ICE Term Project on

Engine Performance Comparison between Laser Ignition System and Conventional Ignition System through Simulation

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ICE Term Project

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CONTENTS

1. ABSTRACT

Energy demand and emission norms are forcing automotive researchers to explore and develop new combustion technologies to comply with stringent emission norms being adopted worldwide and continue the quest for improving engine performance. Laser is emerging as a strong concept for alternative ignition in spark ignition engine. According to ignition theory, a disadvantage of the CIS is that the spark weakens when the engine is running at high speed because it depends on the interrupted current. In contrast, the power of the engine is improved and enhanced by the LIS. The power of the engine meets all operating modes when using the LIS. Laser ignition system is free from spark electrodes hence there is no loss of spark energy to the electrodes, which are also free from erosion effect. The ignition probability and minimum ignition energy (MIE) of premixed gasoline–air mixture for different equivalence ratio was experimented.

2. INTRODUCTION

This study compares the performance of the Honda Future FI 125cc engine between a laser ignition system (LIS) and a conventional ignition system (CIS). SOLIDWORKS software was utilized to design the engine and Matlab/Simulink was used for modeling and simulating engine performance with both LIS and CIS. The ignition system plays an important role during engine operation. Because the ignition system significantly influences the combustion process efficiency and volumetric efficiency, which affects the engine performance. Recently, the laser ignition system (LIS) has been one of the most noteworthy advancements in ignition technology compared to the conventional ignition system (CIS). Indeed, some researchers experimented with 4-cylinder engines using the LIS to evaluate the engine performance. The results revealed the advantages of LIS when used in automobile engines. McIntyre et al. experimented with Ricardo Proteus's engine with a high-compression engine under lean burn mode to test the engine emissions. Their findings indicated lower emissions of hydrocarbon products and carbon dioxide.

2.1 Advantages of Laser Ignition Over Conventional Ignition:

1. Laser ignition can create plasma at the optimal location inside the combustion chamber, improving fuel-air mixture ignition.
2. Unlike spark plugs, lasers don't have physical electrodes that wear out, leading to longer life and reduced maintenance.
3. Laser pulses can be focused exactly where and when needed, allowing for better control over combustion.
4. Lasers can ignite very lean air-fuel mixtures, improving fuel economy and reducing emissions.
5. The high-energy laser-induced plasma promotes rapid flame kernel formation and faster flame propagation.
6. Laser ignition causes less heat loss to engine components compared to spark plugs.
7. Laser ignition works well in high-pressure environments where spark plugs might fail, making it ideal for advanced engine designs.
8. Laser ignition remains consistent and reliable even under extreme engine conditions.

2.2 Laser ignition process:

Laser ignition, or laser-induced ignition, is the process of starting combustion by the stimulus of a laser light source. Laser ignition uses an optical breakdown of gas molecules caused by an intense laser pulse to ignite gas mixtures. The beam of a powerful short pulse laser is focused by a lens into a combustion chamber and near the focal spot and hot and bright plasma is generated. The process begins with multi-photon ionization of few gas molecules which releases electrons that readily absorb more photons via the inverse bremsstrahlung process to increase their kinetic energy. Electrons liberated by this means collide with other molecules and ionize them, leading to an electron avalanche, and breakdown of the gas. Multiphoton absorption processes are usually essential for the initial stage of breakdown because the available photon energy at visible and near IR wavelengths is much smaller than the ionization energy. For very short pulse duration (few picoseconds) the multiphoton processes alone must provide breakdown, since there is insufficient time for electron-molecule collision to occur. Thus, this avalanche of electrons and resultant ions collide with each other producing immense heat hence creating plasma which is sufficiently strong to ignite the fuel. The wavelength of laser depend upon the absorption properties of the laser and the minimum energy required depends upon the number of photons required for producing the electron avalanche.

2.3 Methodology

We developed the SOLIDWORKS model of the Honda Future FI 125cc engine using the specifications provided in the referenced paper. The design was constructed based on various indirect parameters mentioned in the paper, including compression ratio, piston diameter, air intake manifold diameter, connecting rod length, intake and exhaust valve timings, number of valves, crankshaft radius, and engine displacement volume. A comparative analysis between laser ignition and conventional ignition systems was carried out using MATLAB/SIMULINK. By varying parameters such as spark ignition timing and engine displacement, we generated pressure and temperature plots within the cylinder using MATLAB/SIMULINK.

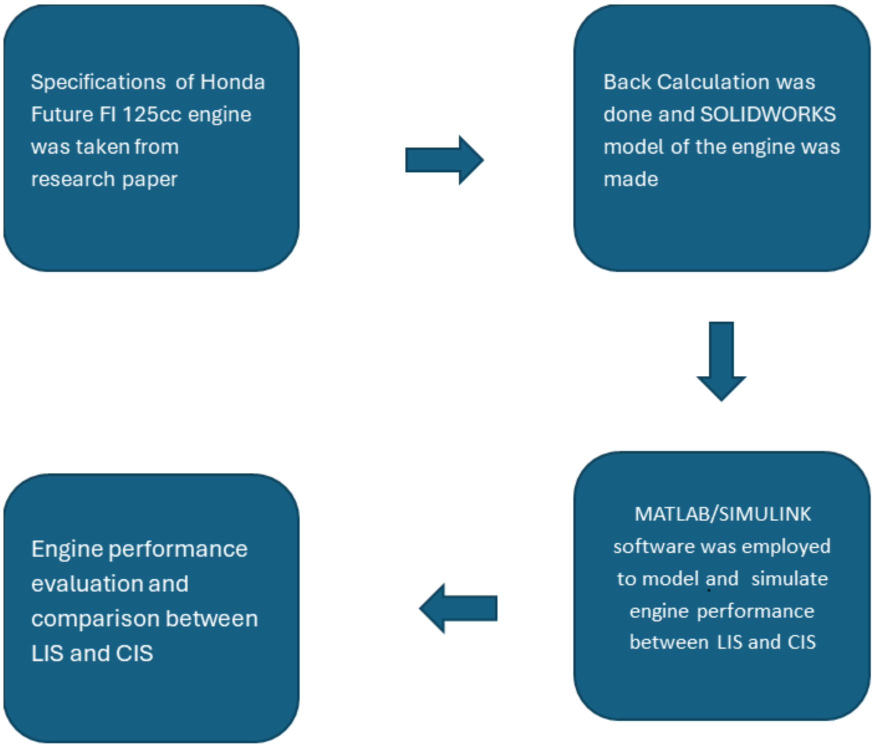

Fig 1: Flowchart related to the work process in this study

SPECIFICATIONS OF HONDA 125cc ENGINE:

