24TTC008 – BEng Project
(CW1 - Project Preparation Report)

Analysis and Modelling of a Single-Cylinder Hydrogen Internal Combustion Engine Using Realis WAVE

(25/12/2024)

By

Sami Khan
(F126225)

A report submitted in part fulfilment of the degree of

Eng (Hons) in Automotive Engineering

Supervisor: Kambiz Ebrahimi

Abstract

The following project discusses the analysis of a single cylinder hydrogen internal combustion engine in Realis WAVE and then the recreation of this model within Simulink. The aim of this project is to produce comparable output profiles and assess the feasibility of Simulink for H2ICE simulation. By validating the model across both platforms, this project seeks to establish a robust simulation approach for hydrogen-fuelled engines, contributing to the development of sustainable combustion technologies. The initial phase, referred to as the foundational stage, is the focus of this report and looks to establish Realis WAVE as a viable blueprint for subsequent Simulink modelling which is further detailed in the final report.

This study utilised the Wiebe function to simulate the combustion process and the Woschni's correlation for heat transfer dynamics. Key outputs from this model which are replicated in Simulink include the Pressure, Temperature and Heat Transfer Rate throughout the engine cycle. This comparative analysis will provide insights into the strengths and limitations of Simulink for hydrogen combustion modelling, highlighting any necessary adjustments or assumptions when translating models between platforms

1. Introduction

1.1 Background on Hydrogen ICEs

Belgian engineer Étienne Lenoir developed the first usable internal combustion engine in the 1860s, using coal gas as a fuel. This invention, although soon eclipsed by the Otto cycle, marked a significant advancement in engine technology. Interestingly, the concept of a hydrogen-powered engine dates to 1804, with Franco-Swiss inventor Isaac de Rivaz's 'de Rivaz engine', considered the world's first internal combustion powered automobile. This engine layout wouldn't make an appearance for a long time after presumably due to lack of infrastructure or the technological limitations.

Hydrogen technology resurfaced during WWII when the GAZ-AA trucks were converted to run on hydrogen under the siege of Leningrad by Boris Shelishch. The 200 GAZ-AA trucks that Schelishch and his colleagues transformed in ten days burned cleaner and longer than the gasoline-powered trucks [1]. Today, hydrogen is being explored by major automotive manufacturers like BMW and Triton EV, demonstrating its potential as a sustainable, low-emission fuel that leverages existing combustion technologies during a crucial transitional phase in the automotive industry.

Hydrogen as an alternative fuel offers significant advantages in the push towards sustainability as the automotive industry navigates through what is often referred to as the "Messy Middle" [2] phase – a transitional period characterised by a mix of traditional combustion engines, Hybrid technologies and net zero emission solutions. The most notable of these advantages is the production of pure water vapor as a byproduct of combustion resulting in a drastic reduction in greenhouse gas emissions compared to generic fossil fuels.

1.2 Objective and Scope of the Report

This project aims to model and analyse a single cylinder hydrogen internal combustion engine (H2ICE) using Simulink, based on a validated model created in Realis WAVE. The focus is to verify the model's accuracy in simulating engine pressure, temperature, and heat transfer rates, achieving a simulated peak deviation of less than 3% for each of these parameters.

The report will cover the analysis of the model in Realis WAVE whilst also highlighting the engine specifications and equations extracted from the model that will eventually be utilized for the Simulink model. Additionally, it will explore the application of the Wiebe function for combustion and the Woschni's correlation for heat transfer. [3, 4]

2. Literature Review

This literature review explores the broader context of hydrogen combustion within internal combustion engines, focusing on its potential as a sustainable alternative fuel. Recognizing hydrogen's clean combustion characteristics—producing only water vapor under stoichiometric conditions—the review evaluates both the potential benefits and the technical challenges posed by its unique properties such as low ignition energy and rapid flame speed [5]

This analysis evaluates hydrogen combustion in engines using the Wiebe function and Woschni's correlation, implemented in Realis WAVE and similar software. It highlights gaps in existing simulation methods and proposes improvements to enhance accuracy and realism. These insights are fundamental to developing robust hydrogen engine simulation approaches.

