MIRAE Vol. 2, No. 1, January 2025
ISSN: 3063-8720, DOI: https://doi.org/10.70935/67m23j34

Article

Design and Development of a Pneumatic Bush Installation Tool for Motorcycle Engine Mounting Production Efficiency

Azzahra Nazwa Asyifa[1,2], Yuliarto Joko Sumbogo[1,*], Dimas Ardiansyah Halim[3], Joko Suparno[1]

[1]Department of Mechanical Engineering, Akademi Teknik Wacana Manunggal, Salatiga, Indonesia
[2]Department of Research and Development, DTECH Inovasi Indonesia Co. Ltd., Salatiga, Indonesia
[3]Department of Mechanical and Industrial Engineering, Universitas Tidar, Magelang, Indonesia

* Corresponding: yuliartoatwm@gmail.com

ARTICLE INFO

Submitted 2 Jan 2025
Revised 29 Jan 2025
Accepted 30 Jan 2025
Published 31 Jan 2025

Abstract.
The increasing demand for efficient and precise manufacturing processes in the automotive industry has led to the development of automated assembly systems, including pneumatic-based tools. This study focuses on designing, developing, and evaluating a pneumatic Bush installation tool for motorcycle engine mounting production efficiency. The tool was tested against manual methods (hammer and jack) to compare installation time, accuracy, and defect rates (NG). A quasi-experimental approach involved trial and error testing, prototype validation, and comparative analysis. The results showed that the pneumatic system significantly outperformed the manual method, with an 80% improvement in efficiency, reducing installation time from 120 seconds (manual) to 45 seconds (pneumatic). Additionally, Bush misalignment was reduced from 40% (manual) to 10% (pneumatic), while installation-induced defects dropped from 35% to only 5%. The findings demonstrate that the pneumatic-assisted tool provides more consistent pressure control, improved accuracy, and reduced error rates, making it a superior alternative to manual methods. This study contributes to the advancement of automated assembly technologies in the motorcycle manufacturing industry.

Keywords: Pneumatic system; Bush installation; Engine mounting; Manufacturing efficiency

INTRODUCTION

In the era of globalization and rapid technological advancements, the automotive industry must produce high-quality products through efficient manufacturing processes. One of the vital components in motor vehicles is the engine mounting, a structural support that stabilizes the engine, absorbs vibrations, and evenly distributes loads [1], [2]. An optimally functioning engine mounting enhances engine performance and driving comfort and plays a crucial role in ensuring safety and operational efficiency. Innovations in design, materials, and production technology for engine mountings continue to evolve in response to increasing demands for higher performance and durability. Amidst the intensifying competition in the automotive industry, production time efficiency and improved assembly quality have become strategic aspects that must be optimized, one of which is by utilizing modern technologies such as pneumatic systems [3]–[6].

Specifically, the Bush installation on the engine mounting is a critical stage in the engine assembly process. This installation must be executed with high precision to ensure the engine mounting can function optimally to absorb vibrations and support engine loads. Conventional installation methods that rely on manual labor, such as hammers or jacks, often pose challenges related to installation inconsistencies, inaccuracies, and relatively long processing times. These limitations reduce product quality and increase the risk of defects (NG), ultimately affecting overall production efficiency. This is where pneumatic technology plays a crucial role, as controlled pressurized air utilization enables the Bush installation process to be carried out automatically, quickly, and consistently. Implementing pneumatic systems is expected to enhance installation precision while minimizing errors commonly found in manual methods [6]–[9].

Previous studies have examined the application of pneumatic technology in various production lines. Arizona et al. [8] conducted tests on a pneumatic-based pineapple cutting machine, which was 3.5 times faster than manual cutting. Kurniawan [4] developed an automated system to improve material handling efficiency in industries, designed to increase productivity, reduce time and production costs, and replace repetitive manual tasks. Meanwhile, Damrath et al. [9] conducted tests using a physics-based simulation model for pneumatic components in automotive production systems. The results indicated that the Physics-based Pneumatic Model could accurately reproduce the behavior of pneumatic components in terms of kinematics, dynamics, and air consumption. Moreover, pneumatic technology can be integrated with automation systems, reducing energy consumption and creating a highly efficient production process [10]–[12].

