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STIRLING ENGINE-POWERED RADIO-CONTROLLED VEHICLE UTILIZING 95 % ALCOHOL

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ABSTRACT

This research project aimed to evaluate the capabilities of a prototype vehicle propelled by a Stirling engine with its power source derived from alcohol-based fuel. The experimentation involved the utilization of an alcohol burner constructed from a canister measuring 85×87 mm, fueled by 95% alcohol. The alcohol underwent combustion to produce heat, which was then harnessed to drive the hot side of the Stirling engine's piston. The findings from the experiments indicated that the ignition temperature of the engine was observed to be 110 °C. At a rotational speed of 348 rpm, the engine demonstrated its maximum torque, reaching 0.006 N.m. Additionally, the Stirling engine exhibited its peak power output at 0.223 W when operating at a rotational speed of 573 rpm. These results contribute valuable insights into the operational parameters and performance characteristics of Stirling engine-driven vehicles utilizing alcohol as a renewable and sustainable energy source. The demonstrated torque and power values provide essential data for further advancements in the development and optimization of Stirling engine technology for practical applications in radio-controlled vehicles and beyond.

KEYWORDS: Stirling engine; External combustion engine; 95 % Alcohol; Radio-controlled vehicles.

1. INTRODUCTION

The Alcohol Stirling Engine stands at the intriguing intersection of cutting-edge engineering, alternative energy, and sustainable technology. Stirling engines, known for their simplicity and adaptability, operate on the external combustion principle, setting them apart from internal combustion engines. In the case of the Alcohol Stirling Engine, the use of alcohol as a fuel introduces an environmentally conscious element, potentially resulting in advantages such as diminished greenhouse gas emissions and reduced reliance on traditional fossil fuels. This inventive engine design exploits heat differentials to propel pistons and generate mechanical work. The incorporation of alcohol, frequently sourced from renewable outlets, aligns with the global pursuit of cleaner energy solutions. The Alcohol Stirling Engine not only holds promise for its potential contributions to the renewable energy landscape but also showcases adaptability across various applications, ranging from power generation to remote off-grid systems and even radio-controlled vehicles. As we delve into the nuances of the Alcohol Stirling Engine, examining its efficiency, performance attributes, and environmental implications, we uncover a compelling narrative of sustainable technology positioned to play a pivotal role in shaping the future of energy systems.

Components of a Stirling Engine

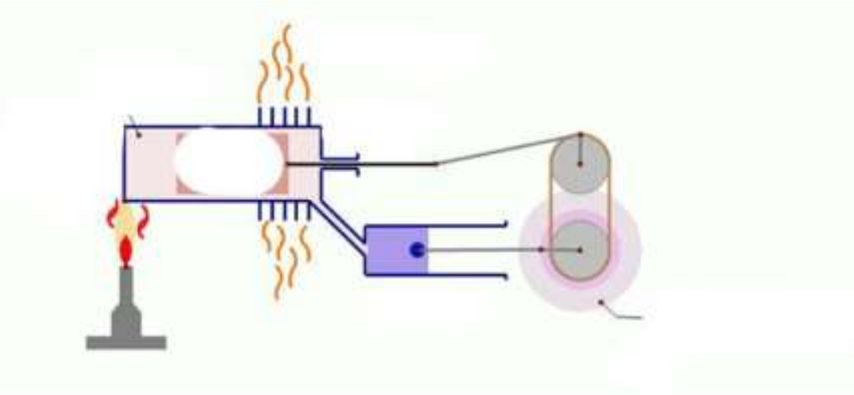

Figure 1: Illustration of the components of a Stirling engine.

The Stirling engine is equipped with two pistons positioned at a phase difference of 90 degrees Celsius. The engine comprises two distinct regions, each featuring a different gas or air and sealed to prevent any gas leakage into the external environment. The smaller piston, referred to as the power piston, plays a crucial role in generating power as it moves outward from the Stirling engine. In contrast, the larger piston, known as the displacer piston, does not contribute to the overall power output of the engine. Functioning as a means to displace or move air within the cylinder, the displacer piston, despite its larger size compared to the power piston, has the capability to move air laterally. Its primary purpose is to shuttle air within the cylinder, facilitating the efficient transfer of heat between the hot and cold sides of the engine. It's important to note that, unlike the power piston, the displacer piston does not actively participate in the power generation process of the Stirling engine.

