Vol-08 Issue 04, April- 2024

Impact Factor: 7.936
ISSN: 2456-9348

iJETRM
International Journal of Engineering Technology Research & Management
www.ijetrm.com

REVIEW PAPER ON DESIGN AND OPTIMIZATION OF INTAKE MANIFOLD FOR FORMULA STUDENT VEHICLE

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ABSTRACT

Traditionally, the design of Formula Vehicle air intake systems has relied on iterative trial-and-error methods. This study introduces a pioneering approach to establish a scientific and engineering foundation for this process. By deconstructing the intake system into its constituent components and exploring the pertinent scientific and engineering principles governing each component's design, this study aims to revolutionize intake system optimization.

Engine data, encompassing details such as cam profile, intake valves, and cylinder specifications, serves as the cornerstone for creating a comprehensive engine simulation model. This model, meticulously crafted, is then employed to sequentially analyze each component of the intake system. Through a meticulous validation process against simulations of the entire engine system, the airflow behavior of individual components is scrutinized.

Physical testing, conducted using a flow bench, is employed to corroborate the simulation results, ensuring the reliability and accuracy of the proposed design solutions. The document proposes a specific geometric design for a restrictor, meticulously crafted to maximize airflow while minimizing pressure drop, thus enhancing the overall performance of the Formula Vehicle engine.

In compliance with Formula SAE competition regulations, a 20mm restrictor is mandated in the intake manifold, serving as the focal point for directing all airflow to the engine. Regardless of whether the engine is single or multi-cylinder, this restrictor poses a challenge, as it diminishes the engine's intake capacity, thereby significantly impacting airflow and, consequently, the engine's power output.

Recognizing the critical role of a well-designed intake manifold in optimizing the performance of internal combustion engines (IC Engines), this document meticulously focuses on the 3D simulation of a single-cylinder KTM 390 Duke Engine. Employing both steady and unsteady analyses through ANSYS FLUENT software, this study aims to unlock novel insights into intake system optimization.

Keywords:
Intake Manifold, Plenum, Restrictor, Velocity Vectors, Pressure Contour.

LITERATURE REVIEW

[1] S S Sawant et al (2017) In this paper by using the trial and iterative method the convergent and divergent angles are calculated. And weight reduction of the system was also considered.

[2] Singhal, A., &Parveen, M. (2013The study discovered an optimal solution to maximize mass flow while minimizing engine resistance. Through extensive simulations using Solid Works Flow Simulation, the study determined optimized converging and diverging angles for the Ventures to achieve this goal.

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[3] Shinde, P. A. (2014) The paper conducted analytical calculations using established methods to determine the minimum air flow rate. Additionally, it utilized Computational Fluid Dynamics (CFD) tools to assess the minimum pressure drop across the restrictor, varying the converging and diverging angles of the venture for analysis.
[4] Logan M. Shelagowski and Thomas A. Mahanak. The paper utilized Computational Fluid Dynamics (CFD) software to analyze and visualize fluid flow dynamics. By optimizing flow parameters, the study achieved maximum flow, resulting in higher volume flow rates (averaging 4.8 CFM) which is expected to enhance low-to mid-range torque, thereby optimizing engine performance.
[5] Shubham Raj et.al (2016) The paper proposed a Venturi-type design aimed at maximizing the engine's intake rate through a 20 mm restrictor by leveraging pressure differences across the Venturi. Analytical calculations were conducted to determine the maximum mass flow rate, while CFD simulations were employed to assess the minimum pressure drop across varying converging and diverging angles. The CFD results indicated that a diverging angle of 14 degrees and 6 degrees yielded the minimum pressure drop.
[6] Kaushal Kishor (2015) The author focused on designing, analyzing, and manufacturing an air intake and exhaust system for a prototype Formula-style car. The approach utilized locally available resources and adhered to the regulations set by two prominent student-level events held in India.
[7] HONG Han-chi et.al (2012) The paper employed Computational Fluid Dynamics (CFD) software to analyze and visualize fluid flow dynamics, aiming to achieve maximum flow. This higher volume flow rate is anticipated to enhance low- to mid-range torque, thereby optimizing engine performance. Additionally, the study utilized 1-Dimensional software GT-Power to simulate engine performance. Parameters such as plenum diameter, intake runner diameter, exhaust runner lengths, and retractor position were optimized using a combination of 1-Dimensional simulation and an orthogonal L9 (34) testing design.
[8] Brogan Ryland's and et.al- The paper emphasizes the complexity surrounding the adoption of 3D printing, which requires reengineering of value streams and collaboration across organizations. Effective preparation involves education, generating interest, and considering various factors. Managers are advised to carefully assess the importance of each aspect. The study highlights the current impacts on manufacturing and supply chains, with notable future implications. Furthermore, it underscores the need to evaluate Australia's position compared to global peers and analyze supply chain costing. Successful deployment is contingent upon reaching a specific level of supply chain maturity, and the paper suggests aiding academia and practice through a decision-making framework.
[9] Alexandru Pirjan Dana-Mihaela Petroşanu in the journal delves into the profound impact of 3D printing on both society and the economy. Beginning with a concise historical overview, it proceeds to explore additive technology and materials utilized in rapid prototyping. The paper critically examines the advantages and limitations of 3D printing before presenting a survey of noteworthy 3D printing solutions, offering comparisons of their technical specifications and pricing. Overall, the study underscores the growing significance of this technology and its profound influence on human life, the economy, and contemporary society.
[10] Thabiso Peter Mpofu and et.al The journal paper titled "The Impact and Application of 3D Printing Technology" concludes that the 3D printing industry is poised for significant growth, supported by growth forecasts. The increasing applications of 3D printing are evident as research in the field expands. The paper highlights the potential transformation in how people acquire products, citing the proposed model by Amazon. Overall, it emphasizes that 3D printing is a game changer with abundant prospects to anticipate.
[11] Baljinder Singh Shahi The paper titled "Advanced Manufacturing Techniques (3D Printing)" concludes that additive manufacturing, in its current nascent stage, demands flexibility from manufacturing firms, requiring them to continuously improve and utilize all available technologies to stay competitive. Proponents of additive manufacturing also anticipate that this technological advancement will serve as a counterbalance to globalization. They predict that end users will increasingly engage in their own manufacturing instead of relying solely on trade with other entities. However, the paper notes that the full integration of additive technologies into

