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Study Diesel-RK Applications in the Computation and Analysis of Technological and Socioeconomic Characteristics of Diesel Engines Using Heavy Fuels in Order to test with Different Piston Bowl Designs

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Abstract

The influence of different piston bowls on the Diesel-RK will be demonstrated in this test as the engine is the heart of vehicles for existence like human heart needed for survival. The piston bowl shows a significant influence on the load stratification in the transition area. The compression ratio shows a trade-off of NOx reduction with unburned hydrocarbons and carbon monoxide emissions. In today's society, people have attempted to employ more simple methods to verify the validity of every research and action. It is here that technical challenges in engine dynamics and combustion are analyzed and solved. Some software resources can help with this. Considering that Diesel-RK software is more appropriate for this design. Diesel-RK is regarded as excellent open-source research software since it is free and capable of accurately simulating the combustion and thermodynamics of diesel engines. Following that, this study aims to present the results of the diesel RK software functions by focusing on a single marine engine that can run on heavy fuels. Characteristically, this heavy fuel oils have a large proportion of heavy molecules, such as long-chain hydrocarbons and aromatics with long branched side chains may the reasons for selection in this paper. Its properties like density, Kinematic viscosity, Flash point, pour point, Sulphur and water content are considered for this study. The process can be carried out with diesel-RK's shallow Hesselman, pan, and Mexican hat piston bowls. Finally, the data is used to assess the pressure, temperature, HRR, NOx, and Soot levels in the various combustion chambers.

Keywords: Mexican Hat, Piston bowl, Pan, Shallow Hesselman, Soot

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INTRODUCTION

The RK test is a simple test that can be used to determine whether diesel fuel can be used without risk in a given application. The RK test, or the Reid-Kettenring test, is known as once the researchers who discovered it. The RK test is performed by adding a small amount of anhydrous ammonia to diesel fuel. The mixture is then introduced into a diesel engine.

For several years, diesel engines have been used in race cars to provide more power and better fuel economy. One of the downsides of using diesel power in racing is that the engines are limited to the type of fuel that can be used. Some racing series, like the NASCAR, have very strict rules about the type of fuel that can be used. Because of this, ethanol has become a popular alternative to traditional gasoline in modern diesel engines [12].

When compared to any other mechanical equipment, the processes of a diesel engine are extremely complex. In-cylinder fluid dynamics affect the performance of Direct Ignition diesel engines because they help with fuel-air mixing and fuel burn rate regulation. The geometry of the combustion chamber is one of the most essential systems in diesel engines, and it must be thoroughly examined in order to produce stable combustion. Even for minor improvements, developing a full-scale engine block is an expensive and time-consuming process. Furthermore, due to the intricate combustion processes of engines, researchers must simulate the complete system prior to casting the engine block [1, 2, 3].

The amount of fuel injected into each cycle is varied to accomplish load; the air flow at a particular engine speed remains practically unchanged. CI engines are utilized in a wide range of applications, including automobiles, trucks, locomotives, ships, and power generation. The most difficult task for current 4-Stroke high-speed Diesel engines is limiting pollutant emissions without sacrificing performance, overall dimensions, or production costs, which are already higher than for comparable Spark Ignition (SI) engines. The 2-Stroke cycle paired with Compression Ignition is an intriguing notion for meeting the above-mentioned conflicting needs. This concept is extensively used in big bore engines, on stationary or naval power plants, where the benefits of the 4-Stroke cycle in terms of power density and fuel conversion efficiency (in some cases greater than 50%) are required [13].

When changing the above engine design parameters, evaluating and analyzing technical specifications and economics of engines, some other software commonly used in calculating the working cycle for diesel engines has not investigated the effect of combustion dynamics and formation of diesel engine emissions.

However, the software mentioned above does not allow for in-depth analysis of the effects of specific engine design features such as combustion chamber geometry, spray beam direction, and other characteristics on combustion process quality.

Landscapes of Diesel RK Package [1]

Diesel-principal RK's characteristics are comparable to those of other thermodynamic software. However, it has new advanced applications that other programs do not have. But here you may add values such as oriented optimization of the combustion process in diesel engines and internal combustion engine (ICE) analysis and optimization, which allows for a significant increase in functioning velocity and allows for the optimization of convoluted diesel engine tasks by assuming that all cylinders in the engine work in the same way.

The thermodynamic cycle of substantially full engines is simulated using the DIESEL-RK software. The software is intended to model and optimize the operation of combustion engines, including 2-stroke and 4-stroke turbocharged engines.

This bundle can simulate the models of the engines listed below.

- Spart Ignition which is gasoline engine;
- Spark Ignition which is gas engines include a pre-combustion chamber system, and engines can use various gases:
- methane, propane-butane, biogas, and synthetic gas;
- Alterable or non-alterable two-stroke engines, reciprocating piston engines (OP motors or Junkers), and OPOC engines;
- Binary fuel (the engine has an independent fuel injection system for different fuels) (Engine with RCCI).