2.1 Hydrogen as a Fuel for Internal Combustion Engines

Hydrogen's potential to drastically reduce greenhouse gas emissions makes it an increasingly recognized alternative fuel for internal combustion engines. Unlike conventional fuels such as petrol or diesel, hydrogen combustion produces no carbon dioxide, aiding in the shift toward carbon-neutral transportation [6]. However, hydrogen's high flame speed presents unique challenges, such as increased risk of pre-ignition and knocking, especially under high pressure [7]. Its wide flammability range allows it to burn from extremely lean to near-stoichiometric mixtures, enhancing operational flexibility but also complicating management in high-performance uses

Moreover, hydrogen's high gravimetric energy density is advantageous for applications requiring lightweight solutions like heavy-duty vehicles but necessitates advanced storage systems due to its low volumetric energy density [8]. Its lean combustion capability can lower NOx emissions and thermal losses if air-fuel ratios are precisely managed [9]. Despite challenges, H2ICEs offer significant potential to leverage existing technology while advancing towards zero-emission vehicles.

Since hydrogen can induce fatigue and embrittlement in metals that are often used in engine components, material compatibility becomes even more important when constructing h-fuelled engines. This raises concerns regarding long-term reliability. Despite these challenges, H2ICEs present an opportunity to satisfy sustainability goals while utilising a significant amount of the existing internal combustion infrastructure. By serving as a workable and transitional technology, this approach closes the gap between traditional fossil fuel engines and future zero-emission alternatives like fuel cells or fully electric powertrains.

2.2 Simulation Modelling of Internal Combustion Engines

In the field of hydrogen-fuelled engine research, 1D simulation tools such as Realis WAVE and GT Power are invaluable for examining the complex combustion dynamics and optimizing engine performance. These tools are particularly adept at addressing the unique challenges posed by hydrogen, such as rapid flame speed and high energy release, critical factors for developing efficient H2ICEs.

The Wiebe function, which is widely recognised for its capacity to strike a compromise between computational efficiency and model accuracy, is used by most simulation software. This feature aids in adjusting parameters to control common problems with hydrogen engines, like knocking and pre-ignition [10]. For example, knocking during the power stroke frequently results in abrupt increases in pressure at Top Dead Centre (TDC). To improve engine stability and performance, the models alter the combustion start time to slightly delay it. This ensures that the pressure rise starts after TDC.

These simulation tools also perform exceptionally well in thermal dynamics analysis, which is essential for controlling the high hydrogen burn rates. Models in Realis WAVE are usually operated from a "cold start," where the interaction between the cooler cylinder walls and the high-temperature combustion gases can significantly increase heat flow during the engine's expansion and combustion stages. This detailed thermal management helps prevent overheating and potential engine failure, thereby extending the durability of engine components [11].

1D simulations also provide accurate heat transfer rate predictions by incorporating sophisticated modelling techniques like Woschni's correlation. In situations when overheating could compromise component integrity and engine performance, this is crucial for forecasting and managing the thermal efficiency of hydrogen internal combustion engines.

The combined capabilities of these software's in providing comprehensive 1D simulations allow for a robust exploration of hydrogen's behaviour in ICEs. This not only enhances our understanding of hydrogen as a viable fuel alternative but also supports the practical application of hydrogen technology in next-generation automotive systems, paving the way for cleaner and more sustainable vehicle technologies.

2.3 Identified Gaps and Future Directions

The project's dependence on oversimplified combustion models, such the Wiebe function, is one of its primary limitations. Although this combustion modelling approach is computationally efficient, it ignores other phenomena such as local flame instabilities or turbulence effects. These specific factors are better mapped in a 3D computational fluid dynamic modelling software though may provide a high computational cost. The study also highlights how challenging it is to transfer parameters between the two modelling platforms.

Further research is vital for integrating H2ICEs into global decarbonization, including developing hydrogen hybrids that combine fuel cells and engines for optimal benefits. Enhancing material durability against high temperatures and hydrogen embrittlement, alongside real-world validation, is key to refining simulations and ensuring model reliability

By addressing these gaps and exploring the future directions, both this project and broader hydrogen ICE research can contribute significantly to advancing clean energy technologies

3. Engine Specifications and Model Setup

This section outlines the key specifications and setup of the single-cylinder H2ICE modelled in Realis WAVE. It details the engine geometry, operating conditions, and fuel properties, providing the foundational parameters for simulation and analysis.