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commercial production is more about complementing traditional subtractive methods rather than completely replacing them.

[12] Sardar, P. and Sardar, A. (2018), The paper titled "Designing of intake manifold for Formula Student car" highlights the prevailing literature's emphasis on optimizing convergent-divergent nozzles to alleviate restrictor effects in Formula Student car intake manifold design for performance enhancement. However, this study introduces a novel approach by incorporating Helmholtz resonator theory and computational fluid dynamics (CFD) analysis to determine the optimal runner length and plenum volume. Through a focus on dynamic processes and transient analysis, the research underscores the significance of fine-tuning engine performance beyond conventional methods. This innovative perspective provides valuable insights for improving acceleration and competitive performance in Formula Student competitions.

[13] Sylvie Dore (1997), The paper titled "Design and fabrication of intake manifold for Formula SAE (Society of Automotive Engineers) race car" discusses the existing literature's focus on the challenges of optimizing the air/fuel mixture within defined constraints in Formula SAE air intake system design. The study utilizes theoretical analysis to narrow down potential runner lengths while stressing the importance of experimental validation for runner configuration and plenum shape. The research also explores innovative rapid prototyping methods, such as functional prototypes and composite lamination, to expedite the design process and offer flexibility in achieving complex shapes. This approach not only saves time but also enhances the development of intake manifolds for Formula SAE vehicles.

[14] Devesh Wani, (2023), The paper titled "Design and Analysis of Air Intake Manifold for Formula Student Cars" reviews existing literature on Formula SAE restrictor design, highlighting the significance of optimizing airflow while complying with competition regulations. Prior studies emphasize the utilization of mathematical modeling and computational fluid dynamics (CFD) to examine airflow patterns and pressure differentials across restrictors. Strategies aimed at maximizing engine performance within restrictor constraints are paramount for achieving success in Formula SAE competitions. Innovative approaches, including adjustments to venturi angles, are investigated to reduce pressure differentials and improve engine efficiency.

[15] Jianmin Xu, (2017), The paper titled "Flow analysis of engine intake manifold based on computational fluid dynamics" surveys existing literature on intake manifold design for multi-cylinder engines, emphasizing its pivotal role in achieving intake uniformity. Prior research has extensively employed computational fluid dynamics (CFD) simulations to assess flow characteristics and minimize intake irregularities. Various intake manifold configurations have been explored to enhance engine intake and combustion efficiency. Notably, the positioning of the inlet end within the intake manifold has emerged as a critical factor in mitigating non-uniformity and optimizing engine performance. These insights contribute to advancing the theoretical framework for designing intricate intake manifold systems aimed at elevating overall engine efficiency and performance.