The "Fuel Spray Visualization" code is included in DIESEL-RK. This code allows simulation results to be displayed as animations, allowing for the modeling of the interaction between fuel sprays and the combustion chamber wall, as well as the degree of swirls and the neighboring spray region. The code assists in determining the ideal shape for the piston crown, as well as the diameter and number of nozzle holes, spray direction and angle, and swirl intensity level. The simulation results can be saved as a Windows multimedia format, an AVI file, or a GIF animation file. The photos collected could be 2D or 3D [14].

Engine input data and software operating parameters are required.

1. Cylinder count with engine type (in-line, V-type, boxer, etc.).
2. Bore plus stroke measurements
3. Ratio of compression which exists* (typically between 13 to 17)
4. Maximum Speed in RPM.
5. The cooling system (liquid, air)
6. Engine application domain
7. Lifting system (for simplicity, single-step turbocharging with cooling and no exhaust gas recirculation (EGR) is usually recommended).
8. Valve count per cylinder
9. Injection pressure (this is required for the assessment of engine robustness; combustion chamber configuration and injector nozzle geometry all depend on the level of injection pressure).

It is suggested that the aforementioned settings be chosen based on the engine's current specifications. If the above-mentioned engine specifications are accessible, the researcher might choose the engine specification on his or her own.

Basic Applications of Diesel-RK software

To fix difficulties with diesel engines, software can be used [7]:

- Predicting torque graphs and engine performance, as well as predicting and optimizing fuel consumption.
- Combustion and emission process analysis and optimization.
- Prediction of a knockout;
- Valve functioning time should be optimized.
- EGR system analysis and optimization.
- Revamping the use of turbocharged turbines and lowering emissions;
- Researching and upgrade the fuel spray properties of both multi-nozzle systems, including spray shape and spray position.
- Convert a diesel engine to a gasoline engine.
- An examination of dual-fuel engines.

PISTON BOWL DESIGN CHARACTERISTICS

The design of the piston bowl plays a vital role in the mixing of the air-fuel mixture in an engine. The mixing of fuel and air must be adequate to offset the impact of fuel rich regions and allow the engine to reach its performance and emissions requirements, which is a crucial goal in the combustion bowl design. Turbulence in the airflow within the combustion bowl has been discovered to aid the mixing process and can be exploited to accomplish this purpose. Through suitable construction of the bowl in the piston crown, swirl caused by the intake port can be augmented or squish generated by the piston as it reaches the cylinder head to create greater turbulence during the compression stroke [4, 11, 15].

In this study, three piston shapes were chosen from a set in the Diesel RK piston bowl catalogue, and they were compared using various characteristics. The comparative analysis will provide insight into the effects of piston shapes on parameters and aid in the identification of crucial aspects in the design of piston bowl geometry.

Those selected shapes been explained as follow;

Shallow Hesselman

The combustion chamber of Hesselman shown in Figure 1 (shallow W) shape is claimed to enhance the in-cylinder turbulence by suppression of swirl and promotion of squish effect [5].

