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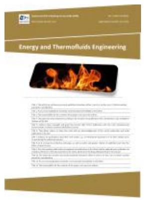

Experimental investigation of fuel and technical performance of motorcycle for modified swing arm

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Abstract: This study presents a compelling case for the development of a motorcycle swingarm using aluminum alloy instead of stainless steel. By significantly reducing the weight of the component, various benefits are achieved, including improved fuel economy, reduced emissions, and lowered primary investment costs in the manufacturing process. The utilization of aluminum alloy not only reduces the weight of the swingarm but also simplifies and economizes the manufacturing process. The process, involving wood pattern making, casting, machining, and painting, is reported to be easier and cheaper compared to the existing method. This suggests that transitioning to aluminum alloy could potentially lead to cost savings and increased efficiency in production, particularly for small-scale manufacturing operations. Furthermore, the successful integration of the modified swingarm into a Suzuki Gixxer motorcycle, following Suzuki's assembly standards, demonstrates its compatibility and suitability for practical application. The swingarm passed all quality requirements and tests as per Suzuki Inspection Standards (SIS), indicating its reliability and performance in real-world conditions. Overall, this study highlights the feasibility and benefits of using aluminum alloy in motorcycle swingarm manufacturing. Beyond reducing weight (around 27%) and improving fuel economy (save up to 0.19 ml per km), this transition offers advantages in terms of production costs, quality enhancement, and environmental impact.

1. Introduction

The increasing prominence of motorcycles as a primary mode of transportation in Bangladesh is undoubtedly influenced by the challenging traffic conditions in urban areas. With motorcycles offering affordability and agility, they have become a preferred choice for many commuters navigating congested streets. The growth of the motorcycle manufacturing sector, with investments from ten companies, reflects both the demand for motorcycles and the country's industrial development. The categorization under SRO No. 139 highlights the regulatory framework governing motorcycle manufacturing, ensuring standards and quality control across the industry. Category 1 encompasses the production of essential components like frames, swing arms, mufflers, wheels, handlebars, and fuel tanks from raw materials. This underscores the importance of local manufacturing capacity in producing key motorcycle parts, reducing dependency on imports and stimulating domestic industrial growth. By producing these components domestically, manufacturers can streamline production processes, reduce costs, and potentially offer more competitive pricing for motorcycles in the market. Moreover, local manufacturing promotes job creation and skill development within the country, contributing to economic growth and sustainability. Overall, the investment and development in motorcycle manufacturing in Bangladesh, guided by regulatory

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frameworks like SRO No. 139, reflect a strategic approach to addressing transportation challenges while fostering industrial growth and self-sufficiency (Austin et al. 2011). The sourcing of raw materials for motorcycle manufacturing in Bangladesh involves a combination of local procurement and imports, as outlined under SRO No. 139 Category 2. This category permits manufacturing companies to utilize small parts sourced either domestically or from international markets in the production of frames and other critical components. Local vendors play a crucial role in supplying these small parts, contributing to the domestic economy and supporting local businesses. At the same time, manufacturers may also opt to import certain components or materials to meet specific quality standards or technical requirements. The utilization of small parts allows for greater flexibility in manufacturing processes, enabling companies to assemble components efficiently while ensuring compliance with regulatory standards and industry specifications. This approach also facilitates the integration of various parts into the final product, contributing to the overall quality and performance of motorcycles produced in Bangladesh. Overall, the combination of local sourcing and imports under Category 2 of SRO No. 139 reflects the dynamic nature of the motorcycle manufacturing industry in Bangladesh, where companies leverage both domestic and international resources to meet market demands and maintain competitiveness (Power et al. 2016). The small part is collected from local vendors or imported from other countries. According to information from Bangladesh's Road Transport Authority (BRTA), until February 2022, the total number of registered motor vehicles was 5110786, of which the total number of motorcycles was 3585485. The motorcycle is the second-largest mode of transportation, except for public buses (Airoldi et al. 2012). The average fuel consumption of motorcycles in Bangladesh is 47.3 km/litre (or 21.14 millilitre per km). Therefore, total consumption of fuel for 3585485 motocycles would be 75797.16 L per km.

Effects of fuel consumption:

- Increase customer daily costs.
- Decrease the reserve fund.
- Increase emission.

Aru et al. 2014 investigated a typical human weight between 65 and 75 kg for economical journey. The combined weight of the motorcycle and rider would be around 200–220 kg. As a result, they can estimate that the motorcycle consumes approximately 70% of the fuel (Aeeraja et al 2012). Obviously, this cannot be eliminated or drastically reduced, but a small reduction in one motorcycle will have a significant impact on the overall fuel consumption of the same model across the country (Frendo et al 2006).

Tom Austin’s tips for achieving higher fuel economy for the motorcycle are mentioned below (Haval et al. 2012):

- Limit maximum speed
- Avoid high RPM.
- Minimize the frontal area.
- Maintain proper tire pressure.
- Minimize the use of brake
- Minimize weight
- Avoid alcohol-gasoline blends.