These studies demonstrate that pneumatic systems can enhance operational speed and pressure consistency, significantly contributing to production efficiency and final product quality. However, most of these studies have focused on general applications of pneumatic systems rather than specifically addressing the Bush installation in engine mountings. On the other hand, research on engine mountings has primarily explored design aspects [13]–[15], materials [16], and vibration analysis [17], [18], leaving a gap in studies that integrate pneumatic technology to improve the efficiency and effectiveness of Bush installation. This gap necessitates further research to develop a pneumatic-assisted installation tool specifically designed for engine mounting motorcycle applications.

Thus, this study aims to develop a pneumatic-based Bush installation tool for engine mountings and evaluate its performance compared to conventional methods. This tool improves production time efficiency while ensuring high-precision component installation, ultimately supporting a more optimal and accurate manufacturing process.

METHODS

This research method follows the flowchart shown in **Figure 1**, which illustrates the entire process from design to the development of the pneumatic Bush installation tool.

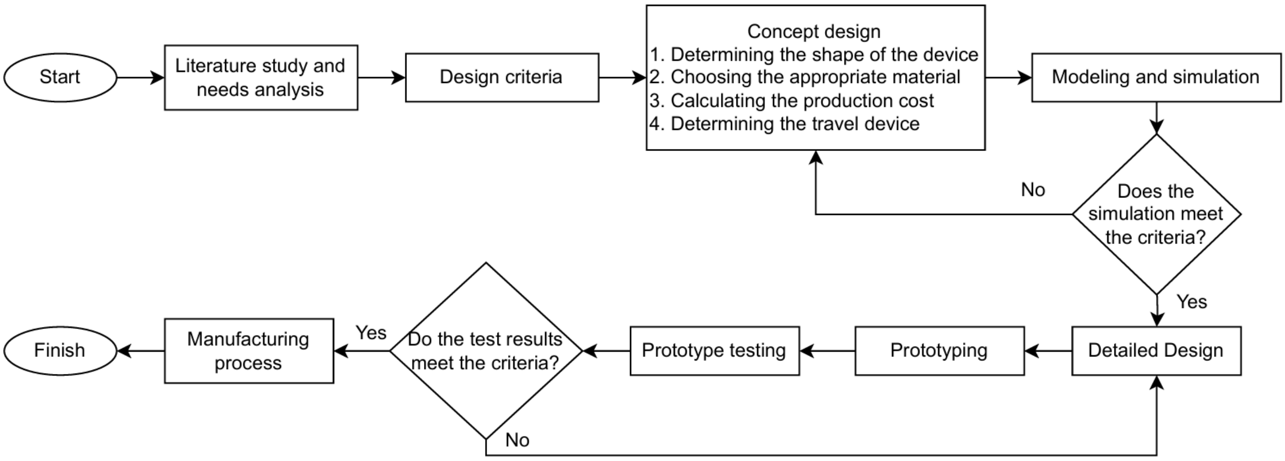


Figure 1. Flowchart of Pneumatic Bush Installation Tool Manufacturing

Problem Identification

In this study, the initial step taken was problem identification, where the main challenges in the Bush installation on engine mounting were analyzed using a fishbone diagram, as shown in **Figure 2**. In the Bush installation process, the human factor (Man) plays a crucial role, primarily when conventional methods are still being used. One of the main challenges is human error, which occurs due to operator fatigue and lack of focus. This happens because the manual installation method heavily relies on operator skills, where repetitive work over a long period can lead to fatigue and increased risk of installation errors [19].