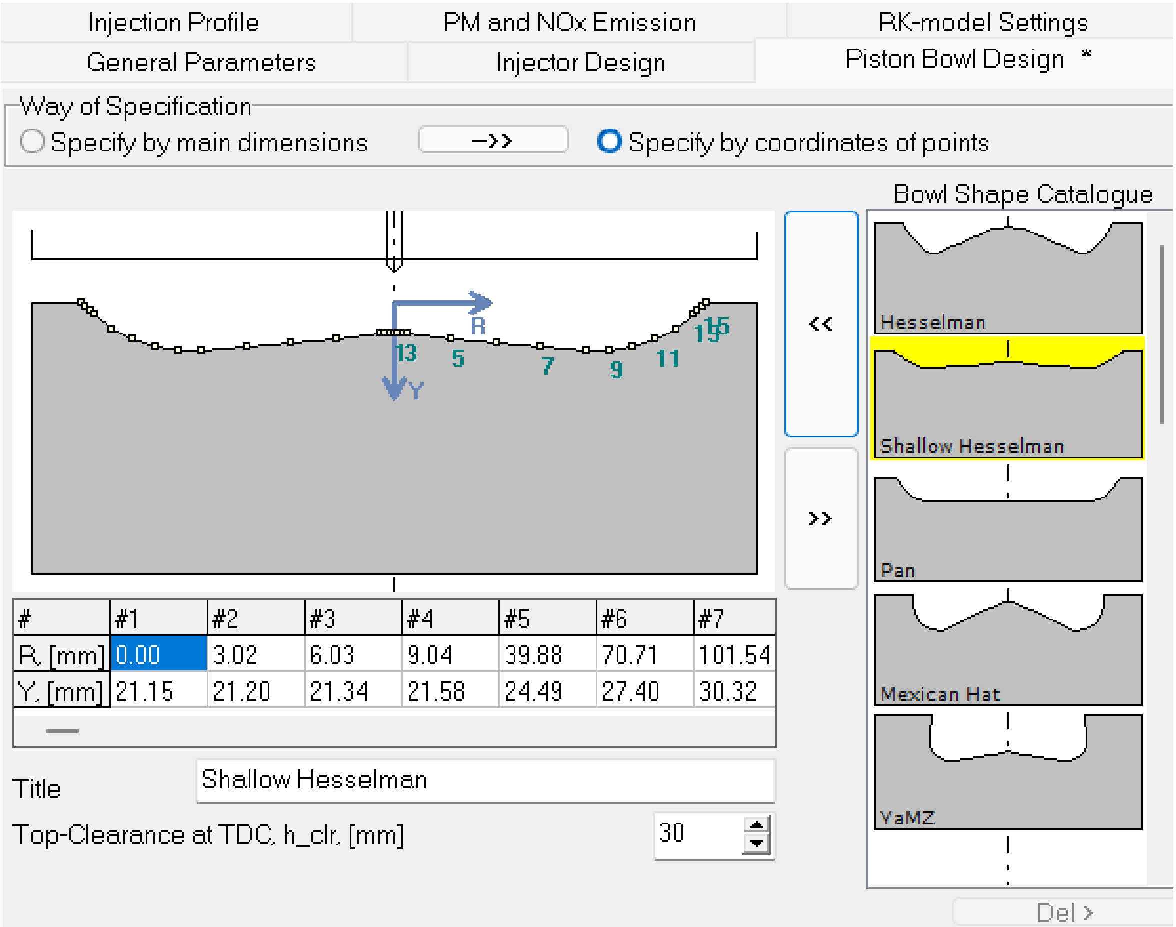

Figure 1. Shallow Hesselman piston bowl catalogue.

Pan

Pan named piston bowl shown in Figure 2 design also one of the designs which most probably used. But, like shallow Hesselman and Mexican hat it's not safe in compression for the formation of complete combustion. So that emission is greater in this type of piston bowl design.

Mexican hat

Here, because of its swirl-inducing nature, this type of piston bowl design is used in compression ignition engines. A more homogeneous air and fuel combination results from increased swirl in the combustion chamber. As a result, this piston bowl form was chosen for a homogeneous mixing [2]. Figure 3 shows Mexican Hat piston bowl catalogue.

Basic Properties of Heavy Fuels

HFO is made from a blend of residual (residual fuel) and cutter stock (distillate diluent, such as marine diesel oil or marine gas oil) combined to obtain a specified viscosity at a specific temperature (typically 50°C, which is an early indicator for storage) [9]. There is no standard for the mixture of residue and distillates used to make HFO. The physical and chemical qualities shown in Table 1 of the HFO will thus vary based on the feed oil's origin (crude oil), the quality or attributes of the feed oil, variations in the distillate added to achieve the desired viscosity, and the refining processes [10].

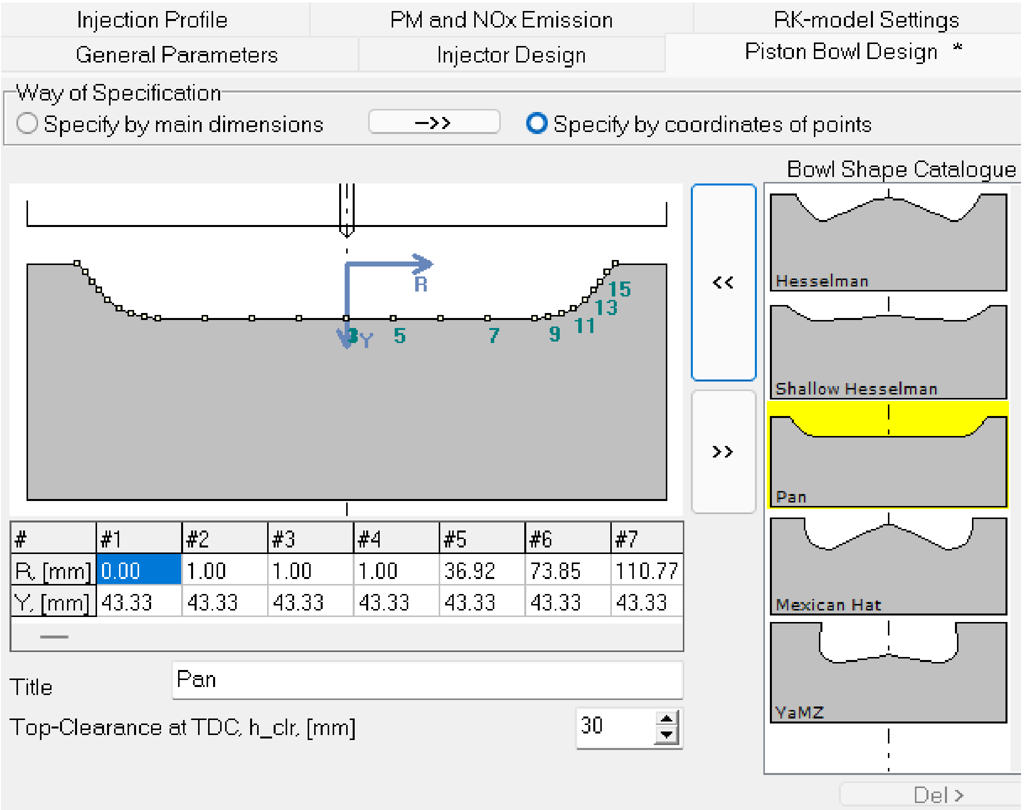

Figure 2. Pan piston bowl catalogue.