2. THE GAMMA-TYPE STIRLING

The gamma-type Stirling engine is a specific configuration within the broader category of Stirling engines, known for its distinctive arrangement of pistons and its efficiency in converting heat energy into mechanical work. In the gamma-type Stirling engine, there are two pistons – a hot piston and a cold piston – connected by a regenerator. This engine operates on the principle of cyclic compression and expansion of a working fluid, typically a gas like helium. The key feature of the gamma-type configuration is the use of a separate displacer piston to oscillate the working gas between the hot and cold ends of the engine. This movement facilitates the transfer of heat between the heat source and sink, promoting the cyclic process necessary for power generation. The regenerator, positioned between the hot and cold spaces, helps optimize heat exchange efficiency by temporarily storing and releasing thermal energy during the engine's operation. The gamma-type Stirling engine is renowned for its smooth and quiet operation, as well as its potential for high efficiency and low maintenance. These characteristics make it suitable for various applications, including power generation, mechanical drive systems, and even in niche applications like solar power plants and space missions where its reliability and versatility are highly valued. Researchers continue to explore ways to enhance the performance and broaden the practical applications of the gamma-type Stirling engine in the pursuit of more sustainable and efficient energy solutions.

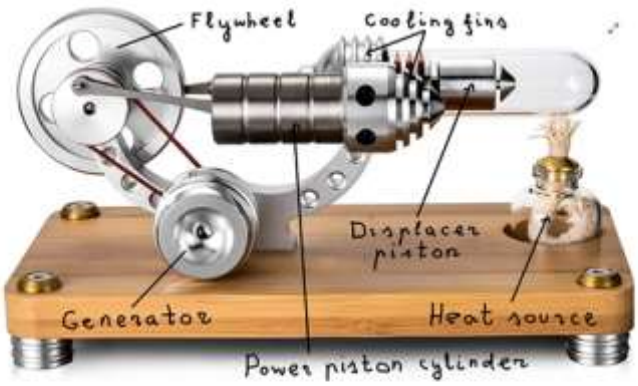

Figure 2: The gamma-type Stirling engine.