PARAMETER	DESCRIPTION	VALUE
Cr	Compression Ratio	9.3
Dp	Piston diameter (mm)	52.4
Din	Air intake manifold diameter (mm)	23.2
L	Connecting rod length (mm)	101.5
Li	Intake valve opening (mm)	0.2
Le	Exhaust valve opening (mm)	0.2
Nv	Number of valves	2
r	Crankshaft radius (mm)	28.95
Vd	Displacement volume (cc)	125

Using the specifications mentioned above we designed SolidWorks model and used them for conducting the simulations and performed tests between Laser ignition system and Conventional ignition system.

Below attached is the SOLIDWORKS model made from the specifications mentioned above.

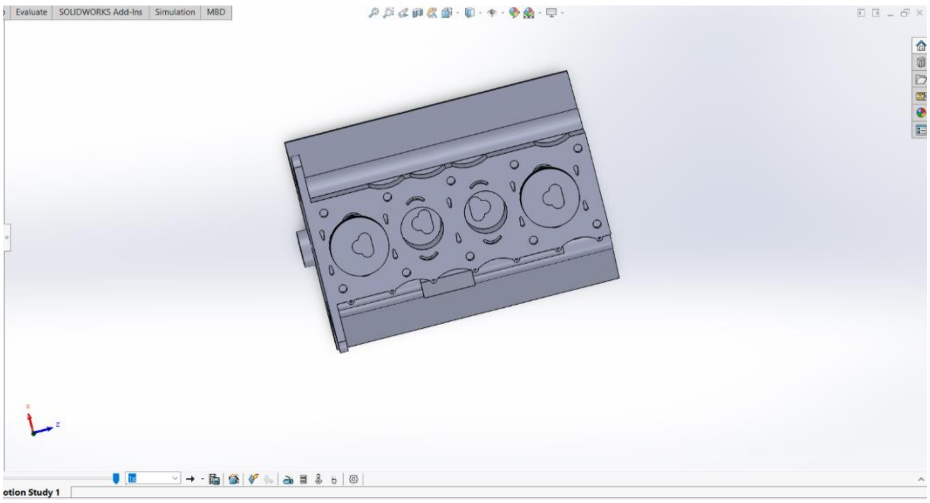

Fig 2: Top View of the Honda Future FI 125 cc engine

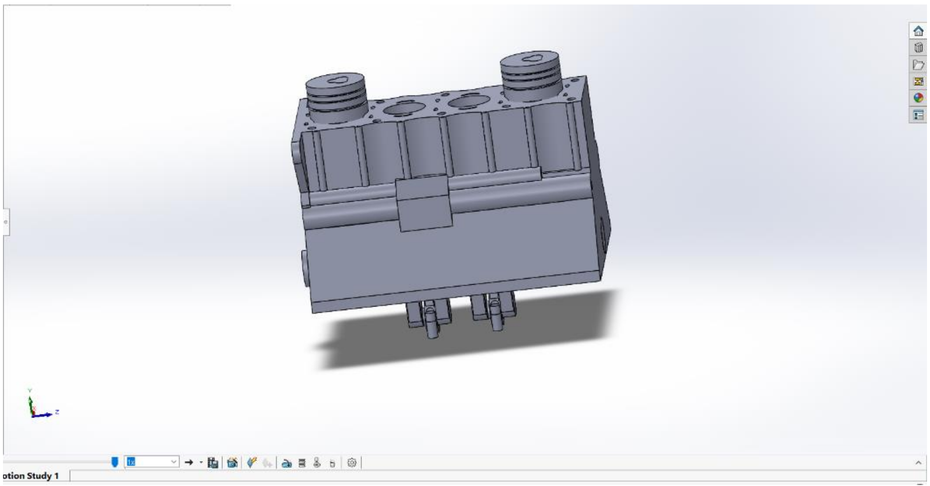

Fig 3: Isometric view of the Honda Future FI 125 cc engine

The SolidWorks modeling process of the Honda engine formed a core component of our project, offering both a practical and technical insight into 3D design, simulation, and virtual prototyping. This modeling process helped us understand the internal layout of the engine and the complexity involved in its manufacturing and assembly.

The engine model we based our design on was a typical single-cylinder, 4-stroke Honda engine known for its reliability and efficiency. Key specifications such as bore and stroke, compression ratio, displacement, valve configuration, and cooling method were meticulously translated into the CAD environment. The model was built as an assembly of several parts including the cylinder block, piston, crankshaft, camshaft, cylinder head, valves, and timing system. Each part was designed individually before being assembled to replicate real-world engine mechanics.

One of the major challenges during the modeling was maintaining correct tolerances and fits between components, particularly for moving parts such as the piston-cylinder and crankshaft-bearing interfaces. SolidWorks' advanced features, such as mates and motion simulation tools, were employed to ensure that parts interacted as intended.

Overall, the SolidWorks model not only represents the physical structure of the Honda engine but also reflects our understanding of engine design principles and mechanical system integration. The hands-on experience with CAD modeling has been invaluable in reinforcing theoretical concepts learned throughout our coursework and has provided a strong foundation for further explorations in mechanical design and automotive engineering.