Reducing the weight of a motorcycle's swingarm can have a significant impact on overall performance and rider experience. The swingarm is a crucial component that connects the rear wheel to the motorcycle's frame and suspension system. By reducing its weight, several benefits can be achieved :

a) Improved Handling: A lighter swingarm can enhance the motorcycle's agility and responsiveness, making it easier to maneuver through traffic and tight corners. This can lead to a more enjoyable and confident riding experience for the customer.

b) Enhanced Acceleration: A lighter swingarm reduces the overall weight of the motorcycle, which can improve acceleration and responsiveness, particularly during quick starts and overtaking maneuvers. This can contribute to a more dynamic and engaging riding experience.

c) Better Fuel Efficiency: Reducing the motorcycle's weight, including the swingarm, can improve fuel efficiency by requiring less energy to accelerate and maintain speed. This can result in cost savings for the customer over time, as well as reducing emissions and environmental impact.

d) Reduced Rider Fatigue: Lighter motorcycle components, such as the swingarm, can contribute to reduced rider fatigue during long rides or in stop-and-go traffic situations. This can lead to increased comfort and satisfaction for the customer, encouraging them to use the motorcycle more frequently.

e) Enhanced Performance Potential: A lighter swingarm opens up opportunities for further performance enhancements, such as fine-tuning suspension settings or optimizing other components. This can appeal to customers who are seeking higher performance capabilities from their motorcycles.

Overall, reducing the weight of the motorcycle swingarm is a strategic approach to improving customer performance and satisfaction, aligning with broader goals of enhancing fuel efficiency, agility, and overall riding experience (Hugar et al 2014).

The research reported in the literature showcases the potential for optimizing motorcycle swing arms to reduce weight without compromising structural integrity. However, by employing materials like Al 7075 aluminum and carbon fiber composites, researchers have achieved significant weight reductions while maintaining or even enhancing strength and stiffness characteristics. In Power et al. (2016)'s study, the transition from AISI 1010 steel to Al 7075 aluminum resulted in a 44 percent reduction in swing arm weight. This demonstrates the advantages of aluminum over steel in terms of density and load-bearing capacity. The utilization of finite element analysis (FEA) with ANSYS software allowed for thorough evaluation and validation of the modified swing arm's performance, ensuring that key variables were not compromised during the weight reduction process. Similarly, Smith and Kienhöfer's (2015) research on carbon fiber swing arms highlights the exceptional stiffness-to-weight ratios offered by composite materials. By utilizing carbon fiber composites, they achieved a 29 percent weight reduction compared to the aluminum counterpart, while maintaining stiffness levels suitable for motorcycle suspension systems. This underscores the superior performance characteristics of carbon fiber in lightweight applications. Additionally, the work by Spanoudakis et al. 2020 on front single-sided swing arms for electric three-wheel motorcycles showcases the importance of structural optimization and simulation in achieving weight reduction goals. Through topology optimization and FEA simulations, they were able to refine the swing arm design to achieve a substantial 23.2 percent weight reduction while ensuring adequate strength and durability for electric vehicle applications. Overall, these studies demonstrate the potential for advanced materials and design techniques to optimize motorcycle swing arms, leading to improved performance, fuel efficiency, and overall rider experience. Continued research in this area holds promise for further advancements in lightweight, high-performance motorcycle components (Jeetendra et al. 2014).

1.1 Main component of the motorcycle and its weight

As shown in Figure 1, the motorcycle structure is made up of seven main components, namely the front fork, mainframe, swing arm, suspension, engine, front wheel, and rear wheel (Huertas et al 2020).

As shown in Table 1, the engine is the most weighted part; it holds 22.4% of the motorcycle, but it is the most complex and critical design that can't be manufactured here. The frame is the second weighted part due to its size and the difficulty of the design; it also can't be manufactured in the desired sand-casting process. Other important parts are constructed with different metals and sizes, which are not possible to manufacture (Hibertton et al. 2022).

For this study and analysis, we selected swingarms due to the advantages of aluminium as it holds 4% of the weight of a motorcycle; any reduction in its weight will affect bike fuel consumption. Also, it is easier to manufacture compared to other parts.

1.2 Motorcycle Swingarm

As shown in Figure 2, the swingarm serves to join the rear wheel to the chassis and control the interaction of the rear wheel with the road using the spring and shock absorber. It is the main part of the motorcycle's rear suspension. Figure 3 shows single sided swingarm, while the Figure 4 shows double sided swingarm with mono suspension (Smith et al. 2015). Additionally, Figure 5 shows the double-sided swing arm dual suspension.