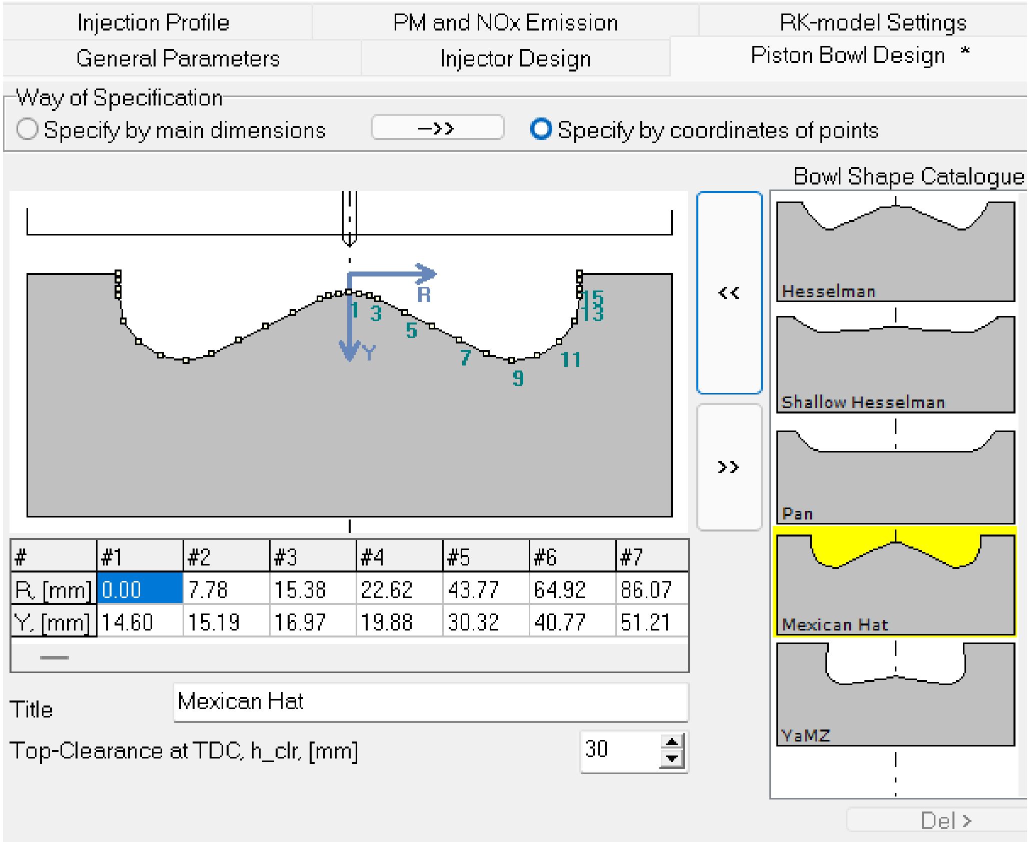

Figure 3. Mexican Hat piston bowl catalogue.

Heavy fuel oils are made from the residues of various refinery distillation and cracking processes. They are viscous liquids with a distinct odor that must be heated before being stored or burned. In medium to large industrial operations, marine applications, and power plants, heavy fuel oils are used in combustion equipment such as boilers, furnaces, and diesel engines.

Table 1. Range of physico-chemical properties for heavy fuel oils [6].

Properties	Test method	Typical range
Kinematic viscosity at 100ºC (mm^2/s)	ISO 3104	6 to 55
Density at 15ºC	ISO 3675 OR ISO 12185	950 to 1010
Flash point (ºC)	ISO 2719	>60
Pour point (ºC)	ISO 3016	<30
Carbon residue %(m/m)	ISO 10370	<22
Ash %(m/m)	ISO 6245	<0.20
Water %(v/v)	ISO 3733	< 1.0
Sulphur %(m/m)	ISO 8754	Inland <3.5 Marine <5
Vanadium (mg/kg)	ISO 14597	<600
Aluminium plus silicon (mg/kg)	ISO 10478	<80

Notes:

a. Although kinematic viscosity is commonly represented in centistokes in technical literature and specifications, the SI units for kinematic viscosity, mm^2/s, are utilized throughout this dossier (cSt).

$$1 \text{ cSt} = 1 \text{ mm}^2/\text{s}$$

b. By ISO heavy fuel oil grades ISO-F-RML 45 and RML 55 have unlimited density and carbon residue levels after researching.
c. It is proposed that the sulfur content of some liquid fuels be reduced (including heavy fuel oil).
d. The goal is to cut down on SO_2 emissions caused by combustion. It is planned that the Sulphur content of these fuels be limited to 1% starting in 2005.