3. SIMULINK and MATLAB simulations

a. Modelling and Simulation of engine performance

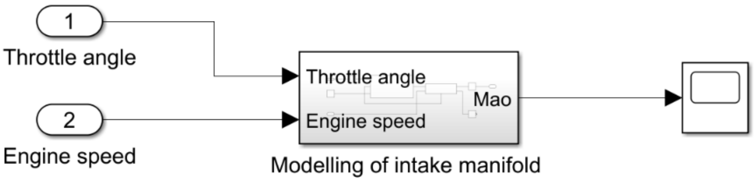

Fig 4a) SIMULINK model of Intake Manifold

Figure 4a) depicts the intake manifold model for the Honda Future FI 125cc engine, including input parameters like throttle angle and speed of the engine. Here we observe there are 2 input parameters i.e. throttle angle (in deg) and Engine speed (in RPM) and the output parameter is mass flow rate of air entering the cylinder.

The relationship between the area of the throttle valve and the throttle angle, along with the dimensions of the throttle valve, was calculated from the given relation:

$$A(\varphi) = -\frac{dD}{2}\left[1-\left(\frac{d}{D}\right)^2\right]^{\frac{1}{2}} + \frac{dD}{2}\left[1-\left(\frac{d}{D}\frac{cos(\alpha_0)}{cos(\alpha_0+\alpha)}\right)^2\right]^{\frac{1}{2}} + \frac{D^2}{2}sin^{-1}\left\{\left[1-\left(\frac{d}{D}\right)^2\right]^{\frac{1}{2}}\right\}$$
$$-\frac{D^2}{2}\frac{cos(\alpha_0)}{cos(\alpha_0+\alpha)}sin^{-1}\left\{\left[1-\left(\frac{d}{D}\frac{cos(\alpha_0)}{cos(\alpha_0+\alpha)}\right)^2\right]^{\frac{1}{2}}\right\}$$

Equation 1: Relationship between the area of the throttle valve as a function of throttle angle

The above relationship was implemented in MATLAB code, which is provided herewith.

```
d=input('Enter throttle shaft diameter: ');
D=input('Enter diameter of throttle valve bore: ');
alpha=input('Enter throttle valve angle: ');
alpha_not=input('Enter initial angle of throttle valve ');
term1=(-(d*D/2)*sqrt(1-(d/D)^2));
term2=(d*D/2)*sqrt(1-(d*cos(alpha_not)/(D*cos(alpha_not+alpha)))^2);
term3=(D^2*asin(sqrt(1-(d/D)^2))/2);
term4=-(D^2*cos(alpha_not)*asin(sqrt(1-
(d*cos(alpha_not)/(D*cos(alpha_not+alpha)))^2))/(2*cos(alpha_not+alpha)))/2;
area=term1+term2+term3+term4;
```

where: d, D, α,α0 represent the throttle shaft diameter (m), the diameter of the throttle valve bore (m), the throttle valve angle (deg), and the initial angle of the throttle valve (deg), respectively.

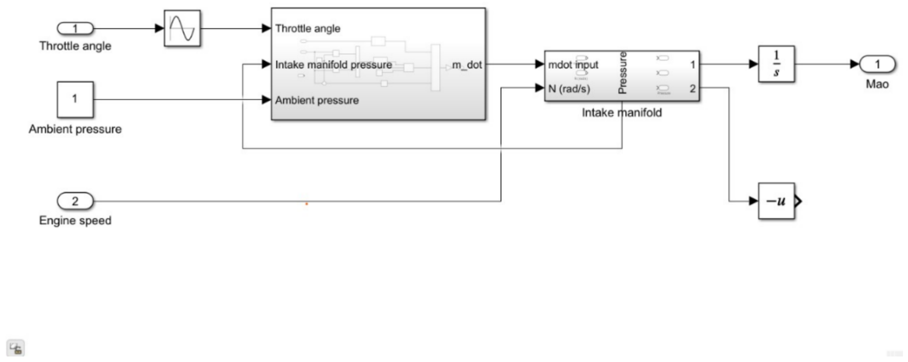

Fig 4b) Subsystem block in intake manifold model for Honda Future 125cc engine

Figure 4b) shows the subsystem model of the intake manifold for the Honda Future FI 125cc engine. It primarily consists of two blocks operating in a closed-loop feedback system, which regulate the throttle flow into the intake manifold. This flow is influenced by input parameters such as throttle angle, intake manifold pressure, and ambient pressure. The resulting output is the air mass flow rate entering the cylinder.

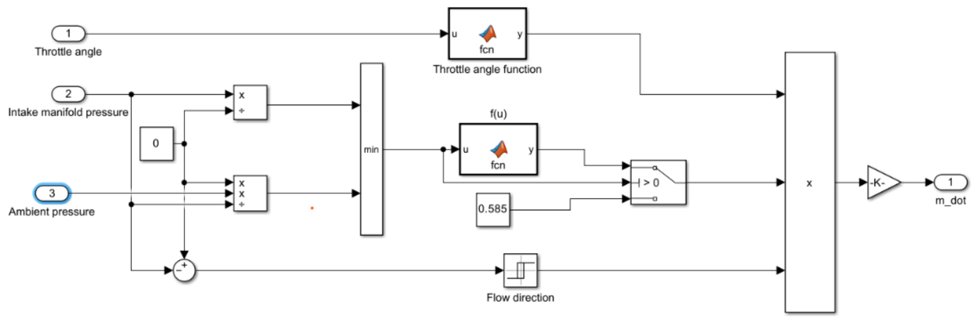

Fig 4c) Calculation of air flow rate passing through the component of throttle valve

Fig 4c) shows the subsystem of the model of airflow rate passing through the throttle valve, encompassing entry of air into throttle valve. The throttle angle influences the pivot throttle angle, valve diameter, and rotation angle. The air mass flow rate is determined after passing through the component of the throttle valve.

