International Journal of Scientific Engineering and Science
Volume 10, Issue 8, pp. 28-33, August 2026. ISSN (Online): 2456-7361

# Comparative Analysis of Austenitic and Ferritic Stainless Steel Exhaust Headers on the Performance of a Standard 110 cc Motorcycle Engine

Ramadhan Nur Kohar[1], Adri Fato[2]
[1]Mechanical Engineering, Dian Nusantara University, Depok City, Jawa Barat, Indonesia
[2]Mechanical Engineering, Dian Nusantara University, Jakarta Selatan, D.K.I Jakarta, Indonesia

***Abstract***— *The exhaust system plays a crucial role in optimizing the performance of an internal combustion engine. This study aims to analyze and compare the effect of using Austenitic Stainless Steel (Series 200) with Ferritic Stainless Steel on exhaust header components on engine power, torque, specific fuel consumption (SFC), and exhaust gas emission levels on a standard 110cc motorcycle. The study was conducted experimentally using a chassis dynamometer (dynotest) for performance measurement, a volumetric method with an external fuel pump to calculate SFC, and a gas analyzer to measure CO, HC, and CO2 emission levels at various rotations of 3000, 5000, and 8000 RPM. The test results prove that the Austenitic header produces superior peak performance at high rotations (8000 RPM) with power reaching 8.65 HP and torque of 7.67 Nm. This is influenced by the thermal insulator properties of Austenitic which keeps the exhaust gas density low thereby optimizing the scavenging effect. In contrast, the Ferritic material demonstrated better acceleration response at mid-range revs (5,000 RPM) with 4.16 HP and 5.89 Nm of torque. Environmentally, the use of Austenitic material proved more effective in reducing CO and HC emissions and producing more ideal CO2 levels at high revs. It was concluded that Austenitic material is highly recommended for achieving maximum performance at high revs, while Ferritic is more suitable for daily commuter vehicles requiring medium acceleration.*

***Keywords***— *Exhaust header, Austenitic, Ferritic, Engine performance, Exhaust emissions.*

## I. INTRODUCTION

Motorcycles with a 110 cc engine capacity are among the most widely used means of transportation in Indonesia due to their fuel efficiency, low maintenance costs, and practicality for daily commuting. Various engineering developments have been carried out to improve engine performance, fuel efficiency, and exhaust emissions. Among these developments, optimization of the exhaust system has been recognized as an effective approach to enhancing engine performance (Al-Azizi et al., 2025).

The exhaust header is one of the most important components of the exhaust system because it directs combustion gases from the engine cylinder to the muffler while operating under high-temperature conditions. The thermal characteristics of the header material influence heat transfer, backpressure, and the scavenging effect, all of which contribute to volumetric efficiency and engine performance. Previous studies have reported that variations in exhaust system materials and operating temperatures directly affect exhaust backpressure and engine efficiency (Nasir et al., 2023).

Among the stainless steel materials commonly used for automotive exhaust headers, Austenitic Stainless Steel and Ferritic Stainless Steel exhibit different thermal and mechanical characteristics. Austenitic Stainless Steel 200 Series offers good toughness and high-temperature strength while reducing production costs through partial substitution of nickel with manganese and nitrogen (Wang et al., 2022). In contrast, Ferritic Stainless Steel possesses higher thermal conductivity and a lower coefficient of thermal expansion, providing better dimensional stability and resistance to thermal fatigue under cyclic heating conditions (Jindal Stainless, 2026; Winoko et al., 2019).

Although the metallurgical characteristics of both stainless steel groups have been widely discussed, direct experimental comparisons of their effects on the performance of standard 110 cc motorcycle engines remain limited. Differences in heat retention and heat dissipation between Austenitic Stainless Steel and Ferritic Stainless Steel are expected to influence engine power, torque, specific fuel consumption (SFC), and exhaust emissions (Budiyono et al., 2023). Therefore, this study experimentally compares Austenitic Stainless Steel 200 Series and Ferritic Stainless Steel exhaust headers with identical geometry on a standard 110 cc motorcycle engine. Material composition was verified through laboratory testing, while engine performance, fuel consumption, and exhaust emissions were evaluated using a chassis dynamometer, a volumetric fuel consumption method, and a gas analyzer.

