PROGRESS IN ENGINEERING APPLICATION AND TECHNOLOGY
e-ISSN: 2773-5303

PEAT

Vol. 6 No. 1 (2025) p. 732-741
https://publisher.uthm.edu.my/periodicals/index.php/peat

Modification of RC Car Design for Autonomous Vehicle Application

Muhammad Haziq Aiman Baharuddin[1], Nofrizalidris Darlis[1]*, Syabillah Sulaiman[1]

[1] *Department of Mechanical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA*

*Corresponding Author: nofrizal@uthm.edu.my
DOI: https://doi.org/10.30880/peat. 2025.06.01.078

Article Info

Received: 20 January 2025
Accepted: 06 February 2025
Available online: 30 April 2025

Keywords

Autonomous, RC car, ultrasonic sensor, Arduino, motor controller, Solid Works, bumper, bracket, screening concept, scoring concept, FEA analysis.

Abstract

The rapid advancement of technology has transformed the automotive industry, paving the way for autonomous vehicle (AV) development. However, designing and implementing a fully autonomous vehicle is complex and costly. To bridge this gap, autonomous RC cars as a cost-effective testing platform have been focused. This study focuses on modifying an RC car to integrate sensors and control systems for autonomous movement. The key challenge lies in designing a compact, lightweight sensor bracket and optimizing sensor placement to ensure smooth navigation without compromising performance. Through a structured design approach, multiple bumper and bracket concepts were generated and refined using concept screening and scoring methods. The selected designs were subjected to Finite Element Analysis (FEA) to evaluate their structural integrity. The results demonstrated that the optimized bumper and bracket designs remained well within the material's yield strength, ensuring durability and stability. The final autonomous RC car successfully navigated a straight path and stopped at a safe distance upon detecting obstacles using ultrasonic sensors. This study highlights the potential of autonomous RC cars as a scalable research platform, offering insights into sensor integration, vehicle stability, and control system development. Future improvements could include multi-sensor fusion and AI-driven navigation for enhanced autonomy. The findings contribute to the advancement of cost-effective autonomous vehicle research, bridging the gap between small-scale models and real-world applications.

1. Introduction

Recent advances in passive and active safety technology have significantly reduced traffic fatalities. However, vehicle crashes killed 1.3 million people and injured 50 million in 2010. According to the National Highway Transportation Safety Administration (NHTSA), human error causes 93% of transportation accidents. To achieve higher levels of safety, the automotive industry has long invested in developing autonomous cars that make judgments with minimal human participation [1}. This project aims to develop an autonomous car at a low cost before its implementation in the automotive industry. Although constructing these RC vehicles requires a considerable initial investment in equipment and materials, it is still a less expensive choice than building or acquiring a fully autonomous vehicle. This enables research and development to continue without facing significant financial pressure. More design and suitable sensors and modification can be done without using more budget until the suitable design can be produced to be implemented in the automotive industry

1.1 Problem Statement and Previous Related Study

Building an actual autonomous car is not an easy task. From the design aspect, autonomous RC cars often use techniques like computer vision, machine learning, and path planning algorithms to interpret sensor data and decide how to steer, accelerate, and brake in response to the environment [2]. RC cars have limited space, so the sensor bracket must be designed in a compact and lightweight form. Ensuring all sensors can be mounted without compromising the car's performance. Incorrect placement can lead to inaccurate sensor data, which is crucial for autonomous navigation. RC cars also have limited battery life. Adding more necessary components, sensors, and computing hardware will increase power consumption significantly. Most RC cars use small lithium-polymer (LiPo) batteries, which are lightweight and only provide a good power-to-weight ratio [3]. Thus, this project aims to develop an autonomous car at a low cost before its implementation in the automotive industry

Previous studies on autonomous RC cars have explored various aspects of automation, sensor integration, and vehicle stability. Hussain and Zeadally (2018) emphasized the need for autonomous vehicles to enhance safety by reducing human errors, which account for over 90% of road accidents. Brummelen et al. (2018) categorized AVs into six automation levels, highlighting that most commercial vehicles still require driver supervision. Researchers like Campbell et al. (2018) and Feng et al. (2018) examined the role of LiDAR, ultrasonic, radar, and camera sensors in navigation and obstacle detection, while Hwang et al. (2022) integrated AI with sensor technology for improved autonomy. Junk (2020) demonstrated the advantages of 3D printing for rapid prototyping, and Genta and Morello (2009) studied vehicle stability factors such as weight distribution and center of gravity. These studies provide a strong foundation for optimizing sensor placement, control systems, and mechanical design in autonomous RC cars.