3.1 Engine Geometry

The engine geometry is defined by several key parameters that impact the combustion process for the model. For the single cylinder hydrogen combustion engine modelled in Realis WAVE the following values have been used

Parameter Name	**Name in WAVE**	**Value**
Compression Ratio	CR	11.8
Exhaust Manifold Diameter	d_ex_manifold	55 mm
Exhaust Port Diameter	d_ex_port	39 mm
Intake Manifold Diameter	d_in_manifold	100 mm
Intake Port Diameter Left	d_in_port_l	61 mm
Intake Port Diameter Right	d_in_port_r	58 mm
Exhaust Valve Lash	EV_lash	0.45 mm
Intake Valve Lash	IV_lash	0.31 mm

Table 3.1: Engine Geometry Parameters in Realis WAVE

3.2 Realis WAVE Model

The engine specification data will be derived from the model that serves as the project's blueprint, which is shown in Figure 3.2.

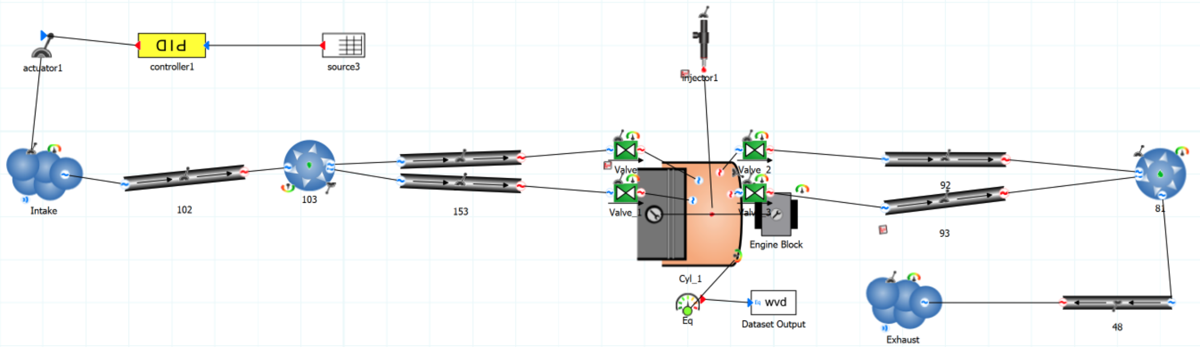

Figure 3.2: Realis WAVE Model

3.3 Operating Conditions

The model operated under specific preset thermodynamic and intake/exhaust conditions to simulate realistic performance. These again are listed below

Parameter Name	Name in WAVE	Value
Air-Fuel Ratio	AFR	64.09
Engine Speed	SPEED	1801.29 rpm
Intake Pressure	p_in	1.208 bar
Intake Temperature	t_in	304.4 K
Exhaust Pressure	p_out	1.122 bar
Exhaust Outlet Temperature	t_outlet	826.9 K
Coolant Temperature	Head_coolant	550 k
Target Airflow	Target_airflow	120.7

Table 3.3: Engine Operating Conditions in Realis WAVE

3.4 Fuel Properties

Hydrogen, as a fuel for internal combustion engines, presents unique characteristics that significantly impact combustion behaviour. Key properties relevant to hydrogen combustion are outlined below

- Stoichiometric Air-Fuel Ratio (AFR): One component of hydrogen by mass requires 34.3 parts of air to totally burn, which is the stoichiometric AFR for hydrogen. This model, however, uses a leaner mixture with an AFR of 64.09, which may result in a slower combustion rate but can also increase efficiency and cut nitrogen oxide (NOx) emissions [12]
- Lower Heat Value (LHV): Compared to other fuels like petrol (44 MJ/kg) or diesel (42 MJ/kg), hydrogen has a substantially greater energy density per unit mass (LHV) of about 120 MJ/kg. We can compute an exact figure of 114 MJ/kg using the model's mass of hydrogen and the combustion heat release. Its high LHV makes it an extremely efficient fuel for combustion applications. However, because of its low density, careful distribution and storage techniques are required to properly use this energy potential.
- Minimum Ignition Energy (MIE): With a minimum ignition energy of ~0.02 MJ, hydrogen is easily ignited, making it beneficial for starting combustion. At an AFR of 64.09, this is sufficient to ignite the lean hydrogen-air mixture due to hydrogen's wide flammability range [13]

- Specific Heat Ratio (γ): A ratio of 1.287 indicates higher heat retention and smoother pressure rise during combustion, reducing peak pressures slightly but improving thermal efficiency and flame propagation under lean conditions.

4. Combustion Model

A popular mathematical model for describing the combustion process in internal combustion engines is the Wiebe function. Because of its versatility in recreating the quick burn characteristics of hydrogen, it is especially valuable to modelling hydrogen combustion. The mass fraction burned (MFB) and rate of heat release (ROHR) during combustion are roughly represented by the Wiebe function. The Wiebe function is helpful for accurately portraying hydrogen's distinct combustion dynamics in an internal combustion engine model since it can simulate various combustion profiles by varying parameters like the burn length, shape, and efficiency factors.