## II. MATERIALS AND METHODS

### a) Research Flowchart

The overall research procedure is illustrated in Fig. 1. The experiment consisted of literature study, exhaust header fabrication, welding, leakage inspection, chemical composition testing, engine performance testing, fuel consumption measurement, exhaust emission measurement, data analysis, and conclusion.

### b) Materials and Experimental Setup

The experimental study was conducted using a standard Honda Beat FI motorcycle equipped with a four-stroke, single-cylinder, SOHC, air-cooled engine with a displacement of 108.2 cc and a programmed fuel injection (PGM-FI) system. Throughout the experiment, the engine remained in its original factory condition, and no modifications were made except for

International Journal of Scientific Engineering and Science
Volume 10, Issue 8, pp. 28-33, August 2026. ISSN (Online): 2456-7361

replacing the exhaust header material. Two exhaust headers with identical geometry were prepared using Austenitic Stainless Steel 200 Series and Ferritic Stainless Steel, allowing the influence of material properties on engine performance to be evaluated without interference from geometric variations.

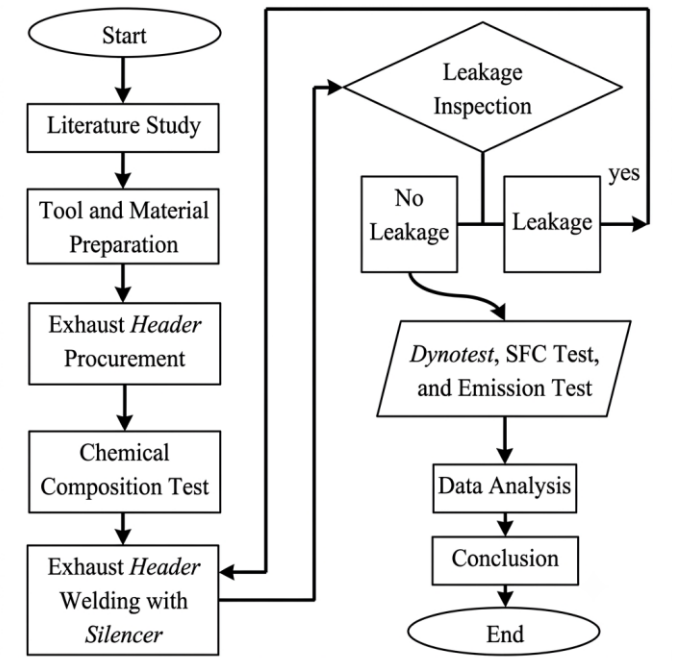


Figure 1. Research flowchart

Engine performance was evaluated using a BRT Super DYNO 50 chassis dynamometer, while exhaust emissions were measured using a QRO-401 gas analyzer. Fuel consumption was determined by the volumetric method using an external fuel pump connected to a graduated fuel bottle, and the outer surface temperature of the exhaust header was measured using an infrared thermometer. Performance tests were conducted at engine speeds of 3,000 rpm, 5,000 rpm, and 8,000 rpm, whereas Specific Fuel Consumption (SFC) and exhaust emission measurements were performed at 3,000 rpm and 5,000 rpm under steady-state operating conditions.

TABLE I. Experimental Conditions

| Parameter | Specification |
|---|---|
| Test motorcycle | Honda Beat FI 110 |
| Engine type | Four-stroke, SOHC, air-cooled |
| Engine displacement | 108.2 cc |
| Fuel system | PGM-FI |
| Fuel | Pertamax |
| Exhaust header materials | Austenitic Stainless Steel 200 Series and Ferritic Stainless Steel |
| Header diameter | 25 mm |
| Header thickness | 1 mm |
| Header length | 470 mm |
| Power and torque test | 3,000, 5,000, and 8,000 rpm |
| SFC and emission test | 3,000 and 5,000 rpm |

*c) Experimental Procedure*

Prior to the performance evaluation, all experimental equipment was prepared and calibrated. Two exhaust headers with identical dimensions but different materials, namely Austenitic Stainless Steel 200 Series and Ferritic Stainless Steel, were installed alternately on the test motorcycle. Before testing, each exhaust header underwent a functional leakage inspection to ensure that the exhaust system was completely sealed and suitable for experimentation.

