu, D.Q.; Burton, R.; Schoenau, G.; Bitner, D. Modelling of orifice flow rate at very small openings. Int. J. Fluid Power 2003, 4, 31–37
[11] Poling, B.E.; Prausnitz, J.M.; O'Connell, J.P. The Properties of Gases and Liquids, 5th ed.; McGraw–Hill: New York, NY, USA, 2001
[12] Poling, B.E.; Prausnitz, J.M.; O'Connell, J.P. The Properties of Gases and Liquids, 5th ed.; McGraw–Hill: New York, NY, USA, 2001
[13] Z. Dimitrova, F.Maréchal, Gasoline hybrid pneumatic engine for efficient vehicle powertrain hybridization, Appl. Energ. 151, 168–177, 2015
[14] Z.Hu,Y.Gui, M.Xu, et al., Design of a variable valve hydraulic lift system for diesel engine, J.Mech. Sci. Technol. 29, 1799–1807, 2015.
[15] X.L. Yu, G.J. Yuan, Y.M.Shen, et al, Theoretical analysis of air–powered engine work cycle, Chin. J. Mech. Eng (In Chinese) 38, 118–122, 2002

ISSN: 2067–3809