Numerous researchers have explored diverse approaches for the advancement of Stirling engine technology. Sparsh Sharma & Yash Sharma.[1] conducted a comparative study of ethanol-blended fuels using a Stirling engine experimental model. The research investigates ethanol's viability as a sustainable alternative fuel for engines, aiming to address the environmental impact of non-renewable fuels like gasoline, diesel, and petroleum. With depleting conventional fuel sources and their contribution to air pollution, finding alternatives is crucial. The experimental study involved a Stirling engine model, using a spirit lamp to combust diesel, petrol, and ethanol-blended fuels. Results showed that ethanol blending is a promising alternative, producing minimal residue and smoke, while maintaining efficiency in terms of torque, power, and energy output compared to traditional fuels. Suyitno et al.[2] studied effects of working fluids on the performance of Stirling engine. This study aims to explore the impact of different working fluids on the gamma-type Stirling engine's performance. The engine, comprising a displacer piston and power piston, utilized air, air-ethanol mixtures, and nano-fluids as working fluids. Nano-fluids were created by immersing ZnO nanoparticles in air-ethanol mixtures produced through flame-assisted spray pyrolysis. Various volume ratios were examined, with the air-ethanol mixture at 5% showing optimal engine performance (torque: 0.29 Nm, power: 10.6 W, efficiency: 3.9%). Introducing ZnO nano-fluids, especially at a 5 x 10-3 volume ratio, enhanced engine performance, presenting torque: 0.43 Nm, power: 16.67 W, and efficiency: 5.95%. Further exploration of nano-fluids as working fluids for larger Stirling engines poses an intriguing challenge for future research. Abdur Rehman et al.[3] carried out the development and analysis of a liquid piston Stirling engine. Stirling engines, operating on external combustion, use pistons to convert external heat into useful work. The Fluidyne design, also known as a liquid piston Stirling engine, employs liquid-filled cylinders to trap working gas. Despite low efficiency, Stirling engines can harness waste heat for water pumping or small-scale work, offering solutions for energy security, water issues, and greenhouse gas emissions. This study investigates the impact of altering water levels and employing different low heat of vaporization liquids on engine performance, establishing a correlation between working liquid volume and heat of vaporization. Kyei-Manu, F. and Obodoako, A.[4] conducted design and development of a liquid piston Stirling engine. Stirling engines, driven by external combustion, employ pistons for useful work with external heat. The Fluidyne design, a liquid piston Stirling engine, uses liquid-filled cylinders to trap working gas. Despite low efficiency, these engines can utilize waste heat for small-scale tasks, presenting opportunities to address energy security, water concerns, and greenhouse gas emissions. This research examines the impact of changing water levels and using a mix of low heat of vaporization liquids on engine performance, revealing a correlation between working liquid volume and heat of vaporization. Narayan, S. et al.[5] studied performance analysis of liquid piston fluidyne systems. This work focuses on designing, constructing, and testing a straightforward water-pumping device that can be easily manufactured without special tools, powered by organic combustion or solar heating. The liquid piston engine, harnessing fluctuating pressure to pump water, is simple in design and has been tested with recommendations for improvements. The study also presents and discusses the underlying theory of the device. Oyewunmi, et al.[6] conducted working-fluid selection and performance investigation of a two-phase single-reciprocating-piston heat-conversion engine. Researchers utilize a validated first-order dynamic model for the Up-THERM heat converter, a two-phase unsteady heat engine belonging to thermofluidic oscillators, offering fewer moving parts and serving as an alternative for remote power generation and waste-heat conversion. Investigating the Up-THERM's performance across various working fluids, we find that high saturation pressures enhance power output, while low vapour-phase densities improve exergy efficiencies. Among 46 fluids, R113 and i-hexane maximize power output, while siloxanes and heavier hydrocarbons optimize exergy and thermal efficiencies. The Up-THERM can deliver over 10 kW with ammonia, R245ca, R32, propene, and butane identified as versatile and optimal fluids for high power across diverse heat-source temperatures. Motamedi, M. et al.[7] performed a solar pressurizable liquid piston Stirling engine. This paper presents a validated dynamic model for a pressurizable liquid piston Stirling engine, incorporating components like a solar fresnel lens, liquid columns, regenerator, pressure intensifier, power piston, and water column. The mathematical modeling includes working gas pressure, liquid columns, and system output dynamics, resulting in nine first-order differential equations solved using the 4th order Runge-Kutta method. With specified conditions, such as a 1.5 m pumping head and temperatures of 100 °C and 20 °C, the working gas pressure exhibits oscillatory behavior, enabling water pumping when surpassing the output column's static pressure. Most of the inquiries in the previously mentioned review papers predominantly concentrated on the characterization of Stirling engine. Nevertheless, there is a scarcity of research addressing enhancements across the entire spectrum of working fluid technology, as well as the enrichment and application Stirling engine through renewable energy production.

As a result, this study seeks to examine advancements in the manufacturing technology, improvement, and application of power generation through Stirling engines. The objective of this research initiative was to evaluate the efficacy of a prototype vehicle powered by alcohol-based fuel with the intention of scaling up in the subsequent phases.

3. RADIO CONTROLLED VEHICLE

Radio-controlled vehicles, commonly known as RC vehicles or RC cars, are miniature vehicles that are powered and operated by remote control. These vehicles have gained immense popularity among hobbyists, enthusiasts, and even competitive racers. The term "radio-controlled" refers to the use of radio signals to remotely control the vehicle's movements. In this research, the radio-controlled car has been modified by integrating a Stirling engine into the vehicle. The Stirling engine is securely positioned in the central area of the car, and small metal plates are used to drill holes for fastening. The engine is attached and secured using nuts, as illustrated in Figures 3-6. This modification not only adds a unique and innovative element to the radio-controlled car but also opens up possibilities for exploring alternative propulsion methods in the realm of remote-controlled vehicles. The careful attention to detail in the installation process reflects a commitment to precision and functionality in combining radio-controlled technology with Stirling engine capabilities.