The chemical composition of both exhaust header materials was first verified through spectrometer analysis to confirm their alloy classifications. The obtained elemental composition was subsequently used to identify the characteristics of Austenitic Stainless Steel 200 Series and Ferritic Stainless Steel before evaluating their influence on engine performance.

Engine performance tests were conducted using a BRT Super DYNO 50 chassis dynamometer. Before each measurement, the engine was warmed to its normal operating temperature of approximately 85 °C. Power and torque were measured under Wide Open Throttle (WOT) conditions at engine speeds of 3,000, 5,000, and 8,000 rpm for each exhaust header material. The same testing procedure was repeated under identical operating conditions to ensure consistency of the experimental results.

Specific Fuel Consumption (SFC) was determined using the volumetric method. An external fuel pump supplied fuel from a graduated bottle while the engine was operated under steady-state conditions at 3,000 rpm and 5,000 rpm. The time required to consume 10 mL of fuel was recorded using a stopwatch, and the external surface temperature of the exhaust header was measured simultaneously using an infrared thermometer.

Following the fuel consumption test, exhaust gas emissions were measured using a QRO-401 gas analyzer. The analyzer probe was inserted approximately 9 cm into the exhaust outlet to minimize contamination from ambient air. Carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide ($CO_2$) concentrations were recorded after stable readings were achieved at 3,000 rpm and 5,000 rpm.

The experimental results obtained from the chemical composition analysis, engine performance, fuel consumption, and exhaust emission measurements were then compiled for comparative evaluation between the two exhaust header materials.

## III. RESULTS AND DISCUSSION

*a) Chemical Composition Analysis*

The chemical composition of both exhaust header materials was analyzed using a spectrometer to verify their alloy classifications before engine performance testing. The results are presented in Table II.

The spectrometer analysis confirmed that the first specimen corresponds to Austenitic Stainless Steel 200 Series, characterized by a relatively high manganese content (9.231%) and a low nickel concentration (1.004%). The substitution of nickel with manganese is one of the distinguishing characteristics of the 200 Series stainless steel family while maintaining the austenitic crystal structure. The chromium content of 14.402% further supports its classification as Austenitic Stainless Steel. The absence of detectable carbon in the analysis is attributed to the detection

International Journal of Scientific Engineering and Science
Volume 10, Issue 8, pp. 28-33, August 2026.
ISSN (Online): 2456-7361

limit of the measuring instrument rather than the complete absence of carbon in the material.

TABLE II. Chemical Composition of Exhaust Header Materials

| Material | Fe (%) | Cr (%) | Ni (%) | C (%) | Mn (%) | Others (%) |
|---|---|---|---|---|---|---|
| Austenitic Stainless Steel 200 Series | 73.631 | 14.402 | 1.004 | ND | 9.231 | 1.732 |
| Ferritic Stainless Steel | 87.350 | 11.460 | <0.0007 | 0.021 | 0.230 | 0.932 |

ND = Not Detected.

In contrast, the second specimen was identified as Ferritic Stainless Steel, with iron as the dominant element (87.35%), chromium content of 11.46%, and an extremely low nickel concentration (<0.0007%). The low carbon (0.021%) and manganese (0.230%) contents are consistent with the characteristics of ferritic stainless steel commonly used in automotive exhaust systems. These results confirm that the two exhaust headers used in this study represent different stainless steel groups with distinct metallurgical characteristics, providing a valid basis for evaluating their influence on engine performance, fuel consumption, and exhaust emissions.

