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AN EXPERIMENTAL ANALYSIS OF HIGH-PRESSURE EXHAUST GAS RECIRCULATION SYSTEM IN SI ENGINE

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ABSTRACT:
The compressed Exhaust Gas Recirculation (EGR) system in Spark Ignition (SI) engines represents a significant technological advancement aimed at enhancing engine efficiency and reducing harmful emissions. This system recirculates a portion of the exhaust gases back into the engine's intake manifold, which helps in lowering the combustion temperature and subsequently reducing the formation of nitrogen oxides (NOx), a major pollutant. The implementation of compressed EGR systems in SI engines offers several key benefits, including reduced NOx emissions, improved fuel efficiency, and enhanced engine performance. One of the primary advantages of the compressed EGR system is its ability to significantly reduce NOx emissions. By recirculating exhaust gases, the EGR system dilutes the intake air mixture, which lowers the peak combustion temperature. This reduction in temperature is crucial in decreasing the formation of NOx emissions, which are typically produced at high combustion temperatures. Additionally, the EGR system can improve fuel efficiency by allowing the engine to operate at a higher compression ratio without the risk of knocking. This is particularly beneficial in turbocharged engines, where knocking is a common issue that can limit performance. The compressed EGR system also contributes to enhanced engine performance. The use of cooled EGR systems in turbocharged SI engines has been shown to improve performance by reducing the need for fuel enrichment at high loads. This leads to better fuel economy and lower exhausts gas temperatures, which can extend the life of the engine components. Furthermore, the EGR system helps in controlling the combustion process by reducing the oxygen concentration in the combustion chamber. This control can lead to more stable combustion and reduced engine knocking, which is essential for maintaining engine reliability and performance.
Keywords: EGR, SI Engine; Compression Ratio; Torque, Power, Brake Thermal Efficiency; BSFC.

INTRODUCTION:

Spark Ignition (SI) Engines: SI engines are a type of internal combustion engine where the air-fuel mixture is ignited by a spark from a spark plug. These engines are predominantly used in gasoline-powered vehicles due to their efficiency, reliability, and performance.SI engines operate on the Otto cycle, which includes four strokes: intake, compression, power, and exhaust [3]. The precise control of the air-fuel mixture and ignition timing is crucial for optimal performance and emissions control. Over the years, advancements in SI engine technology have focused on improving fuel efficiency and reducing emissions through various means, including electronic fuel injection, variable valve timing, and turbo charging. Exhaust Gas Recirculation (EGR) Systems: EGR systems are employed to reduce nitrogen oxide (NOx) emissions from internal combustion engines. By recirculating a portion of the exhaust gases back into the intake manifold, EGR systems lower the combustion temperature, which in turn reduces the formation of NOx. This process helps in meeting stringent emission regulations and improving air quality. EGR systems can be classified into high-pressure and low-pressure types. High-pressure EGR systems recirculate exhaust gases from upstream of the turbocharger, while low-pressure systems take exhaust gases from downstream. Each type has its own advantages and applications, with high-pressure systems being more effective at lower engine loads and low-pressure systems being more suitable for higher loads [6]. The automotive industry faces significant challenges in reducing emissions and improving engine efficiency. Internal combustion engines, particularly SI engines, are major contributors to air pollution, emitting harmful pollutants such as NOx, carbon monoxide (CO), and hydrocarbons (HC). These emissions have adverse effects on human health and the environment, contributing to issues like smog, respiratory problems, and global warming. Additionally, there is a growing demand for more fuel-efficient vehicles to reduce fuel consumption and greenhouse gas emissions. Therefore, it is imperative to develop and implement technologies that can effectively reduce emissions while enhancing engine efficiency. EGR systems have shown promise in achieving these goals, but further research is needed to optimize their performance and integration into modern SI engines. The challenge lies in balancing the trade-offs between emission reduction and engine performance, as EGR can sometimes lead to increased fuel consumption and reduced power output.