The importance of the Wiebe function in hydrogen ICE modelling lies in its ability to adapt to high flame speeds and lean burn conditions typical of hydrogen combustion [14]. This function allows for precise calibration to capture hydrogen's fast combustion initiation and rapid heat release, which are crucial for optimizing efficiency and reducing emissions in hydrogen-fuelled engines.

4.1 Wiebe Function Formula

The primary equation used in the Wiebe function for modelling mass fraction burned (MFB) is:

$$x_\theta = 1 - \exp\left(-a\left(\frac{\theta - \theta_{soc}}{\Delta\theta_{dur}}\right)^{m+1}\right) \tag{1}$$

Where: x_θ the Mass Fraction Burned, representing the portion of the fuel that has burned at any crank angle; a is the efficiency factor; θ is the current crank angle (rads); θ_{soc}: is the start of combustion crank angle (rads); $\Delta\theta_{dur}$: is the combustion duration (rads); m is the shape factor.

4.2 Parameter Calibration

Calibration of the Wiebe function parameters is essential for accurately modelling hydrogen combustion in Realis WAVE. Key parameters include:

- b50: This is the crank angle position at which 50% of the fuel mass has been burned. In hydrogen combustion modelling, b50 is set to an optimal angle to maximize efficiency and control the rapid combustion associated with hydrogen. For this model, b50 is calibrated to 13.162 degrees.

- b10to90: This parameter represents the duration over which the main combustion phase (from 10% to 90% mass burned) occurs. For hydrogen, a shorter b10to90 is desirable to capture the quick energy release. In this model, b10to90 is set to 12.31 degrees to simulate the rapid hydrogen combustion.

- Shape Factor (m): The shape factor ‘m’ controls the profile or steepness of the combustion curve. A higher ‘m’ results in a steeper, more rapid combustion, which is suitable for hydrogen’s high flame speed [15]. For this simulation, ‘m’ is set based on the desired combustion sharpness specific to hydrogen but may need further adjustment in Simulink for optimal calibration.

- Efficiency Factor (a): This factor scales the overall completeness of combustion, affecting the final fraction of fuel burned by the end of combustion. A typical value of 'a' for hydrogen combustion is slightly higher than conventional fuels to ensure near-complete combustion, which is crucial for minimizing unburned hydrogen emissions. In this model, the efficiency factor 'a' is calibrated to align with the lean burn conditions used in hydrogen ICE.

Parameter Name	Name in WAVE	Value
50% Burn Rate	b50	13.162°
10%-90% Burn Duration	b10to90	12.310°

Table 4.2: Engine Burn Rate in Realis WAVE

5. Thermodynamic Modelling

This section delves into the thermodynamic modelling of the hydrogen internal combustion engine, focusing on cylinder volume, pressure, and temperature calculations. It provides the equations and assumptions underlying the simulation, ensuring accurate representation of engine behaviour.

5.1 Cylinder Volume Calculation

The instantaneous cylinder volume at any crank angle, θ, is a function of the engine's bore, stroke, and connecting rod length. The formula for calculating this volume is:

$$V_\theta = V_c + \frac{\pi B^2}{4}\left(L + \frac{S}{2} - \left(\frac{S}{2}\cos\theta + \sqrt{L^2 - \left(\frac{S}{2}\sin\theta\right)^2}\right)\right) \tag{2}$$

Where: V_θ is the instantaneous cylinder volume at crank angle θ (m³); V_C is the clearance volume, which is the minimum volume at TDC (m³); B is the bore diameter of the cylinder (m); S is the stroke length of the piston (m); L is the connecting rod length (m); θ is the crank angle from TDC (rads).

This equation accounts for the changing position of the piston within the cylinder as the crankshaft rotates, providing an accurate volume calculation at each crank angle

5.2 Pressure Calculations

Pressure in the cylinder is calculated using the First Law of Thermodynamics, which states that the change in internal energy of a closed system is equal to the heat added to the system minus the work done by the system. For an internal combustion engine, this can be expressed as:

$$\frac{dP}{d\theta} = \frac{\gamma - 1}{V_\theta}\left(\frac{dQ}{d\theta} - P\frac{dV}{d\theta}\right) \tag{3}$$

Where: P is the instantaneous cylinder pressure (Pa); γ is the specific heat ratio (typically around 1.4 for air-fuel mixtures); V_θ is the instantaneous cylinder volume (m³); Q is the heat release, derived from the Wiebe function (J).