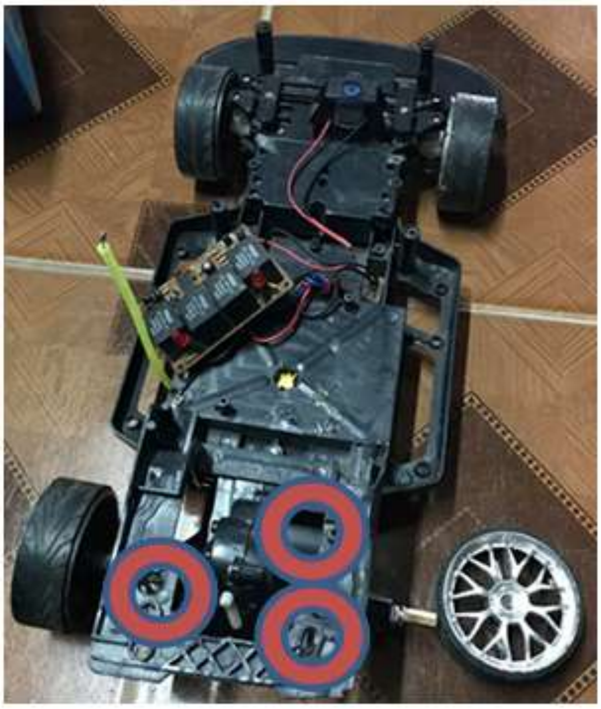

Figure 3: Installed drive belt and hole screw drilled.

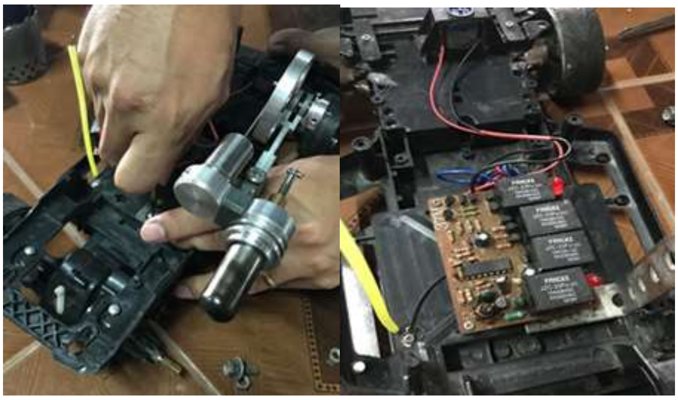

Figure 4: Installed Stirling engine and controlled board.

Figure 5: Wheels installation.

Figure 6: Base and Alcohol Burner Stand.

4. THE MATERIAL AND METHOD

The initial step involves testing the performance of the Stirling engine using alcohol as fuel. The Stirling engine is mounted on a dynamometer (rope brake dynamometer) testing stand, and the experiment is conducted with a prepared alcohol burner. The burner contains 25 milliliters of alcohol. Subsequently, the burner is ignited to heat the Stirling engine's head, initiating its operation. The temperature of the Stirling engine's head is measured using a thermometer that can gauge both hot and cold temperatures. A digital tachometer is employed to measure the wheel rotations, providing assistance in determining the torque on the twist pulley. The load is varied between 5 and 40 grams during the experiment on the rope brake dynamometer, and a spring balance is utilized to measure the load. Additionally, wind speed is measured using an anemometer, and a stopwatch is employed for timekeeping purposes. Refer to Figure 7 for a visual representation of the experimental setup.

Figure 7: The Stirling engine is installed on the dynamometer testing stand, utilizing alcohol as fuel.