*b) Engine Performance Analysis*

The effect of exhaust header material on engine performance was evaluated based on power and torque measurements obtained using a chassis dynamometer. The comparison between the Austenitic Stainless Steel 200 Series and Ferritic Stainless Steel headers is presented in Fig. 2 and Fig. 3.

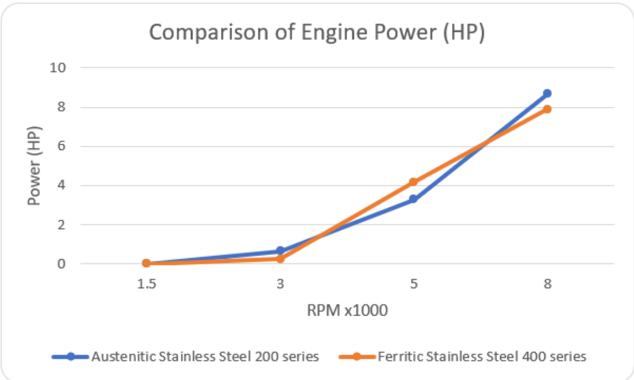


Fig. 2. Comparison of Engine Power versus Engine Speed

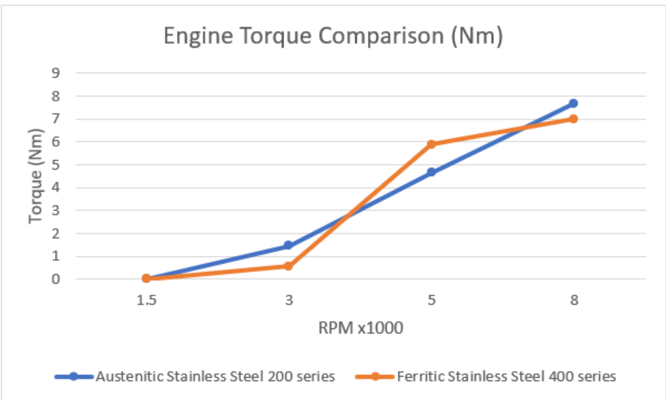


Fig. 3. Comparison of Engine Torque versus Engine Speed

As shown in Fig. 2, both exhaust header materials exhibited an increase in engine power as engine speed increased. However, differences in their performance characteristics became more apparent at medium and high engine speeds. At 3,000 rpm, the power output of both materials remained relatively low because the exhaust gas flow rate and thermal effects had not yet become dominant. At 5,000 rpm, the Ferritic Stainless Steel header produced a slightly higher power output, indicating that its higher thermal conductivity contributed to a favorable exhaust gas flow under medium-speed operating conditions. At 8,000 rpm, however, the Austenitic Stainless Steel 200 Series header achieved the highest power output of 8.65 HP, outperforming the Ferritic Stainless Steel header. This improvement is attributed to the superior heat retention capability of the Austenitic material, which maintains higher exhaust gas temperature, reduces gas density, and enhances the scavenging effect at high engine speeds.

A similar trend can be observed in the torque characteristics shown in Fig. 3. At low engine speed, both materials produced comparable torque values, although the Austenitic Stainless Steel header exhibited a slightly better initial response. At 5,000 rpm, the Ferritic Stainless Steel header generated the highest intermediate torque of approximately 5.89 Nm, indicating that its thermal characteristics promoted effective pressure-wave tuning and improved volumetric efficiency under medium-speed conditions. As engine speed increased to 8,000 rpm, the torque produced by the Ferritic Stainless Steel header began to level off, whereas the Austenitic Stainless Steel 200 Series continued to increase, reaching a maximum torque of 7.67 Nm. This result demonstrates that the Austenitic material is more capable of sustaining exhaust gas velocity under high-flow conditions, thereby improving engine performance at high engine speeds.