2. Literature Review

Nigel Cross [4] stated that one of the most significant engineering product design functions is to review or evaluate design concepts before deciding on a final version for production. The fundamental objective of separating the design and manufacturing processes is to allow suggestions for reviewing new objects before going into production. At its most basic, the checking technique may just be concerned with verifying that various components fit together in the final design; this is an attempt to anticipate potential problems and guarantee that the final design is functional.

Product design and development have many advantages. Norman [5] stated that by producing goods matched to user demands, enhancing functionality, usability, and overall experience can enhance customer satisfaction. Kotler & Keller [6] stated that his process also offers a competitive advantage, as innovative design helps businesses differentiate their products, establish strong market positioning, and attract a loyal customer base.

2.1 Types of Sensor in Autonomous RC Car

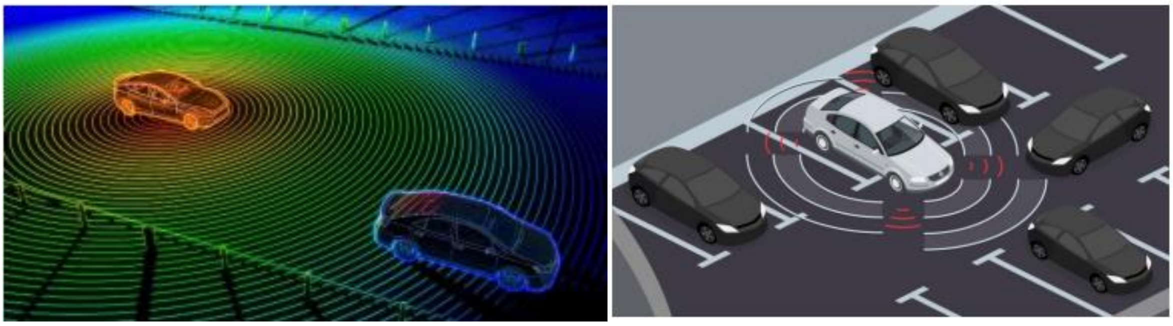
For autonomous vehicles to function properly, it need some sensors that are grouped into three main categories: Light Detection and Ranging (Lidar), Ultrasonic sensor, and cameras.

LiDAR is a remote sensing technology that is used to measure distances. It uses active sensors which emit their energy source for illumination. Fig. 1 (a) shows the LiDAR sensor that is used in autonomous cars. It works on the principle of time of flight (TOF) by sending out a pulsed laser of light and measuring the time it takes for the pulse to be reflected [7]. LiDAR sensors can measure distances faster than 150 kilohertz (150,000 pulses per second) [8], making it suitable for long-range applications with a range of exceeding 250m. LiDAR sensors provide significant advantages for autonomous vehicle technology because of their great precision and accuracy. Lidar technology is also used to build a 3D map as in Fig. 1 (a) to enable the car to see its surroundings and spot potential hazards by determining the size and distance of everything around it. It is great at capturing information in various types of ambient light— whether night or day, sunny or cloudy.

Ultrasonic sensors are a fundamental component in the perception system of autonomous vehicles. Fig. 1 (b) shows how the Ultrasonic sensor works. The main function of this sensor is to detect close-range obstacle detection and navigation. These sensors operate on the principle of emitting high-frequency sound waves (typically above the range of human hearing) and measuring the time it takes to bounce back after hitting an object. The measurement of this round-trip time allows the sensor to determine the distance to the object, enabling the vehicle to detect obstacles and navigate safely in its environment [9].

Radar sensors in autonomous vehicles are commonly integrated invisibly in several locations, such as on the roof near the top of the windshield, behind the vehicle bumpers, or brand emblems. It is essential to ensure the precision of mounting positions and orientations of radars in production, as any angular misalignment could have fatal consequences for the vehicle's operation, such errors including false or late detections of obstacles around the surroundings [10].