Beyond the human factor, the installation method also significantly affects production efficiency and final product quality. Manual installation methods, for example, hammering or jacking, are limited in precision because the applied pressure is inconsistent. This process also takes longer than automated methods, reducing overall production efficiency [8]. The high dependence on manual labor results in variations in installation quality, as each operator possesses different skill levels. Additionally, the lack of standardized installation procedures becomes another challenge, as the absence of a Standard Operating Procedure (SOP) leads to inconsistent installation results.

From a material perspective (Material), Bush in engine mountings is generally made of rubber coated with an alloy metal [14]. This structure is designed to absorb vibrations and support the engine more effectively. However, manual installation risks damaging the Bush due to uneven pressure application or improper component positioning. Therefore, a more precise installation method, such as a pneumatic system, is necessary to reduce the risk of damage and enhance installation efficiency and product quality.

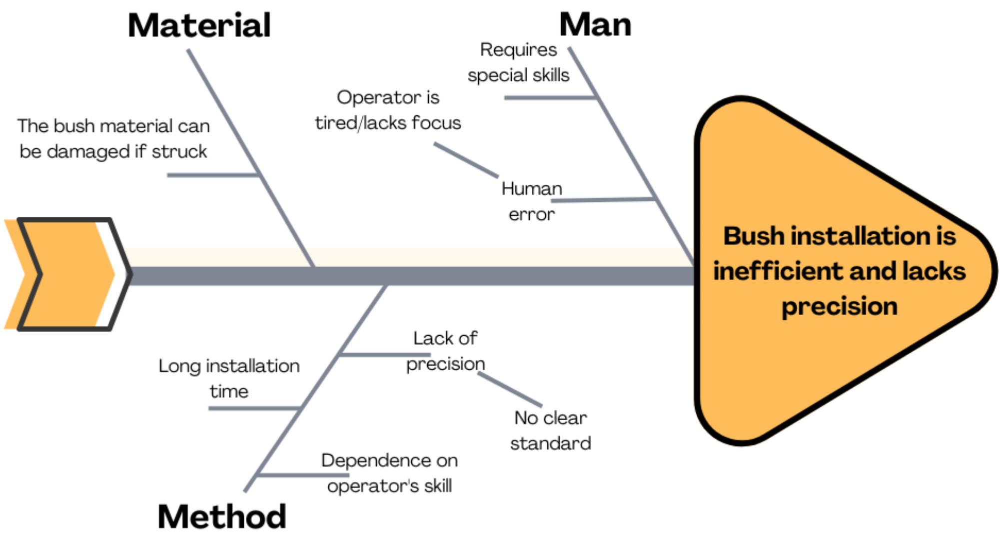


Figure 2. Fishbone Diagram for Engine Mounting Bush Installation

Design Concept

The design concept of the pneumatic-based Bush installation tool was developed by considering four key aspects, namely tool shape, material selection, production cost, and movement mechanism. The tool's shape is designed to be ergonomic and efficient, allowing the operator to use it comfortably and safely, while ensuring that air pressure is optimally distributed for precise Bush installation without the risk of deformation. Material selection focuses on pressure and wear resistance to enhance the tool's durability under various production conditions. The production cost calculation considers materials, manufacturing processes, and additional components, ensuring the tool remains cost-effective without compromising quality and performance. Meanwhile, the movement mechanism is designed to be stable, precise, and automatic, which helps reduce installation time and improve production efficiency. By optimizing these four aspects, the pneumatic-assisted tool is expected to enhance installation accuracy, reduce production time, and increase productivity in the engine mounting manufacturing process.

ISSN: 3063-8720, DOI: https://doi.org/10.70935/67m23j34

Experimental Design

This study employs a quasi-experimental approach to evaluate the efficiency and reliability of the pneumatic-based Bush installation tool compared to conventional methods. The testing process consists of the following stages:

1. Trial and Error

In the initial stage, exploratory trials were conducted to optimize the Bush installation parameters, particularly regarding air pressure and installation tolerance. The primary objective of this phase is to determine the best configuration that ensures a more precise and efficient installation.

2. Prototype Testing of the Pneumatic Bush Installation Tool

The designed prototype was tested under real operational conditions. This testing involved repeated installation of Bush on engine mountings using controlled air pressure and optimized installation tolerances to ensure consistent and accurate results.