The different performance trends observed for the two exhaust header materials are closely related to their thermal properties. Austenitic Stainless Steel 200 Series has lower thermal conductivity, enabling it to retain heat within the exhaust header for a longer period. The higher exhaust gas temperature lowers gas density and facilitates smoother exhaust flow, thereby reducing backpressure and improving scavenging efficiency at high engine speeds. In contrast, Ferritic Stainless Steel transfers heat more rapidly because of its higher thermal conductivity. This characteristic provides better engine responsiveness at medium engine speeds but reduces its ability to maintain exhaust gas energy under high-speed operating conditions. Consequently, the Ferritic Stainless Steel header is more suitable for applications emphasizing mid-range acceleration, whereas the Austenitic


http://ijses.com/

International Journal of Scientific Engineering and Science
Volume 10, Issue 8, pp. 28-33, August 2026. ISSN (Online): 2456-7361

Stainless Steel 200 Series is more effective in maximizing engine power and torque at high engine speeds.

*c) Specific Fuel Consumption Analysis*

The effect of exhaust header material on fuel consumption was evaluated using the Specific Fuel Consumption (SFC) parameter. Fuel consumption was determined by the volumetric method under steady-state operating conditions at 3,000 rpm and 5,000 rpm. The measured SFC values and exhaust header surface temperatures are summarized in Table III.

TABLE III. Specific Fuel Consumption and Exhaust Header Temperature

| Engine Speed (rpm) | Header Material | SFC (kg/kWh) | Temperature (°C) |
|---|---|---|---|
| 3,000 | Austenitic Stainless Steel 200 Series | 0.483 | 183.7 |
| 3,000 | Ferritic Stainless Steel | 1.341 | 207.6 |
| 5,000 | Austenitic Stainless Steel 200 Series | 0.125 | 210.2 |
| 5,000 | Ferritic Stainless Steel | 0.111 | 240.9 |

At 3,000 rpm, the Austenitic Stainless Steel 200 Series header exhibited a substantially lower SFC (0.483 kg/kWh) than the Ferritic Stainless Steel header (1.341 kg/kWh), indicating better fuel utilization under low-speed operating conditions. The lower exhaust header temperature of the Austenitic material (183.7 °C) suggests a different heat transfer characteristic compared with the Ferritic material, which recorded a higher surface temperature of 207.6 °C. According to the experimental observations, this characteristic contributes to smoother exhaust gas flow and improved engine efficiency at low engine speed.

At 5,000 rpm, both materials showed a significant reduction in SFC as engine output increased. The Ferritic Stainless Steel header achieved a slightly lower SFC (0.111 kg/kWh) than the Austenitic Stainless Steel 200 Series (0.125 kg/kWh), while simultaneously exhibiting a higher exhaust header temperature (240.9 °C compared with 210.2 °C). This result is consistent with the engine performance analysis, where the Ferritic header produced higher power at medium engine speed, leading to improved fuel consumption efficiency under these operating conditions.

The experimental findings indicate that the impact of the exhaust header material on fuel consumption is dependent on the engine's operating circumstances. The Austenitic Stainless Steel 200 Series demonstrated superior fuel efficiency at low engine speed, whereas the Ferritic Stainless Steel header achieved slightly better SFC at medium engine speed. These findings are consistent with the observed differences in thermal behavior and engine performance between the two materials.

*d) Exhaust Emission Analysis*

The exhaust gas emissions of the Austenitic Stainless Steel 200 Series and Ferritic Stainless Steel headers were evaluated by measuring CO, HC, and $CO_2$ concentrations at 3,000 rpm and 5,000 rpm. The results are presented in Table IV.

TABLE IV. Exhaust Gas Emission Results

| Header Material | Engine Speed (rpm) | CO (%) | HC (ppm) | $CO_2$ (%) |
|---|---|---|---|---|
| Austenitic Stainless Steel 200 Series | 3,000 | 1.01 | 208 | 4.1 |
| Austenitic Stainless Steel 200 Series | 5,000 | 0.36 | 163 | 5.3 |
| Ferritic Stainless Steel | 3,000 | 1.02 | 212 | 4.9 |
| Ferritic Stainless Steel | 5,000 | 0.48 | 158 | 4.4 |

The emission results indicate that both exhaust header materials produced similar emission characteristics at 3,000 rpm. At 5,000 rpm, the Austenitic Stainless Steel 200 Series header exhibited lower CO emissions (0.36%) than the Ferritic Stainless Steel header (0.48%), indicating more complete combustion. Although the Ferritic Stainless Steel header produced slightly lower HC emissions (158 ppm) than the Austenitic Stainless Steel header (163 ppm), the difference was relatively small. Meanwhile, the Austenitic Stainless Steel 200 Series achieved the highest $CO_2$ concentration (5.3%), suggesting a more efficient oxidation process during combustion. Overall, the results indicate that the thermal characteristics of the Austenitic Stainless Steel 200 Series contribute to improved combustion quality and lower CO emissions under higher engine operating conditions.