[16] Shuqing Guo, (2018), The paper titled "Optimized design of engine intake manifold based on 3D scanner of reverse engineering" addresses challenges associated with designing intricate engine intake manifolds and the drawbacks of conventional testing techniques. To overcome these challenges, the study proposes reverse engineering as a solution, employing CATIA for 3D modeling and Computational Fluid Dynamics (CFD) for fluid analysis. By utilizing simulation results, the research informs an optimized design aimed at enhancing air intake efficiency and minimizing resistance. This approach effectively improves engine performance and intake uniformity, thereby validating its efficacy for manifold design.

[17] M. Naveen Kumar, (2021), The paper titled "Retrospection of the Optimization Model for Designing the Power Train of a Formula Student Race Car" underscores the significance of optimizing vibration decoupling to enhance performance. Essential components such as the engine, clutch, gearbox, and drive shaft play crucial roles in power transmission. Selecting suitable engine platforms, such as the KTM 390, enhances reliability and fuel efficiency. Moreover, adherence to safety regulations and compliance with design procedures as per SAE International rules ensure the integrity of the powertrain system.

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[18] R.K. Tyagi, (2015), Improved intake manifold design for I.C. engine emission control, Spark Ignition engine emissions emphasizes the importance of mitigating air pollutants to meet governmental regulations. Research efforts concentrate on reducing emissions like CO, NOx, HC, and CO2 through innovative engineering solutions, particularly in the realm of inlet manifold design. Comparative studies demonstrate substantial decreases in pollutants, particularly with venturi-based intake manifold configurations showing promising outcomes. Variations in manifold modifications further underscore the efficacy of specific designs, with Inlet Manifold Modified 2 exhibiting superior capabilities in pollutant reduction.
[19] Jisco Shin, (2022), The paper titled "Effect of intake manifold geometry on cylinder-to-cylinder variation and tumble enhancement in gasoline direct injection engine" investigates how intake manifold geometry influences cylinder-to-cylinder variation using CONVERGE v2.4. Results indicate that straight manifolds offer advantages over curved ones, showcasing reduced deviation in volumetric efficiency and stronger in-cylinder flow dynamics, particularly around spark plug timing. Computational fluid dynamics simulations corroborate these findings with experimental data, emphasizing the importance of shortening the distance between intake manifold inlet and port, as well as increasing manifold radius, to enhance in-cylinder flow intensity.
[20] B. Sushma, (2020), The paper titled "A Review on Intake Manifold, 3D printing in intake manifold fabrication" examines the advantages of utilizing 3D printing technology, such as design flexibility, customization potential, and waste minimization, for intake manifold fabrication. Research efforts are directed towards exploring design considerations, geometric optimization strategies, and fabrication processes to enhance engine performance. Additionally, the paper offers a comparative analysis of traditional manufacturing techniques and materials commonly employed in intake manifold production, alongside an evaluation of the benefits and limitations associated with 3D printing in this domain.

CONCLUSION

The Formula SAE competition serves as a dynamic arena for students to immerse themselves in real-world industrial simulations, providing a rich learning environment for honing product development techniques. While rapid prototyping technologies offer promising avenues to accelerate time-to-market, their effectiveness is contingent upon robust support from modern management tools. The success of projects in this domain pivots on a multifaceted approach, encompassing Design for Manufacturing (DFM) principles, collaborative teamwork, and technical acumen. Achieving swift production of cost-effective prototypes requires a blend of ingenuity and deep comprehension of manufacturing processes, particularly for designs with straightforward geometries.
Innovation thrives within the Formula SAE framework, as evidenced by landmark achievements such as the 1996 Formula SAE-ETS team's pioneering integration of rapid tooling technology into pre-production prototype fabrication. The exploration of novel manufacturing techniques through these projects underscores the inventive spirit inherent in Formula SAE participants.
The diverse array of intake designs showcased by Formula SAE teams suggests ongoing exploration towards discovering the most competitive design solutions. To facilitate simplified analysis and comparison, prevalent designs were transformed into conceptual models using Computer-Aided Design (CAD). Furthermore, addressing packaging constraints imposed by Formula SAE rules necessitated the simulation of additional sub-concepts.
This project highlights the paramount importance of accurately monitoring engine speed and Manifold Absolute Pressure (MAP) for optimizing torque utilization on the track, thereby driving engine development from a vehicle performance perspective. While 1-D engine simulations like GT-Power play a pivotal role in intake manifold design refinement, precise calibration using the Wiebe function ensures alignment between simulated and measured cylinder pressure.
However, leveraging a full engine model based on the Wiebe function presents challenges, particularly in instances where data pertaining to engine geometry, thermal properties, and airflow characteristics is limited.