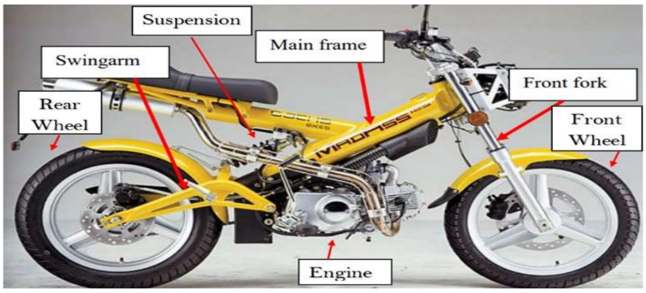

Figure 1. Motorcycle main part (Smith et al. 2015).

Table 1. Weight of Motorcycle Parts.

SL	Name of parts	Weight of parts in KG	% of parts weight
1	Engine	30	22.4
2	Frame	14	10.5
3	Swingarm	5.5	4
4	Rear shock absorber	3.5	2.6
5	Front-wheel	8.0	6
6	Rear wheel	11.5	8.6
7	Front fork	8.5	6.3
8	Others parts	53	40
	Total	134	100

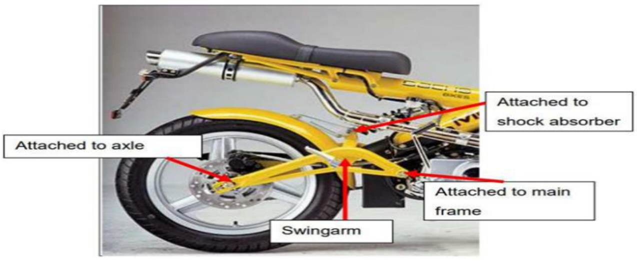

Figure 2. Rear part of motorcycle (Smith et al. 2015).

Figure 3. Single-sided swingarm (Smith et al. 2015).

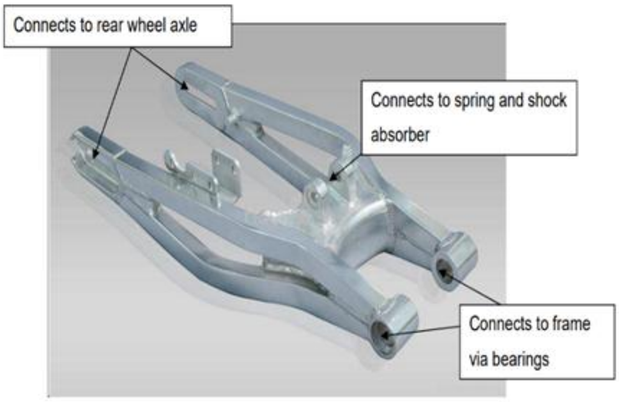

Figure 4. Double-sided swingarm mono suspension (Smith et al. 2015).

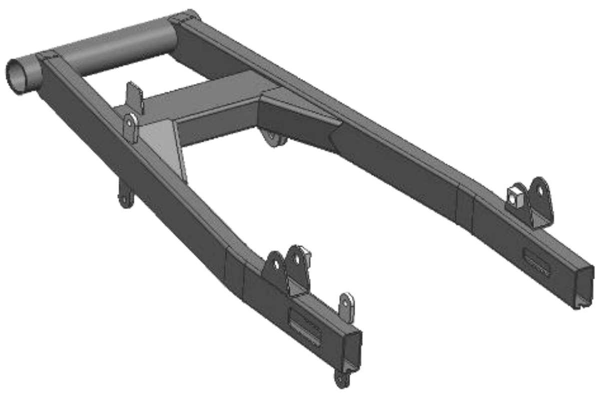

Figure 5. Double-sided swing arm dual suspension (Power et al. 2016).

1.3 Objectives

The specific aim of the present investigation is to deal with the manufacturing feasibility study of a modified motorcycle swingarm using Al7075. The following objects are taken into consideration:

- To reduce the weight of the vehicle by changing the material of the swingarm, which will improve fuel economy.
- To analyze all quality inspection data as per SUZUKI standards for modified motorcycle swingarms. In this present study, a modified swing arm of aluminum alloy (Al 7075) will be developed and its feasibility analyzed.

2. Methodology

2.1 Design of SwingArm

The swingarm, as shown in Figure 6, is the prime component of the rear suspension of the motorcycle. Certainly! The swingarm is a critical component of a motorcycle's rear suspension system, connecting the rear wheel to the frame and allowing for controlled movement of the wheel. Modifying the swingarm by changing the material can have significant implications for the performance, weight, and durability of the motorcycle.

When selecting a new material for the swingarm, several factors need to be considered, including :

i) Strength and Stiffness: The material chosen should possess sufficient strength and stiffness to withstand the forces exerted on it during acceleration, braking, and cornering, while also providing stability and control.

ii) Weight: Reducing the weight of the swingarm can improve the motorcycle's handling and maneuverability. Therefore, selecting a lightweight material without compromising strength is essential.