## IV. Conclusion

Based on the laboratory testing (spectrometer analysis) and engine performance testing (chassis dynamometer) conducted to compare Austenitic Stainless Steel (Series 200) and Ferritic Stainless Steel exhaust header materials on a standard 110 cc motorcycle engine, the following conclusions can be drawn:

1. Effect on High-Speed Engine Performance: The Austenitic Stainless Steel (Series 200) exhaust header demonstrated superior performance at high engine speed (8,000 rpm), producing a maximum power output of 8.65 HP and a maximum torque of 7.67 Nm. This power output was approximately 10.1% higher than that obtained using the Ferritic Stainless Steel exhaust header (7.89 HP).
2. Thermofluid Characteristics: The superior high-speed performance of the Austenitic Stainless Steel header is attributed to its relatively low thermal conductivity, which enables it to retain exhaust gas heat within the header. This characteristic maintains a lower exhaust gas density, allowing the exhaust gases to flow more rapidly with minimal turbulence and resulting in a more effective scavenging effect.
3. Ferritic Stainless Steel Performance at Medium Engine Speed: In contrast, the Ferritic Stainless Steel header

possesses higher thermal conductivity, allowing heat to dissipate more rapidly to the surrounding environment. Consequently, the exhaust gases become denser, which, at 5,000 rpm, provides a more favorable resonance tuning with the standard exhaust header geometry, resulting in slightly better initial torque response and acceleration compared with the Austenitic Stainless Steel header.

4. Material Validation: The chemical composition analysis confirmed that the tested Austenitic Stainless Steel (Series 200) specimen utilized a high manganese (Mn) content as a substitute for nickel (Ni), while maintaining excellent heat retention characteristics, making it suitable for automotive exhaust system applications.

## V. SUGGESTION

Based on the findings and limitations of this study, several recommendations are proposed for future research:

1. Future studies are recommended to investigate the combined effect of exhaust header material and geometric parameters, such as pipe diameter, header length, and bending method, to provide a more comprehensive understanding of their influence on engine performance.
2. Long-term durability evaluations, including thermal fatigue, corrosion resistance, and crack propagation under repeated thermal cycling, are recommended to assess the service life of Austenitic Stainless Steel and Ferritic Stainless Steel exhaust headers in practical applications.
3. Further investigations should include a more comprehensive exhaust emission analysis, particularly NOx emissions, while ensuring proper sealing of the exhaust system and gas analyzer probe to improve measurement accuracy.

## ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the supervisors for their invaluable guidance, constructive comments, and continuous encouragement throughout this research. The authors also acknowledge the Department of Mechanical Engineering, Universitas Dian Nusantara, for providing academic support and research facilities. Appreciation is further extended to the research team whose experimental data served as the basis for the simulation and analysis presented in this study.

## REFERENCES

[1] Ahmed, J., Toor, I.-u.-H., Hussein, M.A., Al-Aqeeli, & N., Baig,M.M.A. (2022). Insight into Structural Changes and Electrochemical Properties of Spark Plasma Sintered Nanostructured Ferritic and Austenitic Stainless Steels. *Nanomaterials*. 12, 1225. https://doi.org/10.3390/nano12071225

[2] Al-Azizi, F. A., Mufarida, N. A., & Aliehudin, A. (2025). Pengaruh Jenis Knalpot terhadap Torsi dan Daya pada Mesin Bore Up 200 Cc. JURITEK: *Jurnal Ilmiah Teknik Mesin, Elektro dan Komputer*. 5(3). https://doi.org/10.51903/juritek.v5i3.6325

[3] Aniekan, I. E., Kelly, O. E., & Abdulsamad, G. (2017). Engineering Material Selection for Automotive Exhaust Systems Using CES Software. *Internatioal Journal of Engineering Technologies-IJET*. 3(2).