The second step involves using a biomass stove to start the Stirling engine. The Stirling engine is mounted on two small-scale model vehicles: one with a radio-controlled chassis and another with a chassis made from acrylic sheets. Alcohol is used as the fuel. Subsequently, the Stirling engine's head is ignited, and a thermometer is employed to measure the temperature (both hot and cold). A digital tachometer is utilized to measure the rotational speed of the twist pulley and the vehicle's wheel. The distance covered by the vehicle is measured, and a stopwatch is used to record the time, as depicted in Figure 8.

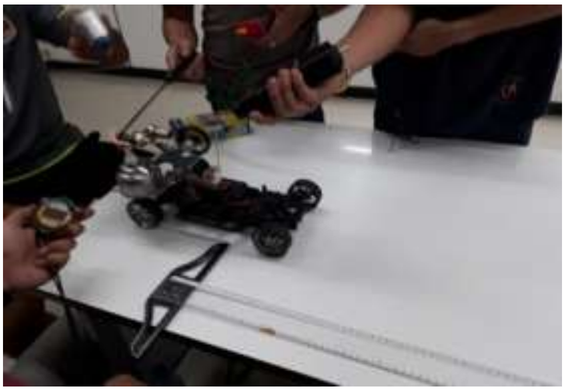

Figure 8: Testing the Stirling Engine-Powered Vehicle Using Alcohol as Fuel.

5. RESULTS AND DISCUSSION

Testing the Performance of the Stirling Engine Using Alcohol as Fuel.

The Stirling engine is mounted on a tightly designed dynamometer testing stand, comprising a steel frame, a spring balance scale (0-10 Newtons), a pulley, a small-sized EN rope used for pulling from the spring balance to the wheel, assisting the engine's force, and a set of test mass discs. The experiment is carried out using a prepared alcohol burner containing 25 milliliters of alcohol. Subsequently, the burner is ignited to heat the Stirling engine's head, initiating its operation. The temperature is measured using a thermometer capable of gauging both hot and cold temperatures in the Stirling engine. A digital tachometer is utilized to measure the wheel rotations, assisting in determining the torque on the twist pulley. Once the hot temperature exceeds 100 °C, the engine is started until it reaches its maximum speed and does not increase further. Then, loads are added using mass blocks of 5, 10, 15, 20, 25, 30, 35, and 40 grams. A stopwatch is used to record the time, and the data is documented in a results log table, with each testing interval lasting approximately 20 minutes. The test is halted after the completion of each testing period.

Table 1: Performance Testing of the Stirling Engine Using Alcohol as Fuel

Time	Temperature (°C)		speed	Load		Calculation			
t (min)	heater	T_c				F=SW	T=F.r	P=2πnT/60	η=P/Q %
	°C	°C	N(rpm)	S(g)	W(g)	(N)	(Nm)	(W)	
0	26.7	26	0	0	0	0	0	0	0
1	110	30	200	0	0	0	0	0	0
2	284	43	390	0	0	0	0	0	0
3	254	47	455	0	0	0	0	0	0
4	321	52	511	0	0	0	0	0	0
5	360	51	620	0	0	0	0	0	0
6	260	38	800	0	0	0	0	0	0
7	282	30	871	0	0	0	0	0	0
8	230	29	988	0	0	0	0	0	0
9	223	50	935	0	0	0	0	0	0
10	246	51	746	14.88	10	0.048	0.002	0.150	0.076
11	327	50	702	14.88	10	0.048	0.002	0.141	0.072
12	403	51	573	29.50	20	0.093	0.004	0.223	0.114
13	422	50	348	44.11	30	0.138	0.006	0.202	0.103
14	466	50	102	51.42	35	0.161	0.006	0.069	0.035

Graph showing the experimental results of heat input into the Stirling engine using alcohol. The graph indicates that the peak temperature reached by the heater was approximately 470 °C, while the temperature on the cold side registered around 50 °C.