3. Testing of the Conventional Method

As a comparison, the Bush installation was performed manually using a hammer and a jack.

Each testing method, whether pneumatic-assisted or manual tools (hammer and jack), was conducted ten times to obtain accurate and representative results. The observed parameters included installation time and the number of defective products (NG), which consisted of damage caused by the installation process and inaccuracies in Bush positioning.

RESULTS AND DISCUSSION

Design and Simulation Process

The design phase in this study was carried out using Autodesk Fusion software to assist in the design process of the pneumatic-based Bush installation tool. The design process began with the development of the pneumatic system, as shown in **Figure 3**, which serves as the main component in the installation mechanism. This pneumatic system was designed using a two-stage pressure system (2-stage system) with a thrust force of approximately 1.5 tons and a maximum air pressure of 8 bar. The primary objective of this design is to ensure that the tool has sufficient pressing force to install the Bush with high precision without causing deformation in the installed components.

ISSN: 3063-8720, DOI: https://doi.org/10.70935/67m23j34

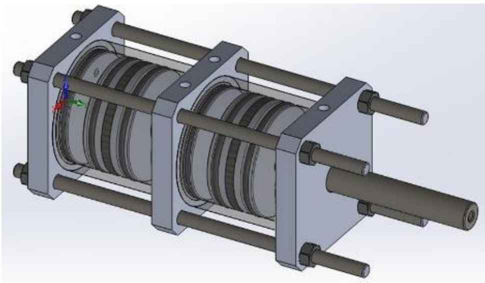


Figure 3. 3D Design of Pneumatic Cylinder

After the pneumatic design was completed, the process continued to the simulation phase to evaluate the structural strength of the tool against the pressure and forces acting during the Bush installation process. This simulation aims to identify potential deformation points or structural failures, allowing necessary modifications before physical production begins. Additionally, airflow simulation and travel device analysis, as shown in **Figure 4**, were conducted to ensure that the generated pressure and movement of the pressing rod align with the requirements for Bush installation, ensuring precision and accuracy in the installation process.

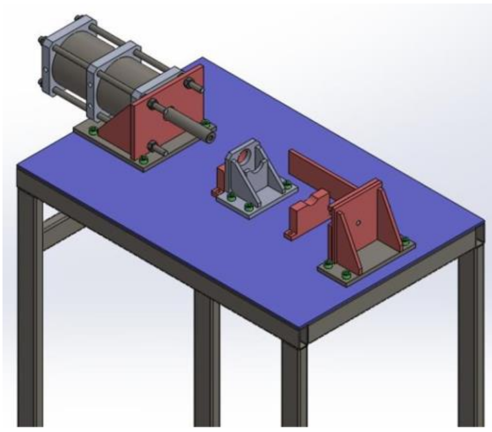


Figure 4. Testing of Pressing Rod Travel

Based on the simulation results, several modifications were made to the initial design, including adjustments to the position of the pneumatic cylinder to enhance pressure efficiency and optimize rod movement, as well as reinforcing the tool structure to improve its durability under workload. With these optimizations, the final design of the pneumatic Bush installation tool is ready to be produced as a prototype.

Prototype Development

After completing the design and simulation stages, the next step is the development of the pneumatic-based Bush installation tool prototype. This process involves several key stages: material selection, component assembly, and initial tool testing.

ISSN: 3063-8720, DOI: https://doi.org/10.70935/67m23j34

1. Material Selection

The materials used for the prototype were selected based on an analysis of the tool's requirements. The materials for the main components are presented in **Table 1**.