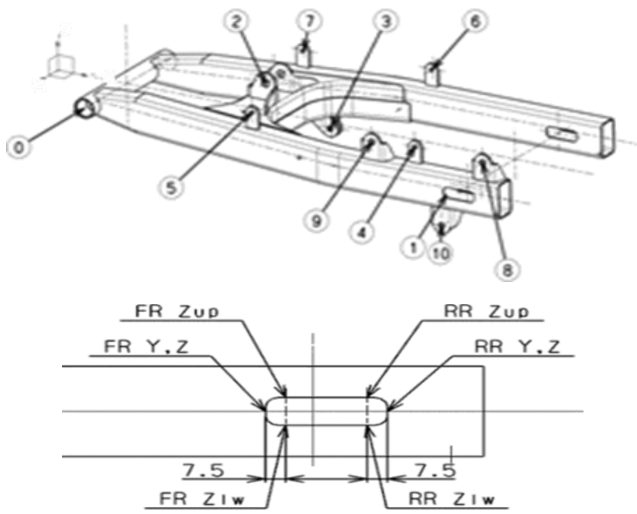

Figure 6. Swing arm 3D design.

iii) Durability: The material should be durable enough to withstand prolonged use and exposure to various environmental conditions without experiencing significant wear or degradation.

iv) Cost: The cost of the material and manufacturing processes should be taken into account to ensure the modification remains economically feasible.

v) Manufacturability: The chosen material should be suitable for the manufacturing processes involved in producing the swingarm, such as casting, forging, or machining.

Common materials used for swingarms include aluminum alloys, steel, and carbon fiber. Each material has its advantages and considerations :

Aluminum Alloys: Aluminum offers a good balance of strength, stiffness, and weight. It's relatively lightweight compared to steel and can be easily machined or formed into complex shapes. However, aluminum may not be as strong as steel and can be more prone to fatigue failure over time.

Steel: Steel is known for its strength and durability, making it a suitable choice for heavy-duty applications. However, steel swingarms tend to be heavier than their aluminum counterparts, which can affect the motorcycle's performance.

Carbon Fiber: Carbon fiber composites offer an excellent strength-to-weight ratio, allowing for lightweight and stiff swingarms. Carbon fiber is also corrosion-resistant and can be molded into complex shapes. However, carbon fiber components are often more expensive to manufacture and repair compared to their metal counterparts.

Before implementing any modifications, thorough engineering analysis, including finite element analysis (FEA) and testing, should be conducted to ensure the chosen material meets the performance and safety requirements of the motorcycle. Additionally, any changes to the swingarm design should consider compatibility with other components of the motorcycle, such as the frame, rear suspension, and chain drive system. The manufacturing process is described below (Lake et al. 2012).

2.2 Design of Pattern

The pattern is a replica of the object to be cast and is used to prepare the cavity into which molten material will be poured during the casting process as shown in Figure 7. The pattern used for sand casting may be made of wood, metal, plastic, etc. The present study selected wood for pattern material (Massaro et al 2011).

Design: Using wood patterns for casting the swingarm is an interesting approach as shown in Figure 7, especially considering their availability and cost-effectiveness. Let's break down the process into steps :

Selection of Measurements: Based on Table 2 , select the appropriate measurements for the swingarm to ensure compatibility with the motorcycle frame, rear wheel, and suspension components. These measurements will serve as the basis for creating the wood pattern.

Sample Pattern Creation: Use the selected measurements to create a sample wood pattern for the swingarm. This pattern should accurately represent the dimensions and geometry of the final swingarm.

Casting the Primary Swingarm: Use the sample wood pattern to create molds for casting the primary swingarm. This involves the use of sand molds formed around the wood pattern, with sprues, gates, risers, cores, and chills incorporated as necessary to facilitate the casting process and ensure quality.

Assembly and Testing: Once the primary swingarm is cast, assemble it with the motorcycle to assess its fit, functionality, and compatibility. Identify any areas that require modification or improvement based on the initial test assembly.

Table 2. Swingarm dimension.

Item no	Content	Dia.	X	Y	Z
0	BOSS	24	220	00	00
1	SLIT	00	550	120	10
2	ABSORBER	14	220	60	20
3	TORQUE LINK	10	246	81	45
4-7	CHAIN CASE	125	495	125	48
8-10	SIDE GUARD	142	600	140	51

Figure 7. Swing arm Wood pattern.

Modifications and Final Pattern Creation: Based on the feedback from the initial assembly and testing, make necessary modifications to the wood pattern to address any issues or improvements identified. This may involve adjusting dimensions, reinforcing certain areas, or refining the overall shape.

Casting the Final Swingarm: Use the modified wood pattern to create molds for casting the final swingarm. Ensure that any modifications made to the pattern are accurately reflected in the casting process.

Quality Assurance and Finishing: After casting the final swingarm, conduct quality assurance checks to ensure it meets the desired specifications and standards. Finish the swingarm as needed, such as smoothing rough edges or applying protective coatings.