This equation allows for calculating pressure at each crank angle by considering the heat released from combustion and the volume changes as the piston moves.

5.3 Temperature Calculation Using the Ideal Gas Law

Temperature within the cylinder is calculated from the pressure and volume using the Ideal Gas Law:

$$\mathrm{T} = \frac{\mathrm{P} \cdot \mathrm{V}}{\mathrm{R} \cdot \mathrm{m}} \tag{4}$$

Where: T is the temperature within the cylinder (K); P is the instantaneous cylinder pressure (Pa); V is the instantaneous cylinder volume (m^3); R is the specific gas constant for the air-fuel mixture ($J \cdot mol^{-1} \cdot K^{-1}$); m is the mass of the gas in the cylinder (mol).

6. Heat Transfer Model

Since heat transfer directly affects engine performance, thermal efficiency, and emissions, it is essential to combustion modelling. A large portion of the heat produced in the cylinder during combustion is lost to the cylinder walls, which reduces the engine's overall efficiency. Heat transfer is especially crucial in H2ICEs because of the high combustion temperature of hydrogen, which can result in more thermal stress on engine parts.

6.1 Woschni's Heat Transfer Correlation

The heat transfer rate, $\dot{Q}$, between the combustion gases and the cylinder walls can be calculated using Woschni's equation

$$\dot{\mathrm{Q}} = \mathrm{h} \cdot \mathrm{A} \cdot \left(\mathrm{T_g} - \mathrm{T_w}\right) \tag{5}$$

Where: h is the heat transfer coefficient ($W \cdot m^{-2} \cdot K^{-1}$); A is the surface area of the combustion chamber (m^2); $\mathrm{T_g}$ is the instantaneous gas temperature inside the cylinder (K); $\mathrm{T_w}$ is the wall temperature of the combustion chamber (K).

Woschni's formula for the heat transfer coefficient, h, is given by:

$$\mathrm{h} = \mathrm{C_1} \cdot \mathrm{p}^{0.8} \cdot \mathrm{T_g}^{-0.4} \cdot \mathrm{w}^{0.8} \tag{6}$$

Where: $\mathrm{C_1}$ is an empirical constant, typically around 3.26 for most combustion applications; p is the cylinder pressure (Pa); $\mathrm{T_g}$ is the gas temperature (K); w is the mean gas velocity (m/s).

For hydrogen engines, which have higher combustion temperatures, Woschni's correlation is particularly useful in managing and estimating the increased heat transfer rates accurately [16].

6.2 Parameter Values for Heat Transfer

In Realis WAVE, specific values and parameters are used in Woschni's heat transfer model to ensure accurate heat transfer prediction. These include:

- Assumed Wall Temperature: This is found using the inner wall surface temperature which according to the model is set at 563.955K
- Empirical Constant: From a simple observation of our model we can see that it is naturally aspirated. This puts out empirical constant value in the range of 0.001-0.005
- Mean Gas Velocity: Simple calculations using the stroke length and the engine speed provide us with a mean gas velocity of 23.72m/s

7. Model Assumptions and Results

7.1 Combustion Assumptions

In this model, the following assumptions are made regarding the combustion process to simplify the simulation:

1. Complete Combustion: The model assumes complete combustion of the hydrogen-air mixture, meaning that all hydrogen fuel is fully converted into water vapor, without any unburned fuel or intermediate products
2. Uniform Burn Profile: Assuming a uniform distribution of combustion throughout the cylinder, the Wiebe function is used to approximate a smooth, predictable burn profile.

7.2 Thermodynamic Assumptions

For the thermodynamic calculations in this model, several key assumptions are made:

1. Constant Specific Heat Ratio (γ): The specific heat ratio, γ, is assumed to remain constant at approximately 1.4 for the hydrogen-air mixture
2. Simplified Gas Properties: Some thermodynamic properties, such as specific heats at constant pressure and volume, are assumed to be constant.
3. Ideal Gas Behaviour: The model assumes that the gas within the cylinder behaves as an ideal gas, following the ideal gas law. This assumption allows for straightforward calculations of pressure, temperature, and volume relationships

7.3 Heat Transfer Assumptions

The heat transfer model also relies on a few simplifying assumptions to make the simulation feasible:

1. Constant Wall Temperature – The model assumes a fixed cylinder wall temperature (563.955K) throughout the cycle to simplify calculations. This is consistent with Realis WAVE and will be mirrored in Simulink for steady-state analysis.
2. Simplified Surface Area Calculation – The surface area is approximated using consistent engine geometry (bore, stroke) rather than recalculating for piston motion
3. Single Heat Transfer Coefficient – A single heat transfer coefficient, based on Woschni's correlation, is used across the combustion chamber

7.4 Discussing Simulation Results

The simulation results, which illustrate pressure (Figures 7.5), temperature (Figures 7.6), and heat transfer rate (Figures 7.7) throughout the engine cycle, are shown. Important information about the hydrogen-fuelled engine's operation and thermodynamic behaviour is provided by these visualisations.

With an emphasis on pressure, temperature, and heat transfer during the engine cycle, the analysis contrasts data on hydrogen combustion in internal combustion engines that were anticipated with those that were observed. Because of its fast flame speed, hydrogen burns with higher peak pressures and faster than hydrocarbon fuels. Exact details are highlighted below for each graph.

Pressure (Figure 7.5): Data shows a spike to 40 bar at Top Dead Centre and a rise to 60 bar shortly after, consistent with hydrogen combustion predictions

Temperature (Figure 7.6): During combustion, temperature peaks at around 2300 K due to the high adiabatic flame temperature, aligning well with theoretical expectations.

Heat Transfer Rate (Figure 7.7): The graph highlights a peak coinciding with maximum gas-wall temperature difference, and a slight increase later in the cycle, matching common observations.

These results emphasize the distinctive thermodynamic characteristics of hydrogen combustion, offering critical data to enhance simulation accuracy."