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Moving forward, continued innovation and interdisciplinary collaboration will propel Formula SAE teams towards groundbreaking advancements in automotive engineering.

ACKNOWLEDGEMENT

We owe our immense thanks to Mr. S. MADHU our guide, Assistant professor in department of mechanical engineering, Guru Nanak Institute of Technology for the sustained interest, constructive criticism, and constant encouragement at every stage of this endeavour.

We extend our deep sense of graduate to Dr. B. VIJAYA KUMAR, Professor & Head of the Mechanical Department & Dr. S. SREENATHA REDDY, Principal and the Management of the Guru Nanak Institute of Technology for providing us the best amenities which enabled us to complete our project in the stipulated time.

Finally, yet importantly, we are very thankful to our parents, friends, and other faculty of Mechanical Engineering department for their constant support in completion of this project.

REFERENCES

[1]. B.S S Sawant et al, Design analysis of air intake system for FSAE Race car–International Journal for Science and Research in Technology (IJSART).

[2]. Singhal, A., & M. Praveen. Air Flow Optimization via a Venturi Type Air Restrictor. InProceedings of the World Congress on Engineering London.

[3]. Shinde, P. A. (2014). Research and optimization of intake restrictor for Formula SAE car engine. International Journal of Scientific and Research Publications, 4(4).

[4]. Logan M. Shelagowski and Thomas A. Mahanak. Formula SAE intake restrictorDesign and Performance. Saginaw Valley State University.

[5]. Shubham Raj, Ashish Kr. Singh, Tuhin Srivastava, Vipul Vibhanshu. "Analysis of Air Intake for Formula SAE Vehicle" Krishna Institute of Engineering and Technology Ghaziabad, UPTU, Vth International Symposium on "Fusion of Science & Technology", New Delhi, India, January 18-22, 2016.

[6]. Kaushal Kishor, –Design and Fabrication of Intake and Exhaust Manifold of a Prototype Race Car‖, Department of Mechanical Engineering National Institute of Technology, Rourkela, India.

[7]. HONG Han-chi, HUANG Hong-wu , BAI Yi-jie, "Optimization of Intake and Exhaust System for FSAE Car Based on Orthogonal Array Testing", Mechanical Department of Xiamen University of Technology, China, International Journal of Engineering and Technology Volume 2 No. 3, March, 2012.

[8]. Brogan Rylands, 3D Printing - To print or not to print? Aspects to consider before adoption -A supply chain perspective in the year 2015

[9]. ALEXANDER Pirjan and Dane-Mihaela Petrosanu, The impact of 3D Printing technology nthe society and economy.

[10]. Thabijo Peter Mpofu, The impact and application of 3D Printing technology, Volume 3, issue6 in June 2014, ISSN 2319-7064.

[11]. Baljinder Singh Shahi, Advanced Manufacturing Techniques (3D Printing), volume 4, issue 4in 2016, ISSN 2320-2092.

[12]. Sardar, P. and Sardar, A. (2018), "Designing of intake manifold for Formula Student car", World Journal of Engineering, Vol. 15 No. 3, pp. 402-406. https://doi.org/10.1108/WJE-09-2017-0289

[13]. Sylvie Dore, (1997) "Design and fabrication of intake manifold for formula SAE (Society of Automotive Engineers) race car", The International Society for Optical Engineering

[14]. Devesh Wani, (2023), Design and Analysis of Air Intake Manifold for Formula Student Cars e-ISSN: 2395-0056 Volume: 10 Issue: 12 | Dec 2023 www.irjet.net p-ISSN: 2395-0072

[15]. Jianmin Xu, (2017), Flow analysis of engine intake manifold based on computational fluid dynamics, IOP

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International Journal of Engineering Technology Research & Management
www.ijetrm.com

Conf. Series: Journal of Physics: Conf. Series 916 (2017) 012043

[16]. Shuqing Guo, (2018), Optimized design of engine intake manifold based on 3D scanner of reverse engineering, 70 (2018). https://doi.org/10.1186/s13640-018-0304-8

[17]. M. Naveen Kumar, (2021), Retrospection of the Optimization Model for Designing the Power Train of a Formula Student Race Car, Volume 2021, Article ID 9465702, https://doi.org/10.1155/2021/9465702

[18]. R.K. Tyagi, (2015), Improved intake manifold design for I.C. engine emission control, Vol. 10(9).

[19]. Jisco Shin, (2022), Effect of intake manifold geometry on cylinder-to-cylinder variation and tumble enhancement in gasoline direct injection engine, Vol 10 (9).

[20]. B. Sushma, (2020), A Review on Intake Manifold, Volume-3, Issue-1, January-2020.