Heavy Fuel Oil Blending Components [6]

Heavy fuel oils can be made from a variety of refinery components laboratory proved, the most important of which are:

- **Long residue:** leftover left behind from crude oil distillation in the atmosphere. As previously stated, this was once a key component of fuel oil mixing, but it is now mostly used as a feedstock for vacuum distillation or thermal or catalytic cracking units.
- Vacuum distillation of crude oil leaves behind a **short residue.** Thermal cracker or Vis breaker residue is the residue from thermal cracking operations designed to maximize the yield of distillate components from atmospheric and vacuum residues.
- Slurry oil (clarified oil) in nature is a heavy fraction from a catalytic cracking operation that converts heavy hydrocarbon fractions into high-quality gasoline components for operations.
- Thermally cracked or visbreaker gas oil is a middle distillate fraction from thermal cracker or visbreaker units.
- The oil from the catalytic cracking unit's intermediate distillate fraction is known as cat cracker cycle oil.
- **Kerosine** is a lighter-colored middle distillate fraction from the atmospheric column.
- **Gas oil** is a middle distillate fraction of the air column that is heavier.
- Vacuum gas oil is a heavy gas oil fraction from the vacuum column.

Sample Engine for Simulation

W8L50DF modeled Engine is Dual fuel which is diesel turbocharged and used for marine purpose has been selected for this purpose. It operates on lean burn perception for the purpose of high compression ratio and magnify efficiency.

I created a diesel engine model in the diesel RK software after completely specifying the specifications.

METHODOLOGY

This Diesel-RK model shown in Figure 4 simulates the design of mixtures and the combustion process in diesel engines. Professor Razleytsev created a method for modeling the RK model between 1990 and 1994. Dr. Kuleshov later improved and supplemented the procedure. The RK model will consider the following factors: fuel spray shape, fuel particle size, fuel spray direction in the combustion chamber, and the dynamics of the fuel spray production and decay process. Swirl dynamics and forms in the combustion chamber Fuel particles interact with swirls and the walls of combustion chambers.

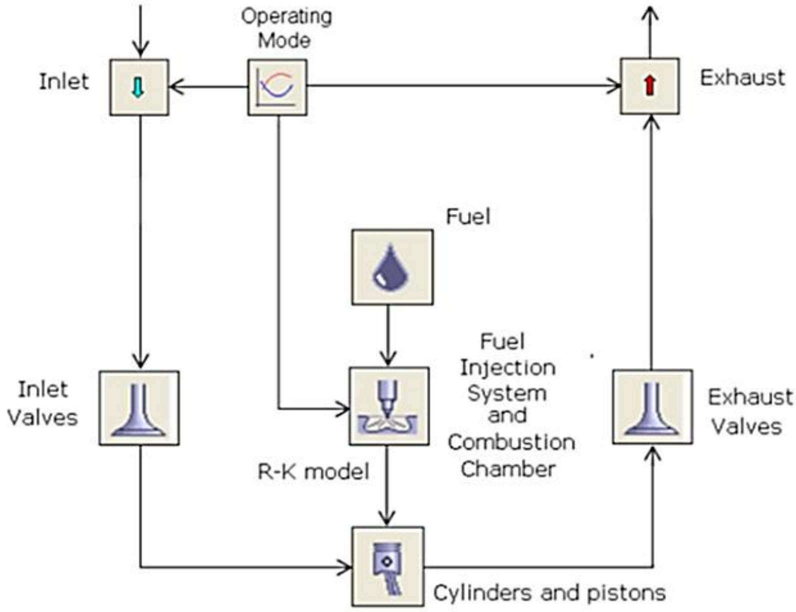

Figure 4. With diesel RK, a simulation model is used to compute the working cycle of a certain diesel engine.

Having those main inputs for the test and analysis the results gained from Table 2 and figures shown above it has been summarized and discussed roughly as below. Here the results are shown mostly as much as visible and clear on excel plotting by picking the results from the diesel rk Graphing system.

RESULTS AND DISCUSSIONS

In-cylinder pressure

The greater cylinder pressures shown in Figure 5 and tremendous torque produced by diesel engines necessitate much sturdier components. In modern turbocharged applications, cylinder pressures are increasing upward to 248.211 bar, and over 551.58 bar in performance applications. For an equal Crank angle setup, the maximum in-cylinder pressures for Shallow Hesselman, Pan, and Mexican hat are 59.52, 59.72, and 59.42 bar, respectively.

In-cylinder Temperature (Average)

Figure 6 below shows the in-cylinder temperature of the heavy fuels which have been applied for the selected engine. Have been discussed that the properties of heavy fuels and application in order to improve engine powers. So that the simulation shows that for different piston bowl design different results. 1321.30, 1322.00 and 1309.40 K are for Shallow Hesselman, Pan and Mexican hat respectively. Here the in-cylinder temperatures of ‘Pan’ piston bowl is maximum for an equal crank angle setup.