7.5 Pressure vs. Crank Angle

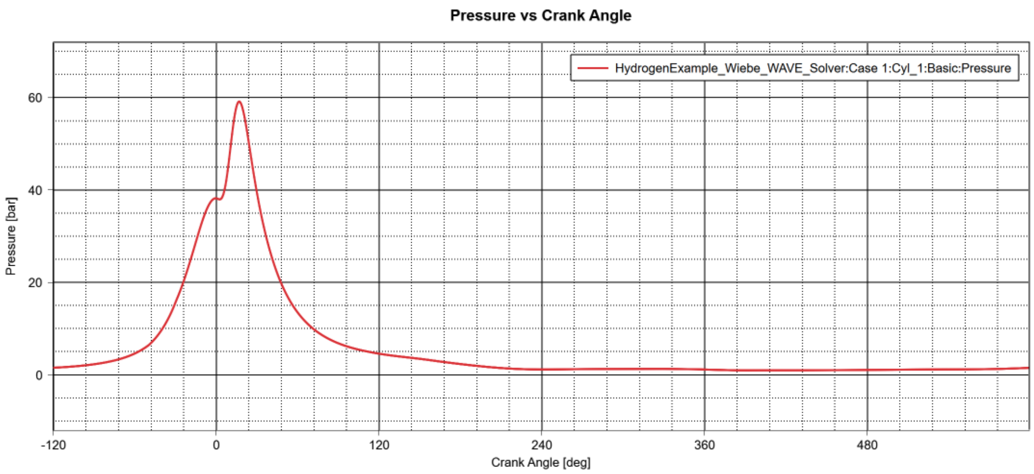

Figure 7.5: Pressure vs Crank Angle Graph

7.6 Temperature vs. Crank Angle

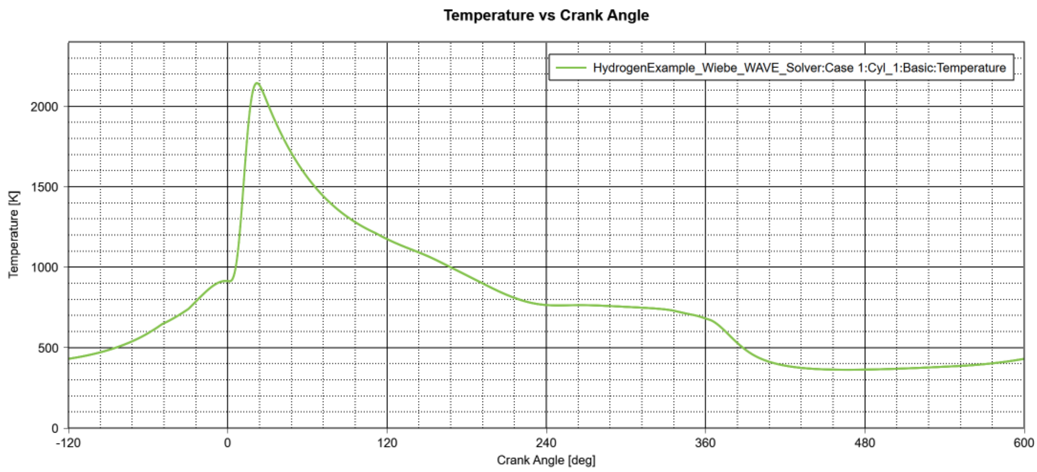

Figure 7.6: Temperature vs Crank Angle Graph

7.7 Heat Transfer Rate vs. Crank Angle

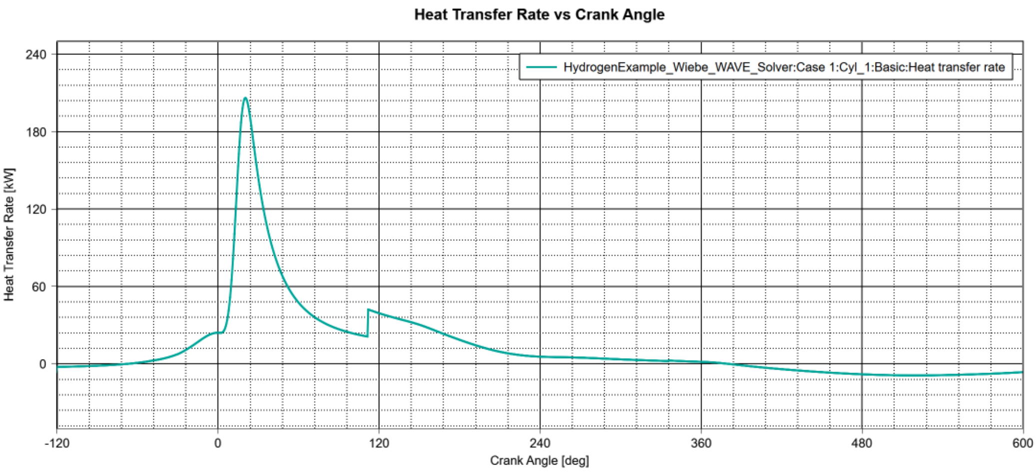

Figure 7.7: Heat Transfer Rate vs Crank Angle Graph

8. Conclusion

8.1 Key Outcomes

The analysis presented in this report convincingly demonstrates that Realis WAVE is a viable software platform for basing our Simulink model. This result signifies the successful completion of the project's initial phase, which involved confirming that Realis WAVE was a suitable model for our simulation. We are now in a good position to go on to the next phase, which is the creation and validation of the Simulink model, having completed this foundational phase. To achieve our objective of developing reliable simulation techniques for hydrogen-fuelled internal combustion engines, this next stage will concentrate on evaluating Simulink's ability to accurately mimic hydrogen combustion processes.

8.2 Project Timeline and Gantt Chart

The plan for my project is listed in the below Gantt Chart. I have listed all the relevant deliverables along with the expected time frames for their completion for both semester 1 and semester 2 (over time this plan may evolve as my findings grow):