The block throttle angle function in the above Simulink model incorporates equation 1 depicted above.

During engine operation, the mass flow rate of air before the throttle valve depends on variables such as the area of the throttle valve, ambient pressure, and coefficient of discharge. The airflow rate before and after the throttle valve was determined following the equation based on Moskwa's thesis

$$\dot{m}_{ai} = C_d A(\varphi) \frac{P_0}{\sqrt{RT_0}} \left(\frac{P_t}{P_0}\right)^{\frac{1}{k}} \left\{ \frac{2k}{k-1} \left[1 - \left(\frac{P_t}{P_0}\right)^{\frac{k-1}{k}} \right] \right\}^{\frac{1}{2}}$$

Equation 2: Relationship between air mass flow rate input and coefficient of discharge , area of throttle valve and pressure.

where: Cd is the coefficient of discharge, $A(\varphi)$is the throttle valve area, $P0$ is the upstream pressure of air, Pt is the pressure of throat throttle (occurred at a minimum area at the throttle valve), k is a specific heat of air ratio, $T0$ is the air upstream temperature, and R is the universal gas constant.

```
f=(Pt/P0)^(1/k)*sqrt(2*k/(k-1)*(1-(Pt/P0)^(k-1)/k))
```

The above MATLAB code was incorporated into the f(u) block and the output in terms of throttle flow is studied.

(1) Throttle Angle Input

- **Throttle angle (in degrees)** is converted to **radians**.
- It is fed into a **Throttle Angle Function (MATLAB Function block)**, which computes the **effective throttle opening area** A(ϕ).

◇ **(2) Pressure Ratio Calculation**

- **Manifold pressure** and **ambient pressure** are used to calculate the **pressure ratio**:
    - Two divisions:

$$\frac{P_m}{P_a}, \quad \frac{P_a}{P_m}$$

- The **minimum** of these two values is taken using a **Min block** to ensure **stable and physically meaningful flow direction**.

◇ **(3) Flow Function f(u)**

- The minimum pressure ratio is input into a **second MATLAB Function block** (f(u)), which implements:

$$f(u) = \left(\frac{P_t}{P_0}\right)^{1/k} \sqrt{\frac{2k}{k-1}\left[1 - \left(\frac{P_t}{P_0}\right)^{(k-1)/k}\right]}$$

- This formula models **isentropic compressible flow** through a nozzle or throttle valve.

◇ **(4) Flow Direction Logic**

- The **difference between ambient and manifold pressure** is checked.
- A **Switch block** (> 0) selects whether the flow exists (only if pressure difference is positive).
- This avoids negative or physically unrealistic flow rates.

◇ **(5) Constant Terms and Gains**

- A **constant multiplier 0.585** is used — this likely represents a combination of:
  - Gas constant scaling ($\frac{1}{\sqrt{RT}}$)
  - Other simplifying constants from air properties.

◇ **(6) Final Mass Flow Rate Calculation**

- All key components are **multiplied together**:

$$\dot{m}_{ai} = C_d \times A(\phi) \times \frac{P_0}{\sqrt{RT}} \times f(u)$$

- The result is in **kg/s**.
- Finally, it is **multiplied by 1000** to convert **kg/s to g/s** for output.

Final Output:

- m_dot (g/s) = **Throttle flow rate of air** passing through the throttle body.

b) Modeling and Simulating the Process of Combustion

MATLAB code

```
CR = 9.3;          % Compression ratio
theta0 = 330;        % Start of combustion in crank angle degrees
m = 2.5;            % Wiebe exponent (controls the shape of heat release curve)
a = 6;             % Wiebe efficiency factor
deltatheta = 60;    % Duration of combustion
R = 287;            % Specific gas constant for air [J/kg·K]
gamma = 1.35;        % Ratio of specific heats (Cp/Cv)
Vd = 500e-6;         % Displacement volume in cubic meters (500 cc)
Vc = Vd / (CR - 1);  % Clearance volume
T0 = 300;           % Initial temperature [K]
P0 = 1e5;           % Initial pressure [Pa]
```

These are the engine and combustion constants used to simulate how pressure and temperature change inside the cylinder.

-

```
thetadeg_all = 0:2.5:720;    % Crank angle from 0 to 720 degrees
T_all = zeros(size(thetadeg_all)); % Array to store temperature
P_all = zeros(size(thetadeg_all)); % Array to store pressure
```

Dividing the crank angle into 2.5° steps and setting up arrays to save the calculated results.

```
if theta < theta0
    xb = 0;
elseif theta > (theta0 + deltatheta)
    xb = 1;
else
    xb = 1 - exp(-a * ((theta - theta0) / deltatheta)^m);
end
```

This is the Wiebe function, a mathematical model for heat release during combustion. xb is the fraction of total heat released.

-

For each crank angle, the code:

1. *Calculates instantaneous volume using piston position:*

V = Vc + 0.5 * Vd * (1 - cosd(theta));

-

1. *Calculates different states:*

- *Compression (180 < ϑ < ϑ0)*
- *Combustion (ϑ0 ≤ ϑ ≤ ϑ0 + Δϑ)*
- *Expansion (ϑ > ϑ0 + Δϑ to 540)*
- *Exhaust (ϑ > 540 to 720)*

Each phase uses ideal gas relations and energy balance to calculate T and P.

-

In the second half of the code, more parameters are added for laser ignition:

```
pulseWidth = 0.72;  % Laser pulse duration in degrees
pulseIntensity = 0.1; % Fraction of total heat from the laser
efficiency = 0.5;   % How efficiently heat converts to temperature rise
```

-

The model assumes:

- *A short, intense laser pulse provides some heat release.*
- *The rest of the combustion follows the Wiebe function (gradual burn).*

```
Q = pulseIntensity * Qtotal * ((theta - theta0) / pulseWidth);
```

If combustion is beyond the laser pulse:

```
xb = 1 - exp(-a * ((theta - (theta0 + pulseWidth)) / deltatheta)^m);
```

After 540° (start of exhaust stroke):

```
if theta > 540
  if isnan(T_exhaust_value)
    T_exhaust_value = T;  % Lock the values at 540°
  end
  T = T_exhaust_value;
```

Temperature and pressure are held constant to simulate the exhaust stroke.