Table 2. Engine used for simulation [1].

Engine specifications	
Model	***W8L50DF***
Engine	Diesel turbocharged and intercooled
Number of cylinders	8/ inline
Bore (mm)	580
Stroke (mm)	500
Piston displacement	113.9 L/cyl
Rated output (kW@rpm)	7800@514
Compression ratio	14
Types of engines	4 strokes

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Number of valves	2inlet and 2 outlet valves
Direction of rotation	clockwise

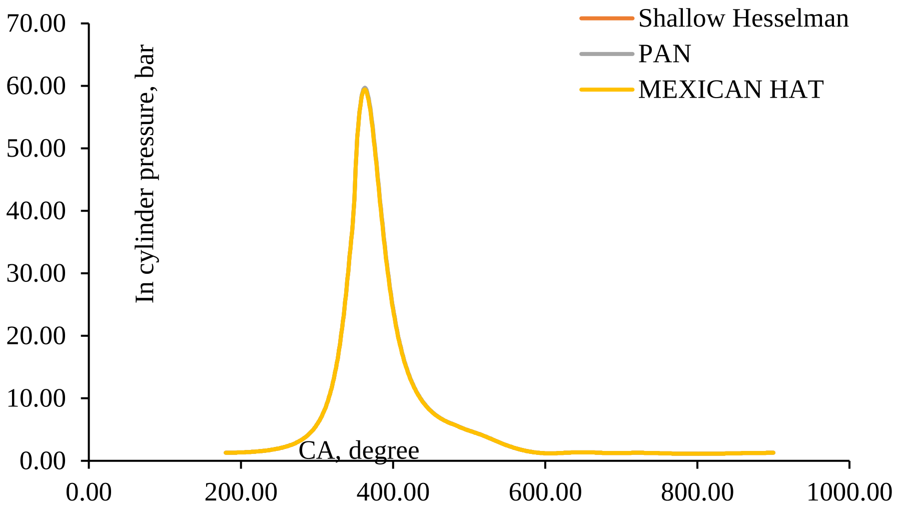

Figure 5. Cylinder pressure.

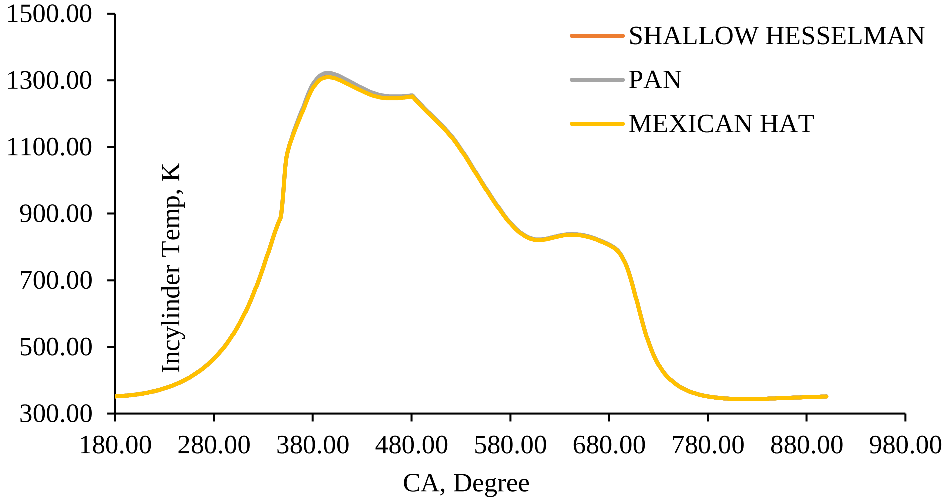

Figure 6. In-cylinder temperature.

Heat Releasing Rate

Figure 7 below shows heat releasing rates of Heavy fuel on diesel engine specified vehicles with different piston bowl designs, i.e., Shallow Hesselman, Pan and Mexican Hat which shows maximum HRR of 4979 and 4975 at equal crank angle of 351.00 degree and 4979 at 351.20 CA respectively.