[4] ASM International Handbook Committee. (1990). *ASM Handbook, Volume 1: Properties and Selection: Irons, Steels, and High-Performance Alloys*. ASM International.

[5] Budiyono, Feriansah, A., & Pradanal, D. A. (2023). Pengaruh Knalpot Standar Dan Knalpot Standar Modifikasi Terhadap Daya Dan Torsi Sepeda Motor Rx King 135 cc. *Jurnal Ilmiah Surya Teknika*. 7(1).

[6] Callister, W. D., & Rethwisch, D. G. (2018). *Materials Science and Engineering: An Introduction* (10th ed.). John Wiley & Sons.

[7] Charles, J. (2005). The new 200 series: an alternative answer to Ni surcharge?. *Revue de Métallurgie*, 102(12), 899-908.

[8] CRYOWorks. (*t.t*). *The 300 Series Austenitic Stainless Steels*. Diakses pada 28 Juni 2026, https://cryoworks.net/wp-content/uploads/2021/09/The-300-Series-Austenitic-Stainless-Steels-8-23-21-Penflex-CryoWorks.pdf

[9] Fatah, K. M. A., & Pratama, A. (2021). Analisis Kinerja Mesin dan Konsumsi Bahan Bakar Sepeda Motor dengan Variasi Kondisi Filter Udara. Seminar Nasional Penelitian dan Pengabdian kepada Masyarakat Universitas Sang Bumi Ruwa Jurai Tahun 2021.

[10] Fujimura, Y., Oka, Y., Imakawa, K., & Oku, M. (2021). Development of NSSC™ EM-T Stainless Steel for Automotive Exhaust Systems. *Nippon Steel Technical Report*, 126.

[11] Hamada, J., & Hayashi, A. (2026). Eco-Frendly Stainless Steel Sheets For Automobiles. *Nippon Steel Technical Report*, 135.

[12] Heywood, J. B. (1988). *Internal Combustion Engine Fundamentals*. New York: McGraw-Hill Education.

[13] Jindal Stainless. (2026). *Understanding the Ferritic Stainless Steel Composition, Properties, and Industrial Significance*. Jindal Stainless. Diakses pada 27 Juni 2026. https://www.jindalstainless.com/blog/ferritic-stainless-steel-composition-industrial-applications/

[14] John. (2024, October 9). 201 Stainless Steel: Definition, Composition, Properties, Processing, Applications, and More. *Steel Group*. Diakses pada 28 Juni 2026, https://steelprogroup.com/stainless-steel/grades/grade-201/

[15] Juuti, T., Manninen, T., Uusikallio, S., Komi, J., & Porter, D. (2019). New Ferritic Stainless Steel for Service Temperatures up to 1050 ºC Utilizing Intermetallic Phase Transformation. *MDPI*. 9, 664. https://doi.org/10.3390/met9060664

[16] Metal Zenith. (2025, May 17). 200 Series Stainless Steel: Properties and Key Applications. Diakses pada 28 Juni 2026, https://metalzenith.com/blogs/steel-properties/200-series-stainless-steel-properties-and-key-applications

[17] Nasir, M., Oktrin, Y. S., Rifdarmon, Wagino, & Balisranislam. (2023). Perbandingan Jenis Knalpot Standar Dengan Knalpot Racing Terhadap Back pressure, Temperature, Dan Suara Pada Sepeda Motor 4 Tak. *Jurnal Teknologi dan Pendidikan Vokasi Indonesia*. 1(1). https://doi.org/10.24036/jtpvi.v1i1.4

[18] Nayak, I. (2022). Thermal analysis of vehicle exhaust system. *International Journal of Multidisciplinary Research and Growth Evaluation*, 3(2), 189-194.