-

COMPLETE CODE :

```
% Constants

CR = 9.3;

theta0 = 330;

m = 2.5;

a = 6;

deltatheta = 60;

R = 287;

gamma = 1.35;

Vd = 500e-6;

Vc = (Vd / (CR - 1));

T0 = 300;

P0 = 1e5;


% Initialize arrays

thetadeg_all = 0:2.5:720;

T_all = zeros(size(thetadeg_all));

P_all = zeros(size(thetadeg_all));


% Loop through crank angles

for i = 1:length(thetadeg_all)

  thetadeg = thetadeg_all(i);

  if thetadeg < 720

    theta = thetadeg;

  else

    theta = mod(thetadeg, 720);

  end

  if theta < theta0

    xb = 0;

  elseif theta > (theta0 + deltatheta)

    xb = 1;

  else
```

```
    xb = 1 - exp(-a * ((theta - theta0) / deltatheta)^m);
end
Qtotal = 300;
Q = Qtotal * xb;
Vi = Vc + 0.5 * Vd * (1 - cosd(theta0));
Ti = T0 * (((Vc + Vd) / Vi)^(gamma - 1));
Pi = P0 * (((Vc + Vd) / Vi)^gamma);
Vj = Vc + 0.5 * Vd * (1 - cosd(theta0 + deltatheta));
Tj = Ti + (((gamma - 1) * 300) / ((Vc + Vd) * R));
Pj = Pi * (Tj / T0) * ((Vc / Vj)^gamma);
Vk = Vc + 0.5 * Vd * (1 - cosd(540));
if theta <= 180
    T = T0;
    P = P0;
    V = Vc + 0.5 * Vd * (1 - cosd(theta));
elseif (theta > 180 && theta <= theta0)
    V = Vc + 0.5 * Vd * (1 - cosd(theta));
    T = T0 * (((Vc + Vd) / V)^(gamma - 1));
    P = P0 * (((Vc + Vd) / V)^gamma);
elseif (theta > theta0 && theta <= theta0 + deltatheta)
    V = Vc + 0.5 * Vd * (1 - cosd(theta));
    T = Ti + (((gamma - 1) * Q) / ((Vc+Vd) * R));
    P = Pi * (T / T0) * ((Vc / V)^gamma);
elseif (theta0 + deltatheta < theta && theta <= 540)
    V = Vc + 0.5 * Vd * (1 - cosd(theta));
    T = Tj * ((Vj / V)^(gamma - 1));
    P = Pj * ((Vj / V)^gamma);
elseif (theta > 540 && theta <= 720)
    T = Tj * ((Vj / Vk)^(gamma - 1));
    P = Pj * ((Vj / Vk)^gamma);
    V = Vc + 0.5 * Vd * (1 - cosd(theta));
end
% Store the values
```

```
    T_all(i) = T;

    P_all(i) = P;

end

% Plot Temperature vs. Crank Angle

figure;

scatter(thetadeg_all, T_all, 15, 'r', 'filled');

xlabel('Crank Angle (degrees)');

ylabel('Temperature (K)');

title('Temperature vs. Crank Angle');

grid on;

% Plot Pressure vs. Crank Angle

figure;

scatter(thetadeg_all, P_all / 1e5, 15, 'k', 'filled'); % Converted to bar

xlabel('Crank Angle (degrees)');

ylabel('Pressure (bar)');

title('Pressure vs. Crank Angle');

grid on;
```

-

```
% Engine and Combustion Constants

CR = 9.3;                  % Compression ratio

pulseWidth = 0.72;             % Duration of laser pulse in degrees

pulseIntensity = 0.1;         % Laser fraction of total heat

theta0 = 330;                 % Start of combustion

a = 6;                      % Wiebe parameter (shape)

m = 2.5;                    % Wiebe exponent

deltatheta = 60;              % Duration of combustion

R = 287;                    % Specific gas constant for air (J/kg·K)

gamma = 1.32;                 % Specific heat ratio (typical for combustion gases)

Vd = 500e-6;                 % Displacement volume (m^3)

Vc = Vd / (CR - 1);           % Clearance volume (m^3)

T0 = 300;                    % Initial temperature (K)

P0 = 1e5;                    % Initial pressure (Pa)

Qtotal = 300;                 % Total heat released (J)
```

```
efficiency = 0.5;            % Effective conversion to thermal energy

% Exhaust conditions (post 540 degrees)
T_exhaust = 500;             % Exhaust temperature (K)
P_exhaust = 1e5;             % Exhaust pressure (Pa) ~ 1 bar

% Arrays for results
thetadeg_all = 0:2.5:720;
T_all = zeros(size(thetadeg_all));
P_all = zeros(size(thetadeg_all));

% Variables to track the pressure and temperature in exhaust phase
T_exhaust_value = NaN;     % Initialize a variable for the exhaust temperature
P_exhaust_value = NaN;     % Initialize a variable for the exhaust pressure

% Main loop over crank angles
for i = 1:length(thetadeg_all)
    thetadeg = thetadeg_all(i);
    theta = mod(thetadeg, 720);    % Ensure theta is within 0-720 degrees

    % Instantaneous volume calculation
    V = Vc + 0.5 * Vd * (1 - cosd(theta));

    % Initial conditions
    Vi = Vc + 0.5 * Vd * (1 - cosd(theta0));
    Ti = T0 * (((Vc + Vd) / Vi)^(gamma - 1));
    Pi = P0 * (((Vc + Vd) / Vi)^gamma);
    if theta <= 180
        T = T0;
        P = P0;
    elseif theta > 180 && theta < theta0
        T = T0 * (((Vc + Vd) / V)^(gamma - 1));
        P = P0 * (((Vc + Vd) / V)^gamma);
```

```
    elseif theta >= theta0 && theta <= theta0 + pulseWidth
        % Laser-assisted rapid combustion
        Q = pulseIntensity * Qtotal * ((theta - theta0) / pulseWidth);
        T = Ti + (efficiency * (gamma - 1) * Q) / (V * R);
        P = Pi * (T / T0) * ((Vc / V)^gamma);
    else
        % Gradual combustion via Wiebe function
        xb = 1 - exp(-a * ((theta - (theta0 + pulseWidth)) / deltatheta)^m);
        xb = min(max(xb, 0), 1);
        Q = pulseIntensity * Qtotal + (1 - pulseIntensity) * Qtotal * xb;
        T = Ti + (efficiency * (gamma - 1) * Q) / (V * R);
        P = Pi * (T / T0) * ((Vc / V)^gamma);
    end
    % After 540 degrees (exhaust phase)
    if theta > 540
        % If T_exhaust_value and P_exhaust_value are not initialized yet, store them
        if isnan(T_exhaust_value)
            T_exhaust_value = T;
        end
        if isnan(P_exhaust_value)
            P_exhaust_value = P;
        end
        % Keep temperature and pressure constant in exhaust phase
        T = T_exhaust_value;
        P = P_exhaust_value;
    end
    % Store results
    T_all(i) = T;
    P_all(i) = P;
end
% Plot Temperature
figure;
scatter(thetadeg_all, T_all, 15, 'r', 'filled');
```

```
xlabel('Crank Angle (degrees)');
ylabel('Temperature (K)');
title('Temperature vs. Crank Angle');
grid on;
% Plot Pressure
figure;
scatter(thetadeg_all, P_all / 1e5, 15, 'k', 'filled');        % Convert from Pa to bar
xlabel('Crank Angle (degrees)');
ylabel('Pressure (bar)');
title('Pressure vs. Crank Angle');
grid on;
```