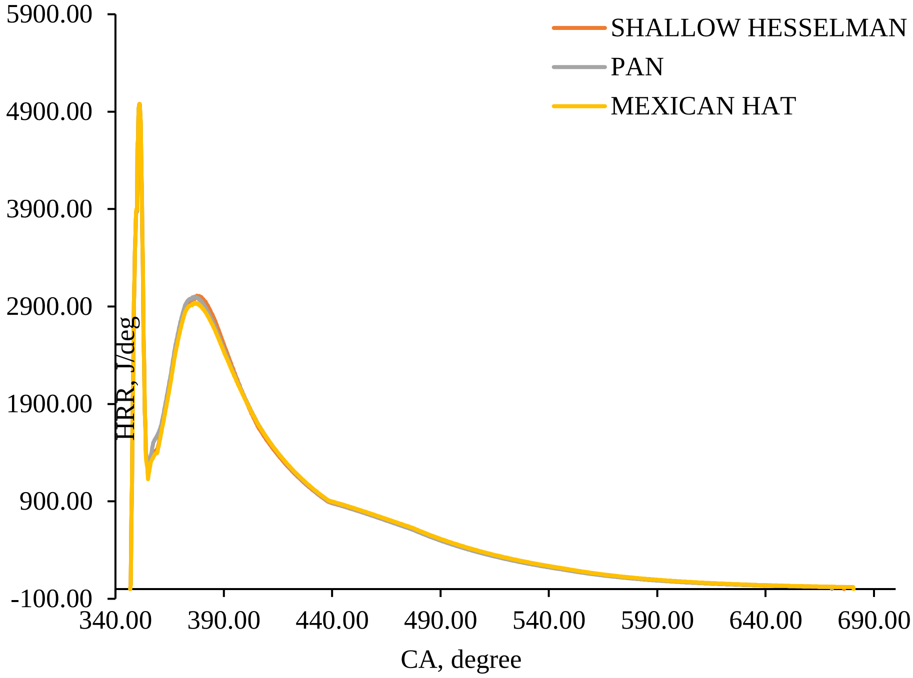

Figure 7. Heat release rate.

The Concentration of Nox in the Cylinder

Because NOx emissions are considered a pollutant of the air environment, the findings in Figure 8 are relevant. From the evaluations it shows,

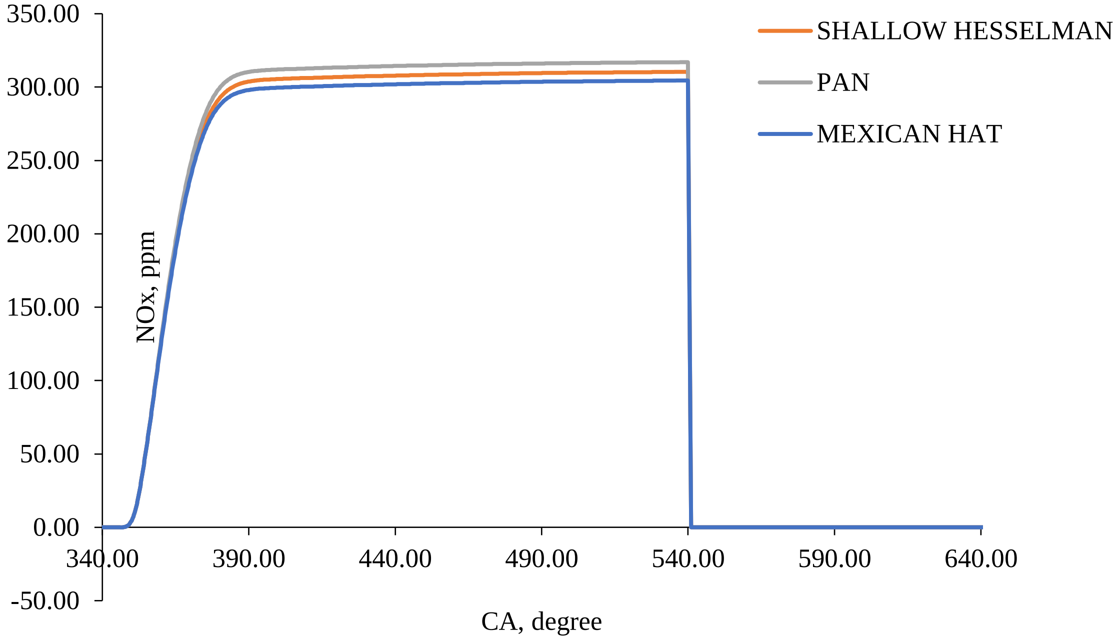

Figure 8. Concentration of NOx in the cylinder.

The Amount of Soot in the Cylinder

The simulation of the amount of generated soot yielded the following findings. Here higher concentration of soot is obtained on pan bowl design for equal crank angles set for shallow Hesselman and Mexican Hat too which is 0.91, 0.90 and 0.89 respectively.

VALIDATIONS

As a result, the aim is the amount to which the survey evaluates the right characteristics that need to be measured, such as the ability of heavy fuels to run on diesel engines for more familiar operations and a double power gain. In this study, pressure, temperature, heat release rate, and emissions (NOx and Soot) were compared between three distinct piston bowl designs. Justified that, the Mexican hat, the most familiar and well-known style of piston bowl design for diesel engines, is more efficient and good in terms of emissions than the other two. i.e., reduced emission and well in operations. Figure 9 shows Soot concentration in the cylinder.