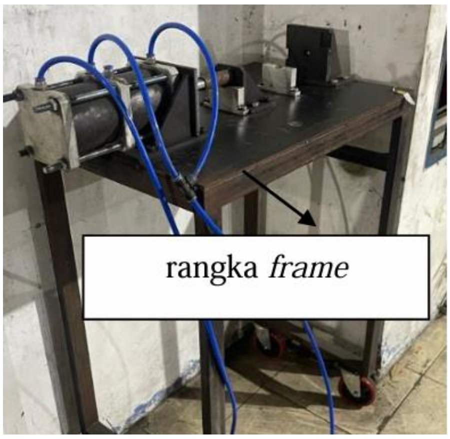
Table 1. Detailed Material of Main Components for the Pneumatic Bush Installation Tool

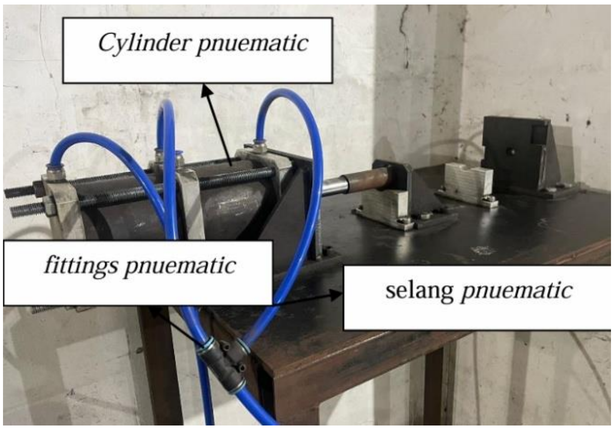
Component	Quantity	Material	Size	Specification	Function
Tool Frame	1 set	Carbon Steel	Custom	High load resistance	Supports the pneumatic system and provides tool stability
Pneumatic Cylinder	1 unit	Aluminum Alloy	Diameter 100 mm	Lightweight, corrosion-resistant	Drives the actuator for the Bush installation
Bush Holder	1 unit	Alloy Steel	Diameter 50 mm	High pressure resistance	Holds the Bush securely during installation
Air Hose	2 meters	High-Quality Elastomer	Diameter 10 mm	Flexible, leak-resistant	Channels pressurized air to the pneumatic system
Control Valve	1 unit	High-Quality Elastomer	Custom	Controls air pressure	Regulates air pressure in the pneumatic system

2. Component Assembly

Figure 5 shows the prototype of the pneumatic Bush installation tool. The assembly process of this tool involves integrating the main components to ensure optimal functionality. The initial stage begins with installing the pneumatic cylinder, which acts as the primary actuator by providing stable pressure during the Bush installation. Next, the air pressure control system is integrated, where a control valve is installed to regulate the air pressure entering the cylinder, ensuring that the pressure remains stable and meets the installation requirements. The final stage involves installing the Bush holding system, which ensures that the Bush remains in a precise position during installation, thereby minimizing potential errors in the assembly process.

ISSN: 3063-8720, DOI: https://doi.org/10.70935/67m23j34





(a) (b)

Figure 5. (a) Full Assembly of the Tool Prototype and **(b)** Zoomed-In View of the Tool

Trial and Error Testing

After the assembly process was completed, the pneumatic Bush installation tool prototype was tested under operational conditions to ensure that the tool functions according to the designed specifications. This testing aimed to verify two main aspects: the functionality of the pneumatic actuator in delivering stable pressure and the accuracy of Bush positioning in the engine mounting.

The trial and error process was performed four times to identify the optimal configuration. In the first three tests, air pressure and Bush positioning inconsistencies were observed. However, by the fourth test, both parameters had aligned with the expected standards, indicating that the tool's settings had been successfully calibrated. **Table 2** provides a detailed overview of the trial and error testing, showcasing the progression through each stage until the optimal conditions were attained.