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4. Results

1. Conventional Ignition Engine

a) For Combustion Initiation at 30degrees before TDC.

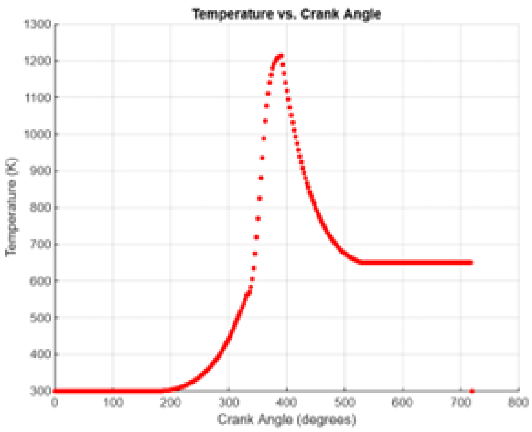


Fig 5i) Variation of temperature with crank angle

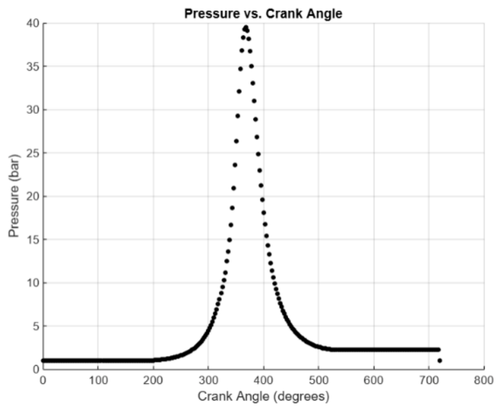
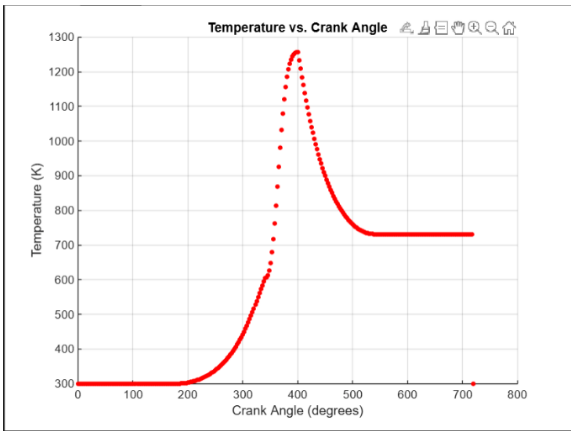


Fig 5ii) Variation of pressure with crank angle

b) For Combustion Initiation at 20degrees before TDC.



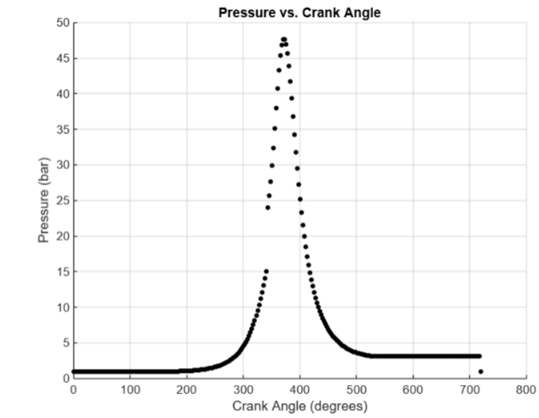
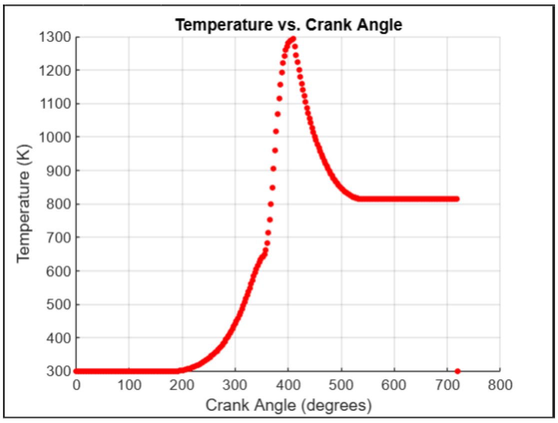


Fig 6i) Variation of temperature with crank angle

Fig 6ii) Variation of pressure with crank angle

c) For Combustion Initiation at 10degrees before TDC.