Cameras are essential sensors in autonomous vehicles, providing comprehensive visual information required for various navigation and safety duties. Cameras are strategically positioned around the vehicle to provide extensive coverage, capturing high-resolution photos of the environment that are subsequently analysed by sophisticated algorithms. These cameras can detect and recognise objects, such as vehicles, pedestrians, bicycles, and other obstacles, which are crucial for avoiding collisions and manuevering safely [11].



(a) **(b)**

Fig. 1: (a) LiDAR Sensor 3D Map (b) Ultrasonic sensor in Autonomous Vehicle

2.2 Vehicle Stability

The center of gravity (CoG) is one of the most important variables influencing vehicle stability. A lower CoG improves stability by lowering the chance of tipping over, particularly when making quick turns or meeting uneven terrain. Properly positioning heavy components like the battery and motor low in the chassis helps achieve a low CoG. [12]. Proper weight distribution across the car's chassis is also important; 14 balanced weight distribution keeps the vehicle from becoming overly front-heavy or rear-heavy, which can cause instability during acceleration, braking, or turning. Ensuring the weight is evenly distributed across all four wheels will help in maintaining optimal traction and stability.

3. Methodology

Creating an autonomous RC car involves a systematic methodology to enable the effective realisation of a vehicle capable of navigating its surroundings without human involvement. This technique includes many major steps, each critical to the successful design, implementation, and validation of autonomous capabilities.

3.1 Model Design

This project is separated into all parts of the design for the RC car. The by-part method was chosen to ensure that the prototype of the autonomous RC car is fully functional. An RC car with a 1:10 scale (21cm x 41cm x 11cm) was used for the study. Table 1 shows the method used to create the autonomous RC car.

Table 1: The method used for creating an autonomous RC car

Part	Product Type	Design Consideration
Chassis and Frame	Chassis kit or custom-built frame	Lightweight but sturdy material. Space for mounting sensors, electronics, and power sources. Good ground clearance and stability for various terrains.
Motors and Wheels	DC motors, servo motors, wheels tyres	Motor power and torque are suitable for the car's weight and intended speed. Wheels with appropriate traction for the environment. Precision control for smooth acceleration, deceleration, and turning.
Power Supply	LiPo batteries, battery management system	Sufficient voltage and capacity to power the motors and electronics (3.7V x 3).

		Safe and efficient power management. Ease of recharging and swapping batteries.
Control System	Microcontroller (Arduino, Raspberry Pi, etc.), motor controllers (ECSs)	Processing power to handle real-time data from sensors and make driving decisions. Interfaces for connecting sensors, motors, and other peripherals. Reliable communication with motor controllers for precise vehicle control.
Sensors	Ultrasonic sensors	Ensure no obstructions are in front of the sensor (clear line of sight). Position sensors slightly angled outward to increase detection range.
Software and Algorithms	Autonomous driving software, Sensor fusion algorithms, Path planning and navigation algorithms, Machine learning models for object detection	Efficient processing to ensure real-time operation. Robust algorithms for obstacle avoidance, path planning, and decision-making. Capability to learn and adapt to new environments and scenarios.

3.2 Idea Generation

This project focused on 2 parts, which are a bracket for the Ultrasonic sensor, which is in the bumper, and motor controller and the Arduino sensor bracket, which will be mounted in the middle of the chassis. The software used for the idea generation process is SolidWorks 2023.

The first part of idea generation is focused on the front bumper, as shown in Table 2. Mounting brackets are used to attach the sensors. The bracket for the Ultrasonic sensor will be mounted on the front of the RC car.

The second part of idea generation is a bracket in the chassis, as shown in Table 3. This bracket for Arduino and Motor Controller will be mounted on the middle chassis of the RC car. Arduino will be in a rectangular area, 70 mm in length and 54 mm in width, while the motor controller will be in a square area, 44mm in length and width.