Table 2. Trial and Error Testing Results

Trial Number	Issues Encountered	Solution
1	Bush could not be properly installed	Increased air pressure from 6 bar to 8 bar
2	Bush could not be properly installed	Reduced machining tolerance of the metal pipe from 0.2 mm to 0.1 mm
3	Some Bushes were still misaligned	Used a 10 mm diameter shaft to ensure alignment
4	No issues, Bush installed correctly	-

ISSN: 3063-8720, DOI: https://doi.org/10.70935/67m23j34

Prototype Testing Results

The pneumatic-based Bush installation tool was tested and compared to the manual method, with each method being evaluated 10 times. The observed parameters included installation time and the number of defective products (NG), which consisted of Bush misalignment and installation-induced damage. The test results demonstrated that the pneumatic method had a significant advantage in terms of installation efficiency and lower error rates than the manual method.

Figure 6 illustrates that the average installation time using the pneumatic-assisted tool was 45 seconds. In contrast, the manual method required 120 seconds, indicating that the pneumatic method was up to 80% more efficient than the conventional approach. These findings align with the study conducted by Indrawati et al. [20], which showed that a vacuum press machine with an electro-pneumatic control system operated more effectively and efficiently than the traditional vacuum process used in vacuum packaging applications.

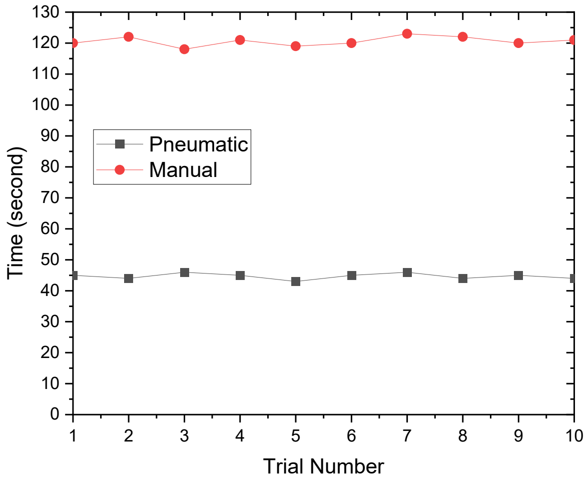


Figure 6. Bush Installation Time on Engine Mounting

Moreover, **Figure 7** illustrates that the number of defective products produced using the pneumatic installation tool was significantly lower, with Bush misalignment at only 10%, compared to 40% in the manual method. Regarding installation-related damage, the manual method exhibited a higher error rate, with 35% of products experiencing defects, whereas the pneumatic method resulted in only 5%.

This difference occurs because pressure in the manual method is less stable, as using hammers or jacks cannot generate a uniform pressing force, increasing the risk of Bush misalignment or component deformation due to uneven pressure distribution. In contrast, the pneumatic system allows for more stable and controlled air pressure, enabling more precise Bush installation with minimal risk of errors. The study conducted by Anwar et al. [21] supports these findings, where their research examined the application of a semi-automatic

ISSN: 3063-8720, DOI: https://doi.org/10.70935/67m23j34

pneumatic shoe press machine in small-scale industries. Their results indicated that the pneumatic system could produce better, more uniform, consistent pressing quality.

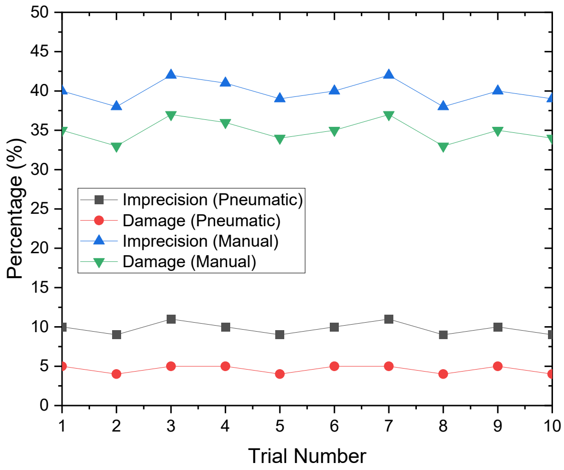


Figure 7. Defective Product (NG) Percentage Rate

CONCLUSION

Based on the research findings, using a pneumatic-based Bush installation tool has been proven to be more efficient and accurate compared to the manual method using a hammer or jack. The tests revealed that the average installation time with the pneumatic system was only 45 seconds, significantly faster than the manual method, which required 120 seconds, resulting in an efficiency improvement of up to 80%. Additionally, the pneumatic method's defective product (NG) rate was lower, with Bush misalignment at only 10%, compared to 40% in the manual method. This difference demonstrates that the pneumatic system provides more stable and uniform pressure, ensuring more consistent Bush installation with minimal errors.