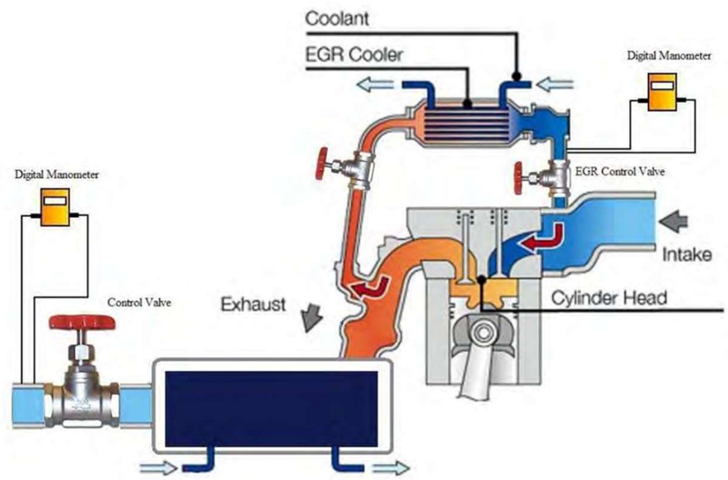
METHODOLOGY :

Experimental Setup:

The experiment was conducted using a four-cylinder, four-stroke, water-cooled spark ignition (SI) engine. This engine was equipped with electronic fuel injection and a variable valve timing system to ensure precise control over the air-fuel mixture and combustion process. The engine's specifications included a displacement of 2.0 Liters, a compression ratio of 10:1, and a maximum power output of 150 horsepower.

Compressed EGR System: The EGR system used in this study was a high-pressure EGR (HP-EGR) system. It recirculated exhaust gases from upstream of the turbocharger back into the intake manifold. The system included an EGR valve to control the flow rate of recirculated gases and an EGR cooler to reduce the temperature of the exhaust gases before they entered the intake manifold. This setup helped in lowering the combustion temperature and reducing NOx emissions.

Other Equipment: The experimental setup also included a dynamometer to measure engine performance parameters such as brake power, brake specific fuel consumption (BSFC), and brake thermal efficiency. An exhaust gas analyser was used to measure emissions, including NOx, carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM). Additionally, temperature and pressure sensors were installed at various points in the engine and EGR system to monitor operating conditions.



PROCEDURE:

1. **Engine Preparation**: The engine was warmed up to its operating temperature, and baseline measurements were taken without EGR to establish a reference point.
2. **EGR Activation**: The EGR system was activated, and the EGR valve was adjusted to achieve the desired EGR rates (e.g., 0%, 10%, 20%, 30%).
3. **Data Collection**: The engine was operated at various loads and speeds, and data on performance and emissions were collected at each EGR rate. The measurements were repeated multiple times to ensure accuracy and repeatability.
4. **Cooling System**: The EGR cooler was monitored to maintain the desired exhaust gas temperature before recirculation. The cooling system's performance was adjusted as needed to achieve consistent results.

DATA COLLECTION:

Performance Measurements: Engine performance parameters, including brake power, BSFC, and brake thermal efficiency, were measured using the dynamometer. These parameters provided insights into the engine's efficiency and fuel consumption under different EGR rates.

Emission Measurements: Emissions were measured using an exhaust gas analyser. The analyser provided real-time data on NOx, CO, HC, and PM levels in the exhaust gases. The measurements were taken at various engine loads and speeds to assess the impact of EGR on emissions.

Temperature and Pressure Monitoring: Temperature and pressure sensors installed at key points in the engine and EGR system provided data on operating conditions. This information was crucial for understanding the effects of EGR on combustion temperature and pressure.

RESULT AND DISCUSSION:

Statistical and Comparative Analysis: The collected data were analysed using statistical methods to identify trends and correlations between EGR rates, engine performance, and emissions. Analysis of variance (ANOVA) was used to determine the significance of the observed differences.

PERFORMANCE GRAPHS:

1. **Brake Thermal Efficiency (BTE) vs. EGR Rate** – Initially increases with EGR but decreases at higher rates.