Table 2: Bumper idea generation

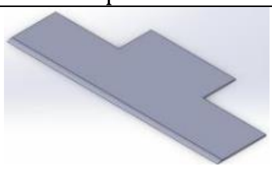
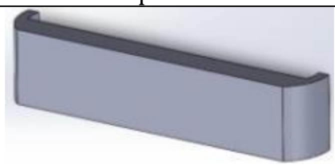
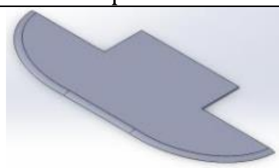
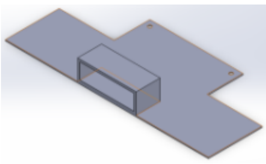
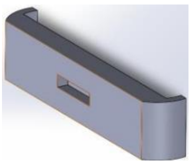
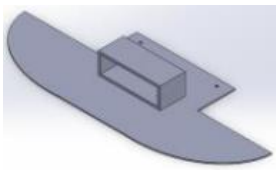
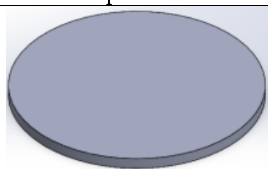
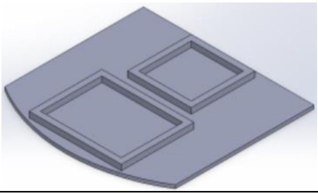
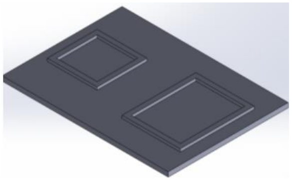
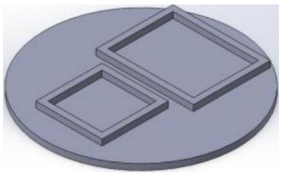
	Option 1	Option 2	Option 3
Shape			
Sensor Position	Front	Middle	Back
Product			

Table 3: Bracket idea generation

	Option 1	Option 2	Option 3
Shape			
Components	Front	Middle	Back
Positions Product			

3.3 Design Selection

Concept screening, also known as Pugh concept selection, is based on a technique created by the late Stuart Pugh in the 1980s [12]. The purpose of the concept screening is to reduce the many product concept ideas generated to a relative few that will get additional refinement and analysis.

There are many criteria that can be focused on for the screening process. From all the 9 designs that have been produced for the bumper, the criteria that must be followed is the ease of maintenance weight. The bumper design should be lightweight, which ensures that the RC car remains agile and performs optimally without excessive strain on the motor and drivetrain. Next, the bumper also has good sensor visibility. The placement and orientation of the ultrasonic sensor are important to ensure that it has an unobstructed field of detection. Proper visibility enables the sensor to function optimally, detecting obstacles and providing accurate data for the car's response system. The bumper also must be suited to the type of RC car. RC cars come in various types, such as on-road, off-road, and crawler models. Each type has specific requirements for bumper design based on their usage scenarios

3.4 Design Analysis

After the scoring process, the design that has a high score will be analyzed for stress value (von Mises) by using Finite Element Analysis (FEA). Finite Element Analysis (FEA) is a numerical method for solving complex engineering problems. It divides a large system into small, manageable elements and solves equations for each element to predict how it behaves under different conditions. The material is ABS plastic. Figure 3.5 shows the material properties of ABS plastics. The yield strength for abs plastic is 29.6MPa to 48 Mpa.

Table 4: Material properties for ABS plastics

Property	Value	Units
Elastic Modulus	2000000000	N/m^2
Poisson's Ratio	0.394	N/A
Shear Modulus	318900000	N/m^2
Mass Density	1020	Kg/m^3
Tensile Strength	30000000	N/m^2
Compressive Strength	-	N/m^2
Yield Strength	-	N/m^2
Thermal Expansion Coefficient	-	/K
Thermal Conductivity	0.2256	W/ (m.K)

3.5 Prototype Testing

For the prototype testing, the printed part is assembled into the RC. The bumper and bracket properly fit, and all the mounted components are stable. The ultrasonic bumper and motor controller also come with Arduino and fit properly with the dimensions and holes designed and printed. All the parts or components can be easily assembled and disassembled from each other. Fig. 2 shows the fully assembled 25 ultrasonic bumper, Arduino, and motor controller bracket on the RC car. For the stopping distance test, the RC car was tested to move in the straight routes of 0.2 m, 0.4m, and 0.6m, and the stop distance of the RC car was recorded. The PWM of the RC car is set to 120, and the safe stop distance of the RC car is 30 cm.