Regarding installation-related damage, the manual method exhibited a higher error rate, with 35% of products experiencing defects, whereas the pneumatic method resulted in only 5%. The primary factor causing this difference is pressure instability in the manual method, where a hammer or jack fails to generate a uniform pressing force, increasing the risk of deformation or misaligned installation. In contrast, the pneumatic system allows for better-controlled air pressure, enabling more precise Bush installation with minimal risk of errors. Thus, this study demonstrates that the pneumatic-assisted tool is a more optimal solution for improving production time efficiency, installation accuracy, and reducing product defect rates, thereby supporting a more modern and high-quality manufacturing process.

REFERENCES

[1] M. H. Harun, M. A. Azhari, R. Yunos, A. K. M. Yamin, and M. Z. Sariman, "Characterization of a magnetorheological fluid damper applied to semi-active engine mounting system," *J. Mech. Eng.*, vol. 5, no. Specialissue3, pp. 248–259, 2018.

[2] A. Adhau and P. V Kumar, "Engine Mounts and its Design Considerations," *Int. J. Eng. Res. Technol.*, vol. 2, no. 11, pp. 763–769, 2013, [Online]. Available: www.ijert.org.

[3] N. Jayakrishnan, N. J. Pradeep, V. A. Athul, U. A. Raj, M. Nithin, and G. Harikrishnan, "Design and manufacturing of a portable pneumatic material handling equipment," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 377, no. 1, 2018, doi: 10.1088/1757-899X/377/1/012044.

[4] R. Kurniawan, "Rekayasa rancang bangun sistem pemindahan material otomatis dengan sistem elektro-pneumatik," *J. Ilm. Tek. Mesin CAKRAM*, vol. 2, no. 1, pp. 42–47, 2022.

[5] Q. Yu, J. Zhai, Q. Wang, X. Zhang, and X. Tan, "Experimental study of a new pneumatic actuating system using exhaust recycling," *Sustain.*, vol. 13, no. 4, pp. 1–14, 2021, doi: 10.3390/su13041645.

[6] Y. Shi, M. Cai, W. Xu, and Y. Wang, "Methods to Evaluate and Measure Power of Pneumatic System and Their Applications," *Chinese J. Mech. Eng. (English Ed.*, vol. 32, no. 1, 2019, doi: 10.1186/s10033-019-0354-6.

[7] J. V. Tuapetel and R. Narwalutama, "Perencanaan Sistem Pneumatik Sebagai Penggerak pada Pintu Gerbong Kereta," *STRING (Satuan Tulisan Ris. dan Inov. Teknol.*, vol. 6, no. 3, p. 244, 2022, doi: 10.30998/string.v6i3.10536.

[8] R. A. Rafil, M. Iqbal, K. H. Kurnia, S. A. S. Sehat, and S. K. Shandy, "Analisis Penggunaan Sistem Aktuator Pneumatik Bertenaga Surya Terhadap Kinerja Mesin Pemotong Nanas," *J. Rekayasa Mesin*, vol. 15, no. 1, pp. 455–472, 2024, doi: 10.21776/jrm.v15i1.1712.

[9] F. Damrath, A. Strahilov, T. Bär, and M. Vielhaber, "Experimental validation of a physics-based simulation approach for pneumatic components for production systems in the automotive industry," *Procedia CIRP*, vol. 31, pp. 35–40, 2015, doi: 10.1016/j.procir.2015.03.078.

[10] Z. Liao, T. Li, Y. Wang, and Y. Cai, "Soft pneumatic actuator optimal design based on isogeometric analysis," *Manuf. Lett.*, vol. 35, pp. 55–63, 2023, doi: 10.1016/j.mfglet.2023.08.001.