[19] Prudhomme, C., Santacreu, P.-O., Evenopel, I., & Proult, B. (2018). Thermomechanical fatigue behaviour of ferritic stainless steel grades for high temperatures applications. *MATEC Web of Conferences*, 165. https://doi.org/10.1051/mattecconf/201816516003

[20] Rajadurai, S., Afnas, M., Ananth, S., & Surendhar. S. (2014). Materials for Automotive Exhaust System. *International Journal of Recent Development in Engineering and Technology*, 2(3), 5-8.

[21] Rolled metal product. (*t.t*). *Stainless Steel Type 409 (UNS40920) in Coil Form*. Diakses pada 28 Juni 2026, https://rolledmetalproducts.com/stainless-steel-type-409/

[22] Saepuddin, A., Tjiptady, B. A., Pradhana, C., Rohman, M., & Meditama, R. F. (2023). Pengaruh Modifikasi Knalpot Terhadap Performa dan Suhu Mesin Pada Sepeda Motor Satria F150. *G-Tech : Jurnal Teknologi Terapan*, 7(1), 280-288.

[23] Sanata, A., & Sholahuddin, I. (2016). Rancang Bangun Knalpot Inovatif Berbahan Baja Karbon Rendah pada *Catalytic Converter* Kendaraan Bermotor. Universitas Jember.

[24] Sangsuebsri, M., Pokwitidkul, S., Wiman, P., Tanaka, Y., & Thublaor, T. (2023). Manganese Constituent in Stainless Steels Oxidized in Oxygen Containing Water Vapor at 800 oC: High Temperature Oxidation and Volatilization. *EDP Science*. 428. https://doi.org/10.1051/e3sconf/202342802012

Volume 10, Issue 8, pp. 28-33, August 2026.
ISSN (Online): 2456-7361

[25] Saputra, E. (2022). *Efektivitas Kain Pelapis Knalpot (Exhaust Wrap) Dalam Mengurangi Laju Korosi dan Kurangnya Energi Thermal*[Skripsi]. Universitas Islam Riau.

[26] Science Direct. (*t.t*). *Baja Tahan Karat Austenitik*. Diakses pada 28 Juni 2026 https://www.sciencedirect.com/topics/engineering/austenitic-stainless-steel

[27] Shao, Y., Li, X., Ma, J., Liu, C., & Yan, Z. (2019). Microstructure Formation of Low-Carbon Ferritic Stainless Steel during High Temperature Plastic Deformation. *MDPI*. 9, 463. https://doi:10.3390/met9040463

[28] Wakid, M., Widyianto, A., & Widowati, A. (2024). *Karakteristik Panas pada Exhaust manifold dengan Variasi Putaran Mesin menggunakan Computational Fluid Dynamics*. Jurnal Pendidikan Vokasi Otomotif, 6(2), 51–70. https://doi.org/10.21831/jpvo.v6i2.70755

[29] Wang, Y., Hu, Y., Mao, F., Li, J., Zhou, J., Zhang, S., wei, L., Misra, R. D. K., Liu, B., Xu, & H., Bai. (2022). Microstructure Evolution And Mechanical Properties Of Bimodal Grain Sized 301 Stainless Steel Strip Induced By Reverse Phase Transformation. *Journal of Materials Research and Technology*. 17, 2772-2781. https://doi.org/10.1016/j.jmrt.2022.01.168

[30] Winoko, Y. A., Rarindo, H., & Hertomo, B. (2019). Desain Dan Analisis Knalpot Berbasis Spongesteel Terhadap Gas Buang Co, Hc, Daya, Dan Sfc Pada Mesin Sepeda Motor. Jurnal Ilmiah Teknologi FST Undana. 13(1).

[31] Yudistirani, S. A., Mahmud, K. H., Ummamy, F. A., & Ramadhan, A. I. (2019). Analisa Performa Mesin Motor 4 Langkah 110cc Dengan Menggunakan Campuran Bioetanol-Pertamax. *Jurnal Mekanikal*, 11(1).