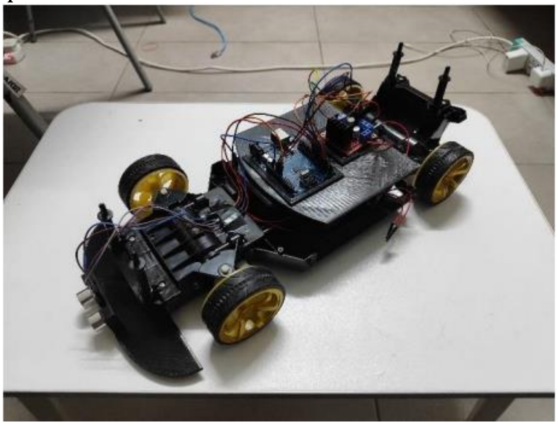
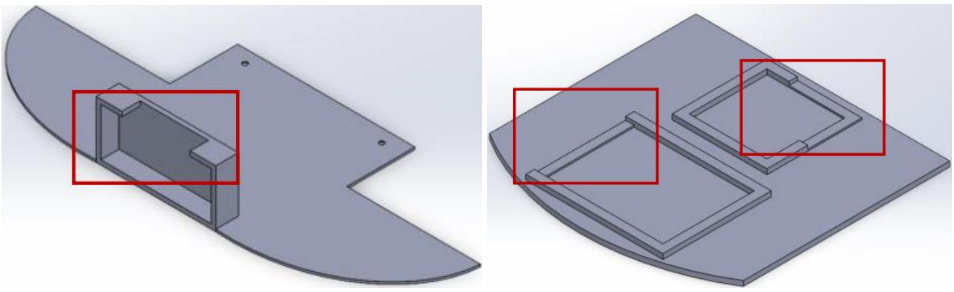


Fig. 2 **:** Fully assembly printed component to the RC

3.6 Design Optimisation

The bumper optimisation that was made during the first idea generation makes some space on top of the ultrasonic placement. This optimisation has been made to make the accessibility to the ultrasonic sensor. Fig.3 (a) shows the optimisation for the ultrasonic bumper.

For the Arduino and motor controller, the dimensions for a few sides of the placement component have been lowered. This ensures that the RC car undergoes the coding process for the Arduino component without installing and uninstalling the component every time the Arduino needs to be coded. Fig. 3 (b) shows the optimisation of the bracket for the Arduino and the motor controller.



(a) **(b)**

Fig. 3**:** (a) Optimization for the ultrasonic bumper, (b) Optimization of bracket for the Arduino and the motor controller

4. Result and Discussion

This section presents the results of the modifications made to the RC car for autonomous vehicle applications, focusing on the design. The study includes the screening and scoring process for the ultrasonic bumper and the Arduino microcontroller bracket to ensure optimal placement and functionality. This section showed the RC car's stopping distance, where it successfully detects obstacles and stops at a safe distance using the ultrasonic sensor. The performance is evaluated to demonstrate how the ultrasonic bumper and microcontroller enable the car to navigate and respond to obstacles effectively. This section presents the results of the modifications made to the RC car for autonomous vehicle applications, focusing on the design. The study includes the screening and scoring process for the ultrasonic bumper and the Arduino microcontroller bracket to ensure optimal placement and functionality.

4.1 Bumper Screening and Scoring Concept

Table 5: Concept screening for bumper

Concept \ Criteria	A1	A2	A3	A4	A5	A6	A7	A8	A9
Ease of Maintenance	+	+	+	+	+	+	+	+	+
Weight (Light)	0	0	0	-	-	-	0	0	0
Sensor Visibility	+	-	-	+	+	+	+	-	-
Suitability to RC types	+	+	+	-	-	-	+	+	+
Sum +'s	3	2	2	2	2	2	3	2	3
Sum 0 's	1	1	1	0	0	0	1	1	1
Sum –'s	0	1	1	2	2	2	0	1	1
Continue	Yes	No	No	No	No	No	Yes	No	No

After the scoring concept, only two designs were selected to continue the process. Both designs, A1 and A7, went through the scoring stage. Both designs were rated based on the selected criteria in the scoring stage, so only one design was for the autonomous RC car bumper.