[11] O. S. Alshahed, B. Kaur, M. S. A. Bradley, and D. Armour-Chelu, "Data-driven system identification and model predictive control of pneumatic conveying using nonlinear dynamics analysis for optimised energy consumption," *Powder Technol.*, vol. 449, no. August 2024, p. 120364, 2025, doi: 10.1016/j.powtec.2024.120364.

[12] R. Abela, P. Refalo, M. Borg, and E. Francalanza, "Pneumatic Control for Sustainable Compressed Air Systems: Multi-criteria Optimisation for Energy Efficient Production,"

Procedia CIRP, vol. 122, pp. 247–252, 2024, doi: 10.1016/j.procir.2024.01.035.

[13] A. Merulla *et al.*, "Weight reduction by topology optimization of an engine subframe mount, designed for additive manufacturing production," *Mater. Today Proc.*, vol. 19, pp. 1014–1018, 2019, doi: 10.1016/j.matpr.2019.08.015.

[14] A. M. N. Azammi, S. M. Sapuan, M. R. Ishak, and M. T. H. Sultan, "Conceptual design of automobile engine rubber mounting composite using TRIZ-Morphological chart-analytic network process technique," *Def. Technol.*, vol. 14, no. 4, pp. 268–277, 2018, doi: 10.1016/j.dt.2018.05.009.

[15] S. Hazra and K. Janardhan Reddy, "Design optimization of engine mounting system for a modular electric vehicle platform with different powertrain characteristics," *J. Phys. Conf. Ser.*, vol. 2198, no. 1, 2022, doi: 10.1088/1742-6596/2198/1/012014.

[16] P. Jaiswal and S. Barve, "Utilization of composite materials for engine mounts & different vehicle structures: A review," *AIP Conf. Proc.*, vol. 2421, no. January, 2022, doi: 10.1063/5.0078199.

[17] S. Bahri and P. S. Yuza, "Analisa Kerusakan (Deformasi) Engine Mounting Kendaraan Toyota Agya Berdasarkan Tingkat Vibrasi Berbasis Mem Accelerometer," *Resist. (elektRonika kEndali Telekomun. tenaga List. kOmputeR)*, vol. 2, no. 2, p. 131, 2019, doi: 10.24853/resistor.2.2.131-136.

[18] J. Adrian, F. A. Kurniawan, D. A. A. Ritonga, and J. Junaidi, "Analisa Perbandingan Getaran Menggunakan Bantalan Mesin (Engine Mounting) Berbahan Dasar Kombinasi Empat Per Spiral Dan Karet Alami Pada Toyota Avanza," *Bul. Utama Tek.*, vol. 19, no. 2, pp. 78–92, 2024, doi: 10.30743/but.v19i2.8102.

[19] R. Septiari, "Analisis Faktor-Faktor yang Mempengaruhi Tingkat Kelelahan pada Pekerjaan Berulang di Industri Manufaktur," *Mek. Maj. Ilm. Mek.*, vol. 19, no. 1, pp. 15–21, 2020, doi: 10.20961/mekanika.v19i1.39924.

[20] R. T. Indrawati *et al.*, "Analisa Unjuk Kerja Mesin Vacuum Press dengan Sistem Elektro-Pneumatik terhadap Kapasitas Produksi pada Proses Vacuum Packaging," *J. Rekayasa Mesin*, vol. 18, no. 1, p. 55, 2023, doi: 10.32497/jrm.v18i1.4322.

[21] S. Anwar and E. Wahjudi, "Implementasi Mesin Pres Sepatu Sistem Pneumatik Semi Otomatis dan Perbaikan Manajemen untuk Meningkatkan Produktivitas Industri Kecil Sepatu Banjarsari Suggested citation," *J. Pengandian pada Masy. Univ. Negeri Surabaya*, vol. 7, no. 2, p. 2022, 2020, doi: 10.30653/002.202272.38.