Installation and Evaluation: Install the final swingarm on the motorcycle and evaluate its performance under various conditions, such as riding on different surfaces and cornering at different speeds. Address any further adjustments or refinements as necessary to optimize performance and durability.

By following these steps, you can successfully modify the swingarm using wood patterns for casting, taking into account the measurements, casting process, assembly, and testing to achieve the desired outcome.

2.3 Casting

Using aluminum casting for the swingarm as shown in Figure 8, offers several advantages, including its ability to achieve precise shapes and surface finishes, as well as its corrosion-resistant properties. Here's a breakdown of the process :

Preparation of the Mold: Precision is crucial when creating the mold for aluminum casting, as it directly influences the final shape and surface finish of the casting. Various materials can be used for the mold (Samantaray 2009). Including tool steel, due to aluminum's lower melting point compared to steel. Alternatively, sand molds can be used, where sand is pressed into the shape of the desired part.

Casting Process: The aluminum is heated until it reaches a liquid state, and then it is poured into the prepared mold. Careful attention is paid to ensure that the aluminum completely fills the mold cavity and that any air pockets are eliminated (Mavroudakis et al. 2006).

Cooling and Solidification: Once the aluminum is poured into the mold, it is allowed to cool and solidify. During this

Figure 8. Swing arm casting.

process, the aluminum takes on the shape of the mold and begins to form the desired part (Raina et al 2015).

Surface Finish and Oxidation: Aluminum castings quickly develop a layer of aluminum oxide on their exterior surfaces after the casting process is complete. This oxide layer acts as a protective barrier, helping to prevent corrosion and improve the casting's durability.

Finishing and Machining: After the casting has cooled and solidified, any excess material or rough edges can be removed through machining or other finishing processes to achieve the desired final shape and dimensions.

By utilizing aluminum casting for the swingarm, you can take advantage of its ability to produce complex shapes with precise tolerances while benefiting from its corrosion-resistant properties. Additionally, the use of sand molds can provide a cost-effective and versatile solution for creating the molds needed for casting.

2.4 Machining Process

Using a milling machine to remove excess material from the swingarm after casting is a common practice in manufacturing as shown in Figures 9 and 10, to reduce the extra material. Here's how the process typically unfolds :

Casting the Swingarm: The swingarm is initially cast using the chosen method, such as aluminum casting as discussed earlier. During casting, excess material or imperfections may occur, which need to be addressed in the machining process.

Machining Setup: Once the casting is complete and cooled, it is mounted securely onto the milling machine. Proper fixturing is crucial to ensure the swingarm remains stable during machining to prevent any unwanted vibrations or movement that could affect the accuracy of the machining process.

Figure 9. Swing arm Milling Machine.

Figure 10. Swing arm Grinding Operation.

Tool Selection: The appropriate cutting tools are selected based on the material of the swingarm (e.g. aluminum) and the desired machining operations. Carbide end mills are commonly used for milling aluminum due to their high cutting speeds and ability to maintain sharp cutting edges.

Material Removal: The milling machine is programmed to remove excess material from the swingarm according to the desired dimensions and geometry. This may involve roughing passes to remove larger amounts of material followed by finishing passes to achieve the final shape and surface finish.

Accuracy and Quality Control: Throughout the machining process, operators monitor the dimensions and surface finish of the swingarm to ensure they meet the specified tolerances and quality standards. Measurements may be taken using precision measuring tools such as calipers or micrometers to verify accuracy.

3. Results and discussion

Switching the swingarm material to aluminum aligns well with the project's goals of reducing weight, increasing fuel efficiency, and maintaining suspension quality to meet SUZUKI standards. Here's how the use of aluminum accomplishes each of these objectives :

Reducing Weight: Aluminum is significantly lighter than materials like stainless steel, which helps in reducing the overall weight of the motorcycle. A lighter swingarm contributes to improved handling, agility, and acceleration, enhancing the overall riding experience.

Increasing Fuel Efficiency: By reducing the weight of the motorcycle, particularly in components like the swingarm, less energy is required to propel the vehicle forward. This results in improved fuel efficiency, as the engine doesn't need to work as hard to achieve and maintain speed.

Meeting Quality Standards: While aluminum is lightweight, it also possesses excellent strength and durability, making it well-suited for applications like swingarms. By selecting high-quality aluminum alloys and ensuring proper engineering and manufacturing processes, the swingarm can meet SUZUKI's quality standards and pass all necessary tests, including those outlined in Table 3.

Furthermore, the density of aluminum is less than stainless steel means that even though the swingarm is made of aluminum, it can still withstand heavy loads and forces encountered during normal motorcycle operation. This combination of lightweight construction and robust performance makes aluminum an ideal choice for the swingarm, aligning perfectly with the project's objectives.