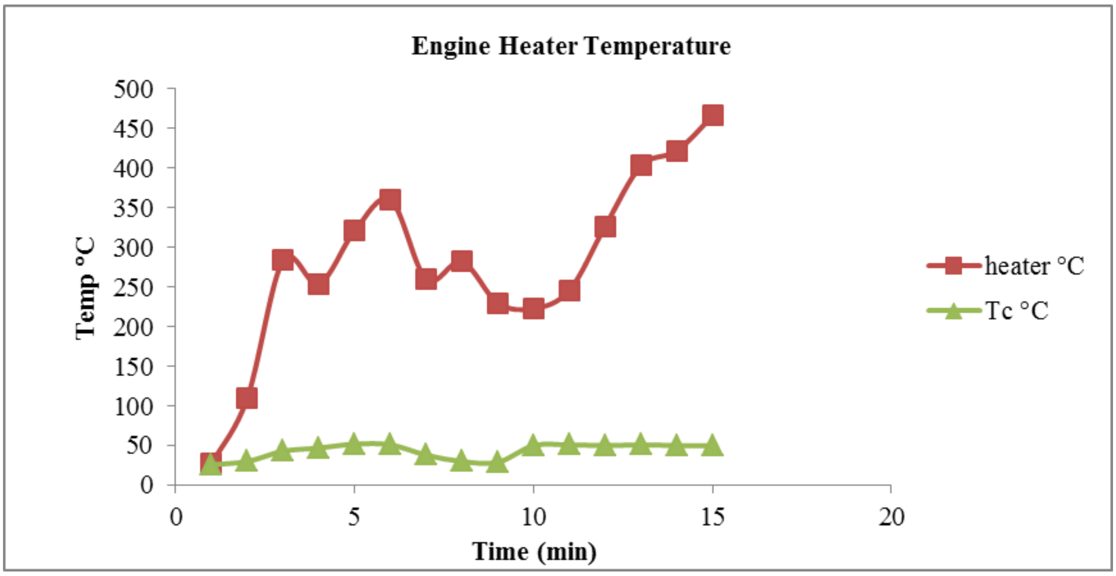

Figure 9: Heat input into the Stirling engine when heated by alcohol.

Graph depicting the performance of the Stirling engine using alcohol as fuel. The graph reveals crucial insights into the performance characteristics of the Stirling engine utilizing alcohol as fuel.

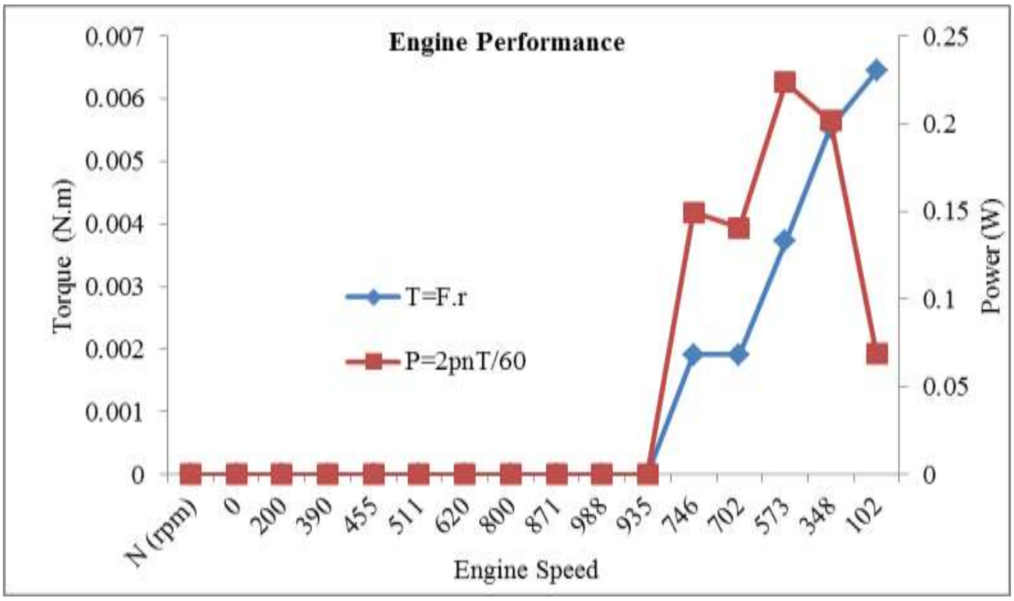

Figure 10: The performance of the Stirling engine using alcohol as fuel.