Table 6: A Rating Scale for Bumper Modifications

Rating Scale	Rating
Much worse than the reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than a reference	5

When higher resolution would enable better separation of conflicting concepts, concept scoring was employed. The selection criteria are weighted according to the objective of the RC design. Table 6 shows the rating scale for bumper modifications, which ranges from 1 to 5. Based on the result of the screening process, the design with the highest criteria concept was selected. The designs that were selected are A1 and A7. Both of these designs go through the scoring process, as shown in Table 7

Table 7: Bumper concept scoring

		Concept			
Model		A1		A7	
Selection Criteria	Weight	Rating	Weight Score	Rating	Weight Score
Ease of Maintenance	15%	5	0.75	5	0.75
Good Aerodynamics	50%	1	0.5	4	2
Fit and Compatibility	35%	5	0.75	5	0.75
Total Score	100%	11	2	14	3.5
Rank		2		1	
Continue		No		Yes	

Based on the scoring result, both designs A1 and A7 have high weight scores for the easiness of maintenance, which is 0.75 due to the ultrasonic bracket being on the front of the bumper. For the aerodynamics aspect, design A7 has a high weight score of 2 because of the curved surface that allows wind to flow smoothly, and for the A1 design, it is 0.5 due to the flat surface that makes wind hard to flow. Both A1 and A7 designs have the same weight score of 0.75 for fit and compatibility criteria

4.2 Bracket Screening and Scoring Concept

Table 8: Concept Screening for Bracket

Concept \ Criteria	B1	B2	B3	B4	B5	B6	B7	B8	B9
Space Optimization	+	+	+	+	+	+	-	-	-
Component Accessibility	+	+	+	+	+	+	+	+	+
Ease of Cable Management	+	-	-	+	-	-	+	-	-
Sum +'s	3	2	2	3	1	1	2	1	1
Sum 0 's	0	0	0	0	1	1	0	0	0
Sum –'s	0	1	1	0	1	1	1	2	2
Continue	Yes	No	No	Yes	No	No	No	No	No

After the scoring concept, two designs were selected to continue the process. Both designs, A1 and A7, were went through the scoring stage. Both designs were rated based on the selected criteria in the scoring stage, so only one design was used for the autonomous RC car bracket.

Table 9: Bracket concept scoring

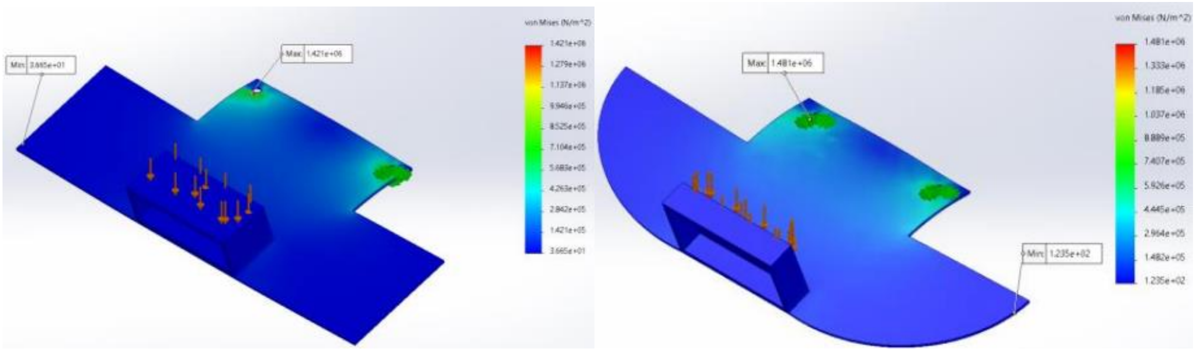
		Concept			
Model		B1		B4	
Selection Criteria	Weight	Rating	Weight Score	Rating	Weight Score
Space Efficiency	35%	4	1.4	4	1.4
Aerodynamic Shape	45%	4	1.8	3	1.35
Mounting and Stability	20%	5	1	5	1
Total Score	100%	13	4.2	12	3.75
Rank		1		2	
Continue		Yes		No	