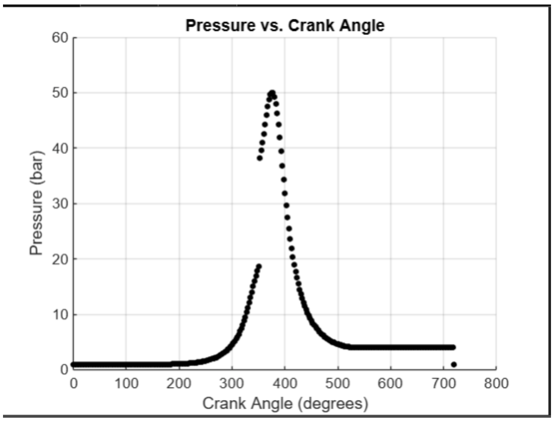
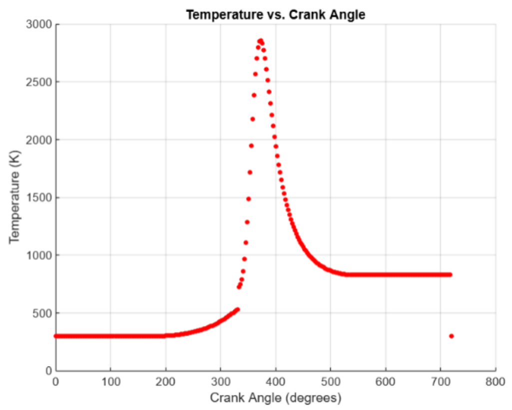


Fig 7i) Variation of temperature with crank angle

Fig 7ii) Variation of pressure with crank angle

2. Laser Ignition System

a) For Combustion Initiation at 30degrees before TDC.



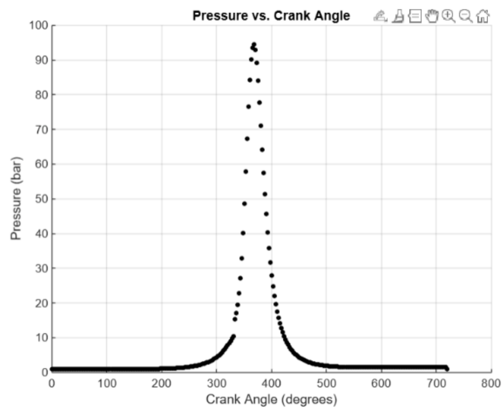
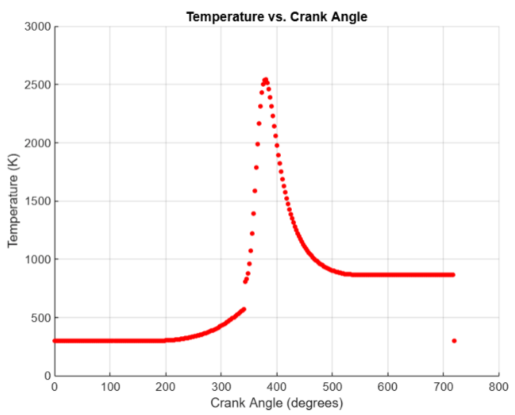


Fig 8i) Variation of temperature with crank angle

Fig 8ii) Variation of pressure with crank angle

b) For Combustion Initiation at 20degrees before TDC.



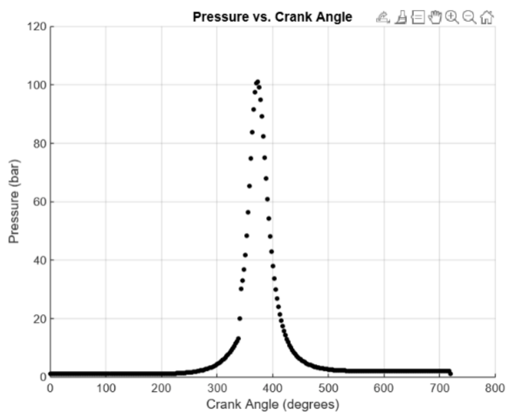


Fig 9i) Variation of temperature with crank angle

Fig 9ii) Variation of pressure with crank angle

c) For Combustion Initiation at 10degrees before TDC.