The engine's ignition temperature, marked at 746 rpm, signifies the starting point of its operation. As the load is systematically increased in 10 g increments, the engine's rotational speed experiences a gradual reduction, eventually reaching 120 rpm under a 35 g load. One noteworthy finding is the engine's maximum torque, recorded at 0.06 N.m occurring at a rotational speed of 348 rpm. Additionally, the engine demonstrates its peak power output, reaching 0.223 W at a rotational speed of 573 rpm. These data points are vital in understanding the operational limits and capabilities of the Stirling engine under the specific conditions of using alcohol as a fuel source. The observed trends provide valuable information for optimizing the engine's performance in practical applications, contributing to the ongoing development of Stirling engine technology.

6. CONCLUSIONS

This research involves testing an alcohol-powered Stirling engine. The alcohol stove, with dimensions of 85×87 mm, serves as an energy source by using heat generated from combustion as fuel to start the Stirling engine. A rope brake dynamometer set is employed to evaluate the efficiency of the Stirling engine, utilizing alcohol as a heat source. In the experiments assessing the performance of the Stirling engine using alcohol as fuel, it was found that the engine's ignition temperature is 246 °C at 746 rpm. As the load is gradually increased at 10 g intervals, the engine's speed gradually decreases until it reaches 120 rpm under a 35 g load. The maximum torque of the engine is observed to be 0.06 N.m. at a speed of 348 rpm, and the maximum power output is 0.223 W at a speed of 573 rpm. The versatility of radio-controlled vehicles spans numerous industries, making them valuable tools for entertainment, education, exploration, and various professional applications.

REFERENCES

1. Kristjan Salev., “How gamma type stirling engine works”. https://www.scienceofgadgets.com/post/stirling-engine-thermodynamics-in-action, 2021.
2. Sharma, S., Sharma, Y., “Comparative Study of Ethanol-Blended Fuels Using a Stirling Engine Experimental Model”. In: Kumar, A., Zunaid, M., Subramanian, K.A., Lim, H. (eds) Recent Advances in Manufacturing and Thermal Engineering. RAMMTE. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-19-8517-1_8, 2023, 2022.
3. Suyitno,Wibawa Endra Juwana, Oky Dwi Hanggara Putra, Sutarmo, Sholiehul Huda, and Ahmed Hissen, “ Effects of Working Fluids on the Performance of Stirling Engine”. The 12th Annual National Seminar of Mechanical Engineering (SNTTM XII) October 23rd-24th, Bandar Lampung, Indonesia, 2013.
4. Abdur Rehman Mazhar, Hassan Zamir Khan, Muhammad Kashif Khan, Adeel Ahmed and Muhammad Hassaan Yousaf, “Development and Analysis of a Liquid Piston Stirling Engine”. The Proceedings of the 2nd International Conference on Advances in

Mechanical Engineering. Eng. Proc., 2022; 23(1): 34. https://doi.org/10.3390/engproc2022023034.

5. Kyei-Manu, F.; Obodoako, “A. Design and Development of a Liquid Piston Stirling Engine”. https://www.swarthmore.edu/sites/default/files/assets/documents /engineering /FK_AO_Final.pdf
6. Narayan, S.; Singh, R.; Rana, R., “Performance Analysis of Liquid Piston Fluidyne Systems”. Mech. Test. Diagn, 2015; 5: 12–18.
7. Oyewunmi, O.A.; Kirmse, C.J.W.; Haslam, A.J.; Müller, E.A.; Markides, C.N., “Working-Fluid Selection and Performance Investigation of a Two-Phase Single-Reciprocating-Piston Heat-Conversion Engine”. Appl. Energy, 2017; 186: 376–395.
8. Motamedi, M.; Ahmadi, R.; Jokar, H., “A Solar Pressurizable Liquid Piston Stirling Engine” Part 1, Mathematical Modeling, Simulation and Validation. Energy, 2018; 155: 796–814.