Overall, the decision to switch to an aluminum swingarm not only addresses the project's specific goals but also offers additional benefits such as improved handling, fuel efficiency, and overall ride quality for the motorcycle.

Deburring and Finishing: After machining, any sharp edges or burrs left on the swingarm are removed through deburring processes to improve safety and aesthetics. Additionally, the surface finish may be further refined through processes such as sanding or polishing to achieve the desired appearance.

Figure 11. Weight of existing modified swingarm

Figure 12. Weight of swingarm

Final Inspection: Once machining and finishing are complete, a final inspection is conducted to ensure the swingarm meets all requirements and specifications. This may involve visual inspection, dimensional checks, and functional testing to validate performance.

By using a milling machine to remove excess material from the swingarm after casting, manufacturers can achieve precise dimensions, smooth surface finishes, and high-quality components ready for assembly onto the motorcycle. The existing swingarm weight is 5.48 kg as shown in Figure 11 and the weight of the modified swingarm weight is 4.08 kg as shown in Figure 12. It is seen that the weight of the modified swingarm is reduced to 27% by changing the material, which is one of the key findings of the present study. The weight of a motorcycle will be lighter if it is the same way as changing the material of other parts such as the frame body, sari guard, main stand and side stand, etc.

3.1. Reduce the weight of the swingarm

By considering the material as aluminum due to its lightweight and heavy withstanding capacity, the density of aluminum is less than that of stainless steel, as seen in Table 3, so the weight of the swingarm reduces when using aluminum. The existing swingarm weight is 5.48 kg, as shown in Figure 11, and the modified swingarm weight is 4.02 kg, as shown in Figure 12. It is seen that the weight of the modified swingarm is reduced to 27% by changing the material. The weight of a motorcycle will be lighter if it is changed in the same way as the material (Sivakrishna 2014).

Table 3: Compare material properties between stainless steel and aluminum alloy (Power et al. 2016 & Spanoudakis et al. 2020).

Table 3. Compare material properties between stainless steel and aluminum alloy (Power et al. 2016 & Spanoudakis et al. 2020).

SL	Property	AISI 1020	AI SI1010	Al 7075	Al6061
1	Density, g/cc	7.87	7.87	2.81	2.7
2	Young's modulus, GPa	205	210	71.7	68
3	Poisson's ratio	0.33	0.3	0.33	0.33
4	Ultimate tensile strength, MPa	460	365	572	290
5	Ultimate yield strength, MPa	294	305	503	240

3.2 Fuel Economy of Motorcycles:

SUZUKI GIXXER bike fuel consumption data analysis: parameters (Shashanka 2013).

- Single rider.
- Existing bike weight: 135 kg
- Modified bike weight: 133.5 kg
- Fuel consumption: 1 liter.

Existing motorcycle

Fuel consumption: 40 km/l

Fuel consumption per km = 25 ml

Modified swingarm motorcycle

Fuel consumption: 40.3 km/l

Fuel consumption per km: 24.81 ml

Fuel savings compared to an existing motorcycle (25 - 24.81) = 0.19 ml

If the same process changes for all motorcycle swingarms in Bangladesh, the below result will be found.

Total registered motorcycles: 35, 85,485. Fuel saved per km = 0.19 ml

Total save = 3585485 × 0.19 = 681.24 L.

Total cost saved per km = 681.24 × 89 =60630.36TK

3.3 Motorcycle functional inspection

Functional tests are done for motorcycles after the assembly of a modified swingarm. By using a chassis dynamometer, as shown in Figure 13 (Teerhuis et al. 2012).

Quality justification as per SIS (Suzuki Inspection Standard)

- Meter calibration test
- Front brake force test
- Rear brake force test
- Top speed test

3.3.1 Meter Calibration Test

The meter calibration test conducted using a chassis dynamometer provides valuable information about the accuracy of the motorcycle's speedometer. Here's how the test results can be interpreted :

Test Setup: The chassis dynamometer is used to simulate road conditions while the motorcycle is stationary. In this case, the rear wheel is clamped, and the front wheel is allowed to rotate freely against the dynamometer's roller.

Test Procedure: The motorcycle's speedometer is compared to the speed readings displayed on the dynamometer's screen. The dynamometer measures the speed based on the rotation of the front wheel against the roller.

Test Results: The dynamometer screen displays a speed reading of 40 km/h, while the motorcycle's meter shows a speed reading of 45 km/h. The difference between these two readings is +5 km/h (45 km/h - 40 km/h), indicating that the motorcycle's speedometer is reading higher than the dynamometer's measurement.

Interpretation: The discrepancy between the dynamometer's reading and the motorcycle's meter reading suggests that the motorcycle's speedometer may be reading slightly higher than the actual speed. This could be due to factors such as inaccuracies in the speedometer calibration or variations in tire size and pressure.