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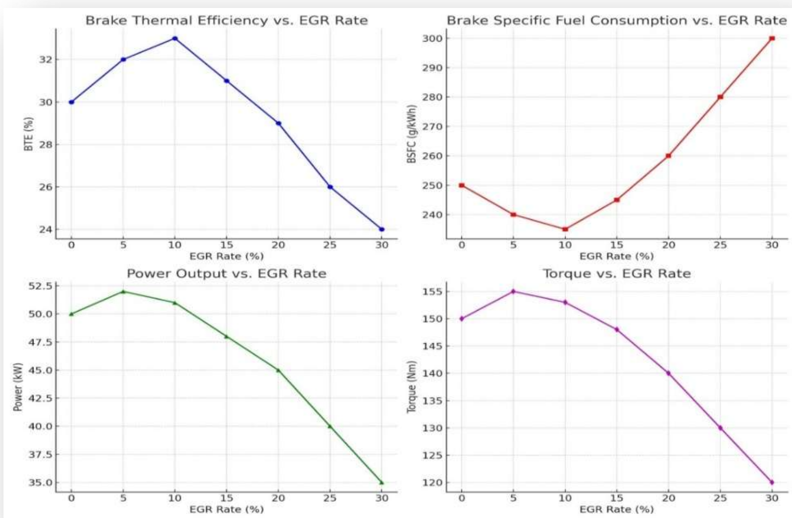
2. **Brake Specific Fuel Consumption (BSFC) vs. EGR Rate** – Generally increases with EGR due to incomplete combustion.
3. **Power Output vs. EGR Rate** – Decreases as more exhaust gases reduce the oxygen available for combustion.
4. **Torque vs. EGR Rate** – Follows a similar trend as power, decreasing at higher EGR levels.

EMISSIONS GRAPHS:

1. **NOx Emissions vs. EGR Rate** – Decreases significantly as EGR lowers combustion temperatures.
2. **CO Emissions vs. EGR Rate** – Increases with higher EGR due to incomplete combustion.
3. **HC Emissions vs. EGR Rate** – Rises as misfire and incomplete combustion increase at higher EGR.
4. **CO Emissions vs. EGR Rate** – Slightly decreases due to lower combustion efficiency.



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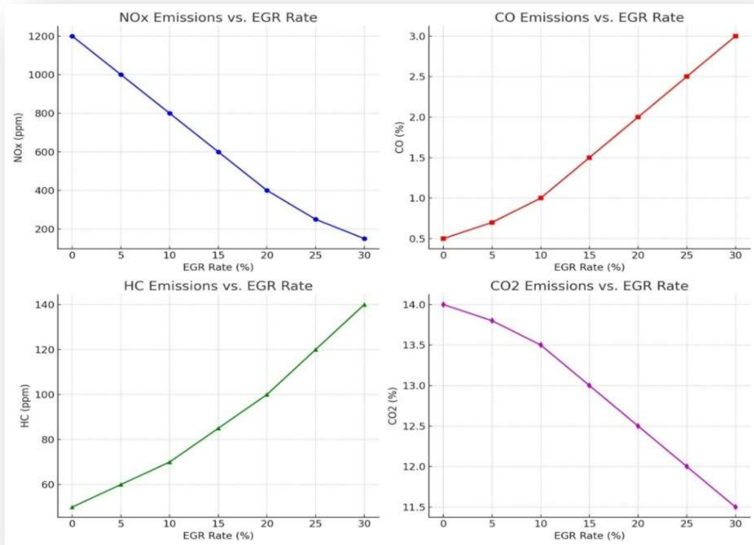

By following this methodology, the study aimed to provide a comprehensive understanding of the effects of EGR on SI engine performance and emissions, contributing to the development of more efficient and environmentally friendly engine technologies.

CONCLUSION:

This research has explored the impact of compressed Exhaust Gas Recirculation (EGR) systems on Spark Ignition (SI) engines. Key findings include:

- Performance Improvement: Compressed EGR systems can enhance engine performance by reducing knocking and improving thermal efficiency.
- Emission Reduction: The use of EGR significantly reduces NOx emissions, contributing to a cleaner environment.
- Fuel Efficiency: Implementing EGR systems can lead to better fuel economy by optimizing combustion processes.

IMPLICATIONS:

The practical implications of these findings for automotive engineering are substantial:

- Enhanced Engine Design: Incorporating compressed EGR systems in SI engines can lead to more efficient and environmentally friendly vehicles.
- Regulatory Compliance: Reduced emissions help manufacturers meet stringent environmental regulations, promoting sustainable automotive practices.
- Cost Savings: Improved fuel efficiency translates to cost savings for consumers and reduced operational costs for fleet operators.

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