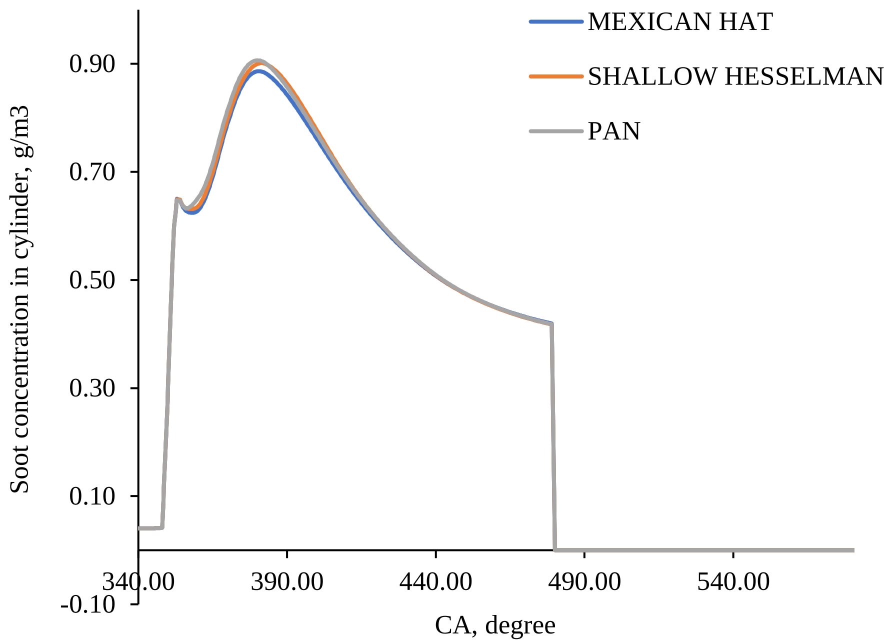

Figure 9. Soot concentration in the cylinder.

CONCLUSION

This study goals to explore the effects of piston bowl geometry on emission, performance and combustion. This is a comparative study of three different piston bowl shapes on parameters as described above. The compositions of NOx and soot formation is more in PAN, from those forms of piston bowl design selected for our case. Even though the properties may depend, it varies with design of piston bowl as shown above. Not only the emission parts since the in-cylinder pressures and Temperatures are maximum in this case it’s possible to conclude that as temperature increases in the cylinder the resultant emission formation is higher too.

REFERENCES

1. Van Viet Pham, Research on the application of diesel-rk in the calculation and evaluation of technical and economic criteria of marine diesel engines using the unified ULSD and biodiesel blended fuel, (JMERD) 42(2) (2019) 87-97, ISSN: 1024-1752.
2. Various piston bowl-configurations and their effects on soot fuel consumption and no. (www.researchgate.net/)
3. Software for engine simulation and optimization on (www.diesel-rk.com).
4. Chetan S Bawankar, Rajesh Gupta; Effects of piston bowl geometry on combustion and Emission characteristics on diesel engine: a cfd case study, IJRET eISSN: 2319-1163, pISSN: 2321-7308, Volume: 05 Issue: 07, Jul-2016.

5. Sridhar Gururaja Rao, Experiments and Modelling Studies of Producer Gas based Spark-Ignited Reciprocating Engines, A Thesis, Department of Aerospace Engineering Indian Institute of Science Bangalore – 560 012, India. February 2003.
6. Heavy Fuel Oils, Prepared by CONCAWE's Petroleum Products and Health Management Groups.
7. Olaiya Kamorudeen Adesina, Alabi Ismaila Olanrewaju and Okediji Adebunmi Peter, Performance, Characteristics of a Single-Cylinder Two-Stroke Diesel Engine using Diesel-RK Software, International Journal of Scientific & Engineering Research Volume 11, Issue 6, June-2020 ISSN 2229-5518.
8. Diesel RK HW DI CI Engine external performance.pdf (https://www.diesel-rk.bmstu.ru/Eng/index.php?page=download.
9. Lewis, A. 2002. Composition, properties and classification of heavy fuel oils. Third R&D Forum on High-density Oil Spill Response. Brest March 2002 pp.11–25.
10. Moldestad, M. Ø., Lewis, A., Hauge, M. & Royset, J.-A. 2007. Safety at Sea. Oil Weathering. Demo A: Inventory, Classification and Risk Assessment of Oil Transport on the North Sea. SINTEF and the Norwegian Coastal Administration (NCA) report.
11. Numerical analysis on the combustion and emission characteristics of forced swirl combustion system for DI diesel engines: Energy Conversion and Management 86 (2014) 20–27.
12. Diesel vs. Gas engines: what's the difference? (https://www.uti.edu/blog/diesel/gas-vs-diesel-engines).
13. Gautam Kalghatgi, Richard Stone & Paul Miles, The scope for improving the efficiency and environmental impact of internal combustion engines. Transportation Engineering, Volume 1, June 2020, 100005.
14. Engine Simulation & Optimization Software, Diesel Rk.
15. Prabhakara Rao Ganji, Rudra Nath Singh, V R K Raju and S Srinivasa Rao, Design of piston bowl geometry for better combustion in direct-injection compression ignition engine. Sådhanå (2018) 43:92, https://doi.org/10.1007/s12046-018-0907-x.