Adjustment: To ensure accurate speed readings, adjustments may be necessary to calibrate the motorcycle's speedometer. This could involve recalibrating the speedometer using manufacturer-recommended procedures or adjusting the speedometer cable or sensor settings.

Verification: After making adjustments, it's important to retest the motorcycle's speedometer calibration to verify that the readings are within the acceptable range of accuracy (±5 km/h in this case). This may involve conducting additional tests on the chassis dynamometer or comparing the speedometer readings to GPS-based speed measurements.

Overall, the meter calibration test provides valuable feedback on the accuracy of the motorcycle's speedometer and helps ensure that the vehicle's speed readings are reliable and consistent with actual road speed, which is within the Suzuki standard range as seen in Figure 13 (Satyanarayana 2020).

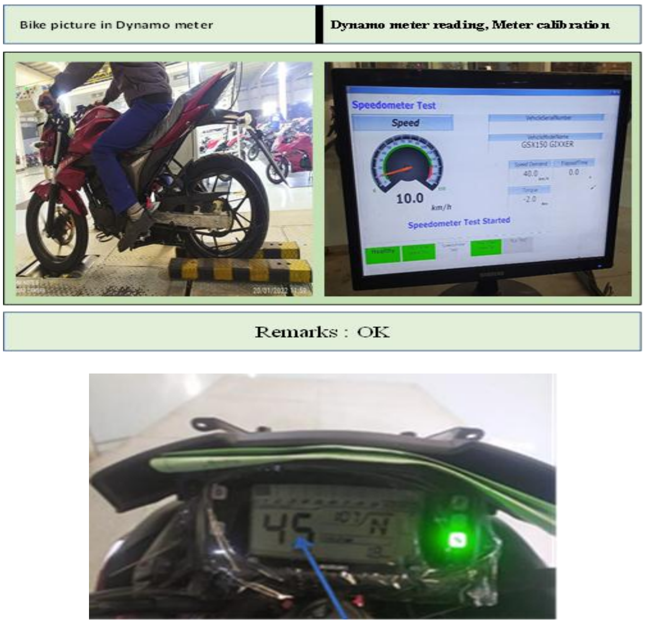

Figure 13. Motorcycle meter calibration test

3.3.2 Front brake force test

During the front brake force test, the rear wheel is fixed with a clamp to prevent it from rotating, allowing for the measurement of the force applied by the front brake. Here's how the test results can be interpreted :

Test Setup: The motorcycle is placed on a test stand or dynamometer with the rear wheel securely clamped to prevent rotation. The front brake is applied, and the force exerted by the front brake system is measured.

Test Procedure: The start button is pushed to activate the front brake system, and the motorcycle's front brake force is measured. In this case, the reading on the screen indicates a front brake force of 753 N.

Interpretation: The measured front brake force of 753 N falls within the specified range of 200–800 N as per SUZUKI standards. This indicates that the front brake system is operating within acceptable limits and meets the required performance criteria.

Compliance: Since the measured front brake force is within the specified range, the motorcycle passes the front brake force test and is compliant with SUZUKI standards.

Quality Assurance: Ensuring that the front brake force falls within the specified range is essential for maintaining safety and performance standard. Regular testing and adherence to manufacturer standards help ensure the reliability and effectiveness of the motorcycle's braking system.

Figure 14. Front brake force test.

Overall, the measured front brake force of 753 N indicates that the front brake system is functioning properly and meets SUZUKI's standards for front brake force limits. The motorcycle passed the front brake force test as shown in Figure 14 (Sushant 2015).

3.3.3 Rear Brake Force Test

During the rear brake force test, the motorcycle's rear brake force is measured with the front wheel clamped and the rear wheel rotating against a roller. Here's how the test results can be interpreted:

Test Setup: Following the front brake force test, the motorcycle transitions to the rear brake force test. The front wheel is clamped to prevent rotation, and the rear wheel is allowed to rotate against a roller. This setup allows for the measurement of the force applied by the rear brake.

Test Procedure: The start button is pushed to activate the rear brake system, and the motorcycle's rear brake force is measured. In this case, the reading on the screen indicates a rear brake force of 576.9 N.

Interpretation: The measured rear brake force of 576.9 N falls within the specified range of 200–800 N as per SUZUKI standards. This indicates that the rear brake system is operating within acceptable limits and meets the required performance criteria (Sharma et al.2012).

Compliance: Since the measured rear brake force is within the specified range, the motorcycle passes the rear brake force test and is compliant with SUZUKI standards.

Safety and Performance: Ensuring that the rear brake force falls within the specified range is crucial for maintaining safe and effective braking performance. The rear brake contributes to the overall braking capability of the motorcycle and plays a significant role in stopping distance and stability.