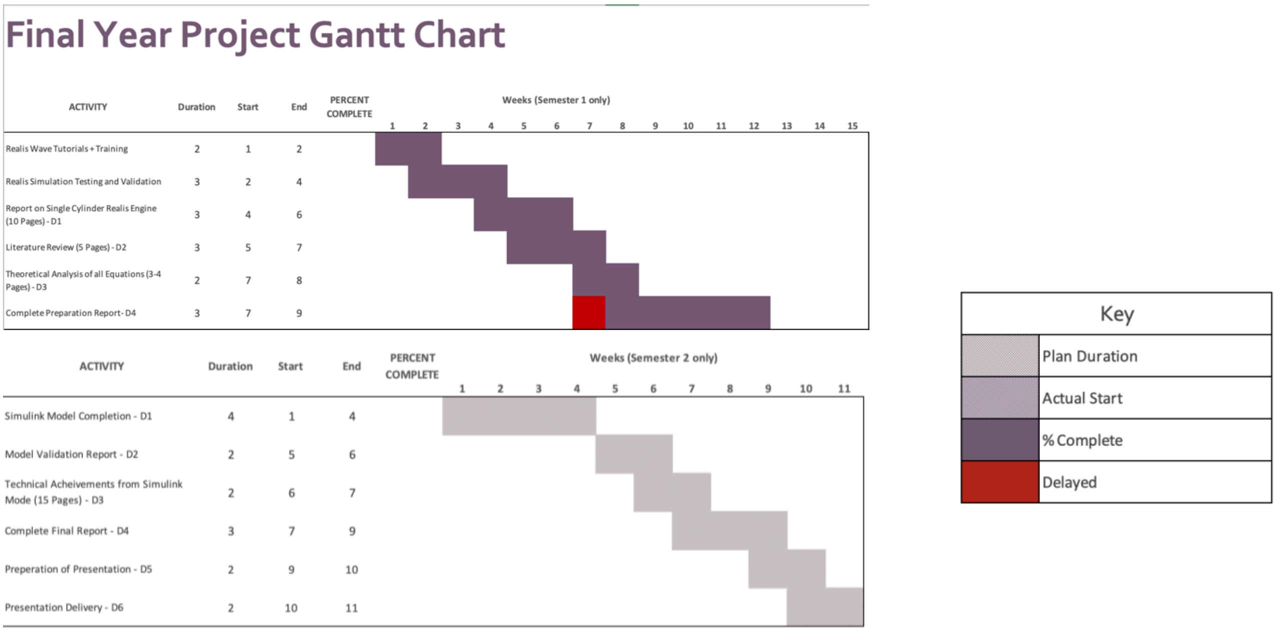

Figure 8.2: Final Year Project Gantt Chart

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Ethics Awareness Form for Taught Student Projects

All students should discuss with their supervisor whether their project might conflict with the University's ethical principles which can be found in the Ethical Policy Framework.

Students should complete the second column in the table below, discussing with their supervisor as appropriate.

Aspect of project	**Does the project involve this aspect? (Yes / No)**	**If Yes, follow the process(es) below**
Investigations with human participants and activity falling under the Human Tissue Act	**No**	1. Complete the Ethical Quick Test 2. Follow the process outlined on the HPSC Website
Military Applications, Dual Use Technologies or Security Sensitive Research	**No**	1. Complete the Ethical Quick Test 2. Follow the process outlined in Appendix 4
Accessing potentially security-sensitive material (e.g. online terrorist content or materials)	**No**	1. Complete the Ethical Quick Test 2. Follow the process outlined in Appendix 5
Funding by philanthropic gifts	**No**	Follow the process outlined in Appendix 6
Animal testing	**No**	Contact the Research Governance Officer: researchpolicy@lboro.ac.uk
Possible conflict with ethical principles partially or wholly outside the above.	**No**	1. Complete the Ethical Quick Test

Student Declaration

I confirm that I have discussed the ethics awareness form with my supervisor and, if appropriate, followed the relevant guidance / made the relevant application.
Student name: Sami Khan
Student ID number: F126225
Signature:
Date: 03/01/2025

Supervisor Declaration
I confirm that I have discussed the ethics awareness form with my supervisee and, if appropriate, requested that they follow the relevant guidance / make the relevant application.
Supervisor name: Kambiz Ebrahimi
Signature:
Date: 06/01/2025

Meeting Log

Meeting minutes serve as a record of the meetings for this project. These are documented in a OneNote Notebook and distributed via email following each meeting. An example of one of these meeting minutes is shown below, complete with all the dates.

My Notebook

+ Add section

Meeting Log

+ Add page

MM5 15/11/2024
MM6 19/11/2024
MM7 29/11/2024
MM8 09/12/2024
MM9 20/12/2024
MM10 06/01/2025
MM11 07/02/2025
MM12 21/02/2025
MM13 28/02/2025
MM14 14/03/2025
MM15 21/03/2025
MM16 (28/03/2025)
MM17 (06/04/2025)
MM18 (11/04/2025)
MM19 (19/04/2025)

MM20 (28/04/2025)

30 April 2025 10:34

MEETING MINUTES

- Final Report discussion
- Changes Requested
- Figures Reviewed

KEY ACTIONS

SAMI

- Add additional output (Torque-Power Curve?)
- Make final alteration to Figure 6.2
- Complete and submit Report

KAMBIZ

- No actions required

Student Declaration

I confirm that I have had these meetings with my supervisor and can verify that they took place as scheduled.
Student name: Sami Khan
Student ID number: F126225
Signature:
Date: 03/01/2025

Supervisor Declaration

I confirm that I have had these meetings with my supervisee and can verify that they took place as scheduled.
Supervisor name: Kambiz Ebrahimi
Signature:
Date: 06/01/2025