Based on the scoring result, both designs B1 and B4 have high weight scores for space efficiency, which is 1.4 due to the rectangular bracket's base shape. For the aerodynamics shape aspect, design B1 has a high weight score of 1.8 because of the curved surface on the front of the bracket shape that allows wind to flow smoothly, and for the B4 design, it is 1.35 due to the flat surface on the front of the bracket shape that makes wind hard to flow. Both A1 and A7 designs have the same weight score of 0.75 for mounting and stability criteria due to the big surface that attaches to the RC car.

4.3 FEA Analysis of Ultrasonic Bumper

The FEA results for the ultrasonic bumper design A1 reveal that the high-stress zones experience a maximum von Mises stress of 0.8924 MPa, which is significantly lower than the yield strength of ABS material, which is 30 MPa. This indicates that the bumper will remain in the elastic region, meaning it will not undergo permanent deformation or failure under typical loading conditions, such as impacts. On the other hand, the low-stress zones have a stress value of only 0.04887 Pa, which is almost negligible and suggests that these areas are unaffected by the applied loads. These low-stress regions do not contribute to failure and do not need any adjustments. Overall, the design is safe, with the bumper performing well under expected conditions. Fig. 4 (a) shows the FEA results for bumper design A1

The ultrasonic bumper design A7, has been analyzed for stress distribution under ultrasonic sensor force in the bracket. The findings identify two separate stress zones: a high-stress zone with a von Mises stress of 1.481 MPa and a low-stress zone with a von Mises stress of 123.5 Pa. ABS has a yield strength of 30 MPa, suggesting that the bumper can withstand the ultrasonic sensor weight without any risk of permanent deformation or failure. These high-stress areas are located at the screw bracket where the bumper is tied to the body of the RC car. Fig. 4 (b) shows the results of the FEA analysis for bumper A7.



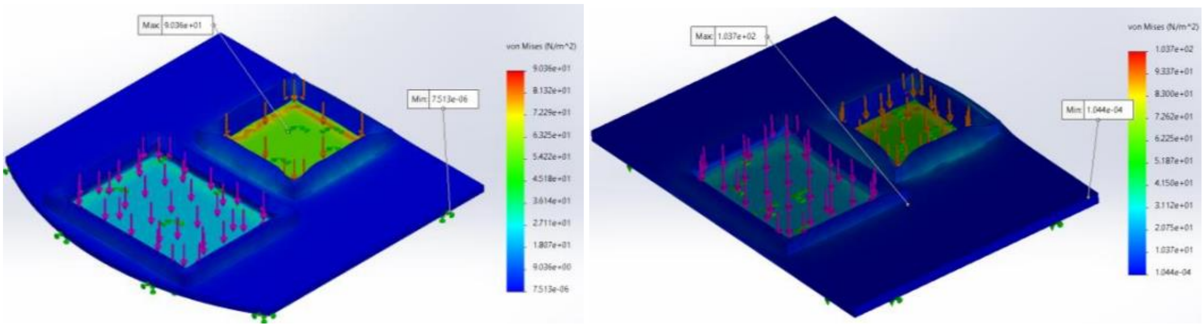
(a) **(b)**

Fig. 4: (a) A1 Bumper Design, (b) A7 Bumper Design

4.4 FEA Analysis of Arduino and Motor Controller Bracket

The FEA results for the B1 Arduino and motor controller bracket show that the design is structurally and operates within safe limits. The high-stress zones have a von Mises stress of 90.36 Pa, which is much lower than the yield strength of ABS which is 30 MPa, showing that the material will not deform or fail under ordinary loading circumstances. The low-stress zones have a stress value of 7.513 µPa, significantly lower than the material's yield strength, indicating negligible loading and being within the elastic limit

The stress analysis of the B4 Arduino and motor controller bracket reveals that the design is highly robust and capable of withstanding typical operational loads without risk of failure. The high-stress zones experience a stress of 103.7 Pa, much lower than ABS's yield strength of about 30 MPa. This indicates that these areas are well within the material's capabilities and are not at risk of yielding or plastic deformation. Furthermore, the low-stress zones, with a stress value of 104.4 µPa, experience negligible forces, effectively making them stress-free. Both stress values are far below the yield strength of ABS, ensuring the part remains structurally safe under normal conditions. Overall, the stress distribution suggests that the bracket design is efficient in load distribution, with no significant concerns for material failure.