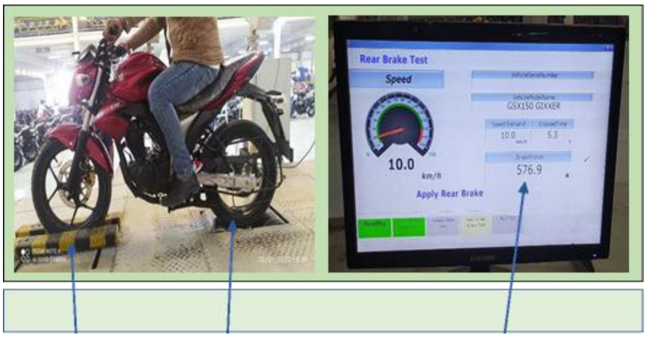

Figure 15. Rear brake force test.

Quality Assurance: Regular testing and adherence to manufacturer standards help ensure the reliability and effectiveness of the motorcycle's braking system. Monitoring brake force ensures that the braking system meets safety requirements and provides consistent performance under various operating conditions.

Overall, the measured rear brake force of 576.9 N indicates that the rear brake system is functioning properly and meets SUZUKI's standards for rear brake force limits. The motorcycle passed the front brake force test as shown in Figure 15 (Power et al. 2016).

3.3.4 Top Speed Test

During the maximum speed test, the motorcycle is operated on a dynamometer to simulate road conditions while ensuring the vehicle remains stationary. Here's how the test results can be interpreted :

Test Setup: Following the rear brake force test, the motorcycle transitions to the maximum speed test. The motorcycle is placed on the dynamometer, and the rear wheel is allowed to rotate against the roller. The test setup ensures that the motorcycle remains stationary while the dynamometer measures the speed (Spanoudakis et al. 2020).

Test Procedure: The motorcycle's engine is started, and the throttle is adjusted to maintain maximum speed. In this case, the reading on the dynamometer screen indicates a maximum speed of 96.29 km/h.

Interpretation: The measured maximum speed of 96.29 km/h falls within the specified limit of 100±5 km/h as per standards. This indicates that the motorcycle's maximum speed is within the acceptable range and meets the required performance criteria.

Compliance: Since the measured maximum speed is within the specified limit, the motorcycle passes the maximum speed test and is compliant with the standards.

Figure 16. Top speed test.

Table 4. Quality test results summary.

SL	Name of Test	Parameter Range	Result	Remarks
1	Meter calibration, km	±5	40 (dynamometer) 45 (bike screen)	ok
2	Front brake force, N	200-800	753	ok
3	Rear brake force, N	200-800	576.9N	ok
4	Top speed, km/h	100±5	96.29	ok

Safety and Performance: Ensuring that the maximum speed falls within the specified limit is essential for maintaining safety and compliance with regulatory requirements. It also ensures that the motorcycle performs within expected parameters under normal operating conditions.

Quality Assurance: Regular testing and adherence to manufacturing standards help ensure the reliability and performance of the motorcycle. Monitoring maximum speed ensures that the motorcycle meets safety requirements and operates safely under various conditions.

Overall, the measured maximum speed of 96.29 km/h indicates that the motorcycle's performance is within the specified limit, ensuring compliance with safety and regulatory standards. The motorcycle with a modified swingarm passed the top speed test, as shown in Figure 16 (Syed et al. 2018).

4. Conclusions

The present work focuses on the development of a motorcycle swingarm using aluminum alloy instead of stainless steel. While maintaining the same dimensions, the manufacturing process is shifted from MIG welding to casting, a change facilitated by the new material choice. The transition to casting makes the modified swingarm manufacturing process easier compared to the existing method. One significant outcome of this transition is a notable reduction in the weight of the motorcycle swingarm, with a remarkable 27% decrease achieved as a result of the current work. This weight reduction contributes to overall improvements in the motorcycle's performance, including agility, handling, and fuel efficiency. Moreover, the assembled modified swingarm motorcycle has successfully passed all quality SUZUKI inspection standards. These rigorous tests, which assess various parameters such as front and rear brake force and top speed, ensure that the motorcycle meets SUZUKI's strict quality requirements for safety, reliability, and performance. From this research work, it is found that Al7075 can be used for manufacturing a motorcycle swingarm, which will be advantageous to an existing one in the following ways:

- 1.1% weight reduction of the vehicle after changing the modified swingarm
- Motorcycle fuel consumption is reduced.
- Motorcycle speed and acceleration improved.
- The manufacturing process is easier than the existing process.

It's great to see that the motorcycle passed the front and rear brake force tests and the maximum speed test according to Suzuki standards. The rear brake force was recorded at 576.9 N, falling within the acceptable range of 200–800 N specified by Suzuki. Additionally, the maximum speed recorded was 96.29 km/h, which is within the allowable limit of 100±5 km/h. These results indicate that the modified swing arm, manufactured using aluminum alloy and casting, not only reduced the weight of the motorcycle but also maintained or improved its performance characteristics. After passing these quality tests, the motorcycle demonstrates its compliance with Suzuki's rigorous standards for safety and functionality.

Disclosures

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