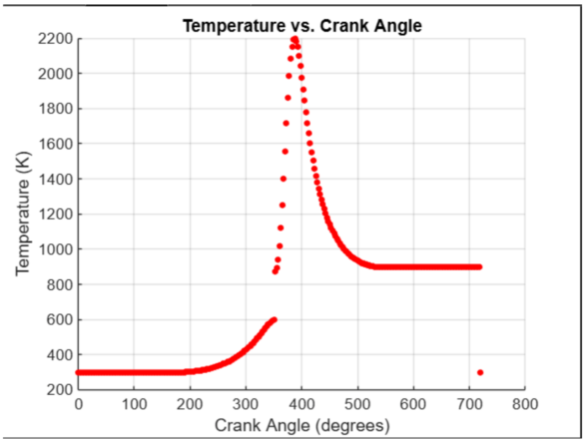


Fig 10i) Variation of temperature with crank angle

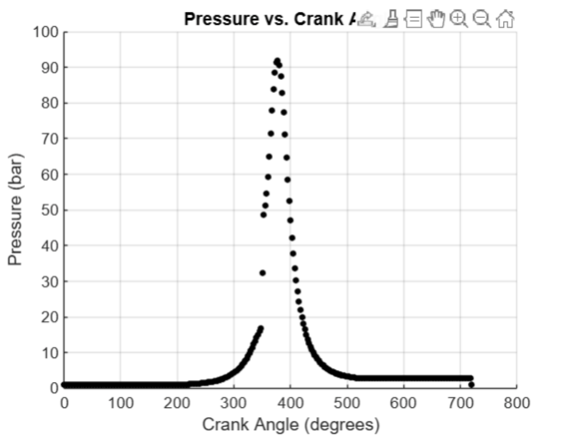


Fig 10ii) Variation of pressure with crank angle

Comparative study of various engine parameters with varying combustion angles

Combustion Angle	Conventional			Laser		
	Pmax (bar)	Tmax (K)	Texhaust (K)	Pmax (bar)	Tmax (K)	Texhaust (K)
330	39.3	1227	654	95.2	2789	854
340	47.1	1265	732	100.1	2590	890
350	51	1304	815	92.9	2234	955

5. DISCUSSION :

The following conclusions are drawn based on the analysis of the P–θ and T–θ diagrams for the laser ignition system and the conventional spark ignition engine:

1. Peak Pressure and Temperature:

- The laser ignition system achieves higher maximum cylinder pressure and temperature compared to the conventional ignition engine.

- This is due to more precise and effective ignition, resulting in faster and more complete combustion.

2. Rate of Pressure and Temperature Rise:

- The rate of increase of pressure and temperature after ignition is steeper in the laser ignition engine.

- This indicates a faster combustion process and a more rapid release of thermal energy.

3. Mean Effective Pressure (MEP):

- The MEP is higher for the laser ignition system than for the conventional system.

- This suggests better energy conversion efficiency and higher work output per cycle.

4. Exhaust Temperature:

- The laser ignition engine shows a higher exhaust temperature compared to the conventional engine.

- Although this seems counterintuitive, it is likely due to the higher in-cylinder temperatures and the possibility of combustion extending later into the expansion stroke, leaving more residual heat in the exhaust gases.

5. Effect of Ignition Timing on Peak Pressure and Temperature:

- In the conventional ignition engine, as the combustion initiation angle moves closer to 360° (TDC), both Pmax and Tmax increase steadily.

- In the laser ignition engine, Pmax and Tmax initially increase but then start to decrease when combustion initiation is very close to TDC, suggesting a narrower optimal ignition window for laser ignition.

6. Effect of Ignition Timing on Exhaust Temperature:

- For both ignition systems, exhaust temperature increases as the ignition timing advances towards TDC.

- This is consistent with more complete combustion and higher in-cylinder temperatures, although it may also indicate that less heat is converted into mechanical work when combustion occurs too early.

6. CONCLUSION :

We made a solidworks model of a 4 stroke engine and had performed a motion study which helped us in being more clear about when the air fuel mixture (in case of SI Engine) and Air (in case of CI Engine) enters the combustion chamber, what process maybe the mixture inside be going through in each interval of crankangle rotation. We simulated the pressure and temperature changes using a Simulink model, and Matlab was used for plotting the graphs.

In conclusion, the laser ignition system demonstrates superior combustion characteristics compared to the conventional spark ignition engine, as evidenced by higher peak pressure and temperature, faster combustion rates, and greater mean effective pressure. These advantages result from more precise ignition control and improved flame propagation. However, the system also exhibits higher exhaust temperatures, which, although counterintuitive, can be attributed to extended combustion duration and higher in-cylinder heat retention. Additionally, while advancing ignition timing benefits both systems, the laser ignition engine shows a narrower optimal timing range, with peak performance occurring within a limited crank angle window. Overall, laser ignition enhances engine performance but requires careful optimization of ignition timing and thermal management.

7. SCOPE OF IMPROVEMENT :

There are several improvements and additions we could have made to our project:

1. We could have included the calculation of **Indicated Mean Effective Pressure (IMEP), Thermal Efficiency and Volumetric Efficiency** for the better understanding of the engine's performance.
2. **Heat losses to the coolant** were not considered in our model, which could have made our simulation more realistic.
3. For laser ignition, we assumed a **linear heat release**, but using an **exponential or more accurate heat release function** would have brought the model closer to real-world behavior.
4. We could have completed the **motion study of the 4-stroke, 4-cylinder engine** and added more components to improve the visual understanding of engine operation.
5. Running simulations for **engines of different sizes** could have helped us see which ignition system performs better under various conditions.
6. We assumed many parameters—like **ignition duration (Δθ)** and **Wiebe function constants (a and m)**—to be the same for both engines, which may not reflect actual differences.
7. Our model did not include the **actual intake and exhaust processes**, such as how the air or air-fuel mixture enters during the suction stroke and how exhaust gases exit during the exhaust stroke.
8. We have assumed air to be an ideal gas and also used ideal gas equations which had led to deviations in the result.

FAILED ATTEMPTS :

The idea to simulate the engine using Simulink was initially inspired by a research paper titled *Comparative Study.pdf*. Our first approach was to replicate the model presented in the paper, with the intention of later modifying and improving it to make it more realistic. The original model consisted of three key components: the intake manifold model, the combustion model, and the friction model—each designed to represent the respective physical processes of air intake, combustion dynamics, and frictional losses within the engine. While we were nearly successful in replicating the intake manifold model, we encountered significant challenges in implementing the combustion model due to the complexity and interdependence of its parameters. The flow of the model was difficult to interpret, which prevented us from making further progress. As a result, we decided to build our own Simulink model based on classroom concepts and insights gathered from various research papers.

We also planned to make a video to explain how laser ignition works, but we couldn't complete it. We faced issues getting the piston movement to work properly in our SolidWorks animation, and we ran out of time before we could finish the video.

8. REFERENCES

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