(a) (b)

Fig. 5: (a)B1 Bracket Design, (b) B4 Bracket Design

Fig. 6: (a)RC car without sensor installation, (b) RC car with sensor installation

5. Conclusion

In conclusion, the design process that focuses on a bumper design for the ultrasonic sensor and a bracket design for the Arduino and motor controller must be suitable to the RC car to ensure the RC car can move autonomously without human help. The bumper design with a bracket for the ultrasonic sensor can ensure the autonomous RC car can stop when the ultrasonic detects the obstacle in front of the car. Additionally, the bumper's shape and design must be optimised for aerodynamics, as it should not generate excessive drag while still providing adequate protection. A well-designed bumper also supports the car's maneuverability, preventing it from being easily knocked off course during its autonomous operation. Using materials like ABS plastics can reduce the cost of printing, but the material still has a good quality.

Acknowledgement

The author would like to express his gratitude to Universiti Tun Hussein Onn Malaysia for giving him this opportunity to publish this study.

References

[1] Choi, J. K., & Ji, Y. G. (2015). Investigating the Importance of Trust on Adopting an Autonomous Vehicle. International Journal of Human-Computer Interaction, 31(10), 692–702. doi:10.1080/10447318.2015.1070549
[2] Thrun, S., Montemerlo, M., Dahlkamp, H., et al. "Stanley: The Robot That Won the DARPA Grand Challenge." Journal of Field Robotics, vol. 23, no. 9, 2006, pp. 661–692.
[3] Burke, A. F. "Batteries and Ultracapacitors for Electric, Hybrid, and Fuel Cell Vehicles." Proceedings of the IEEE, vol. 95, no. 4, 2007, pp. 806-820.
[4] Engineering Design Methods: Strategies for Product Design.. Google Books. Retrieved May 18, 2024, from https://books.google.com/books/about/Engineering_Design_Methods.html?id =O-cSEAAAQBA
[5] Norman, D. A. (2013). The Design of Everyday Things. Basic Books
[6] Kotler, P., & Keller, K. L. (2016). Marketing Management. Pearson.
[7] Campbell, S., O'Mahony, N., Krpalcova, L., Riordan, D., Walsh, J., Murphy, A., & Ryan, C. (2018). Sensor Technology in Autonomous Vehicles : A review. 2018 29th Irish Signals and Systems Conference (ISSC). doi:10.1109/issc.2018.8585340
[8] C. Ilas, "Perception in autonomous ground vehicles", International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 2013
[9] Ultrasonic sensor AFEs. (n.d.). Www.Ti.Com. From https://www.ti.com/sensors/specialty-sensors/ultrasonic/overview.html
[10] Yeong, D. J., Velasco-Hernandez, G., Barry, J., & Walsh, J. (2021). Sensor and Sensor Fusion Technology in Autonomous Vehicles: A Review. Sensors, 21(6), 2140. doi:10.3390/s21062140
[11] Autonomous Vehicles Sensors and Their Vulnerability to Weather Conditions. Sensors, 21(16), 5397. https://doi.org/10.3390/s21165397
[12] Thrun, S., Montemerlo, M., Dahlkamp, H., Stavens, D., Aron, A., Diebel, J., ... & Mahoney, P. (2006). "Stanley: The robot that won the DARPA Grand Challenge." Journal of Field Robotics, 23(9), 661-692.
[13] Daniel D. Frey Æ Paulien M. Herder Æ, Ype Wijnia Æ Eswaran Subrahmanian Æ, and Konstantinos Katsikopoulos Æ Don P. Clausing, The Pugh Controlled Convergence method: model-based evaluation and implications for design theory. Res Eng Design, 2008. Accessed: Jun. 29, 2022. [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.318.6554&rep=rep 1&type=pdf