DIESEL - RK

Software for engine simulation and optimization

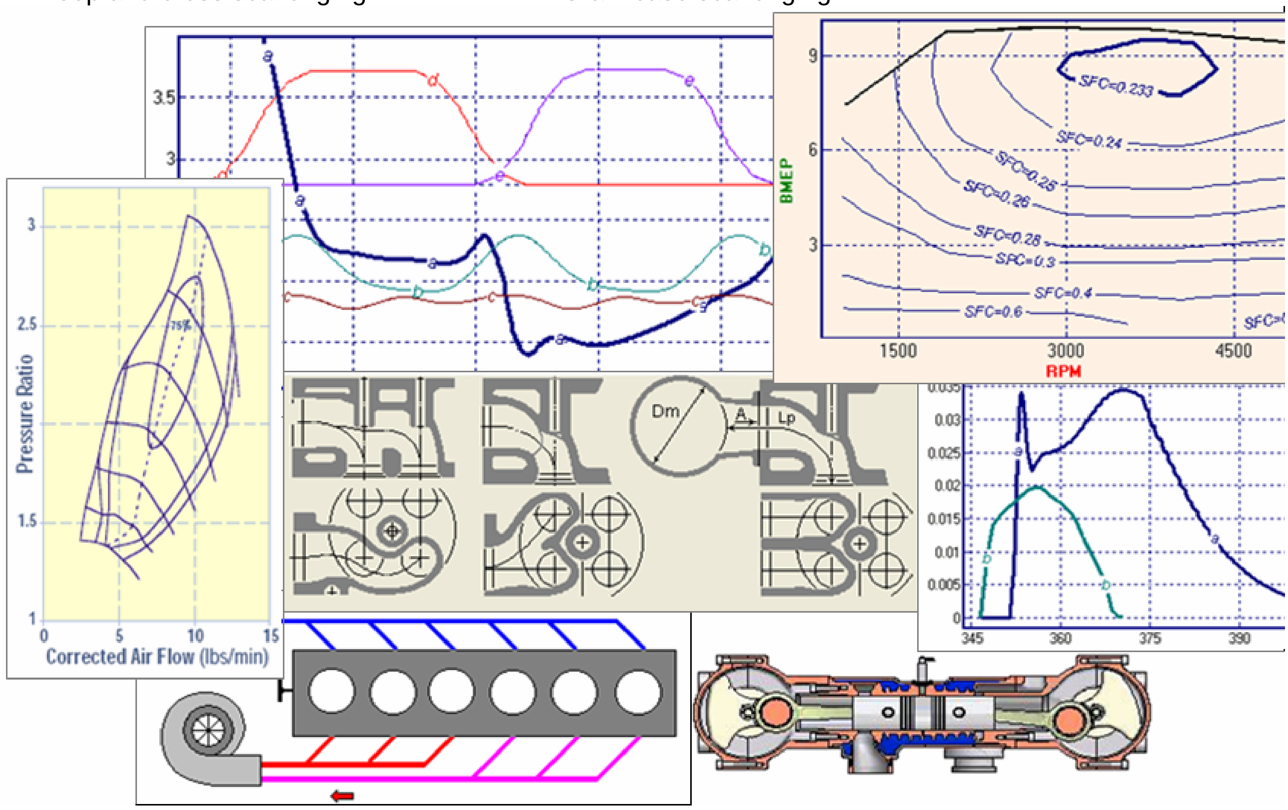
www.diesel-rk.com

The full cycle thermodynamic engine simulation software DIESEL-RK is designed for simulating and optimizing working processes of **two-** and **four-stroke** internal combustion engines with all types of boosting. The program can be used for modeling the following types of engines:

■ DI Diesel engines (with PCCI/HCCI). ■ SI petrol engines. ■ SI gas engines ■ DF engines.

For two-stroke engines the DIESEL-RK supports the following scavenging schemes:

- Uniflow scavenging.
- Loop and cross scavenging.
- Junkers (OP) & OPOC schemes.
- Crankcase scavenging.
- Z-engine concept



Typical applications include:

- Torque curve and other engine performances predictions.
- Fuel consumption prediction and optimization.
- Combustion and emission analysis and optimization.
- Knock prediction.
- Valve timing optimization.
- EGR analysis and optimization.
- Turbocharger and bypasses matching and optimization.
- Conversion of diesel engines into gas engines.

The program DIESEL-RK makes it possible to simulate the working process of any type of internal combustion engines with high accuracy of predictions with the use of minimum empirical coefficients. The values of these coefficients are constant for any configuration and operating modes of engines and over the whole operating range including part load and idling.

■ The DIESEL-RK is a best tool for a new engine concept analysis because one allows creation of a new project very easily and quickly. Philosophy of work of pre- and post-processors is focused to help an engineer.

■ The modern models of combustion and emission formations together with built-in optimization procedures allow optimal emission control corresponding with the actual emission regulations. These functions were fully tested in industry.

■ A model of the gas exchange takes into account the non-steady 1D gas flow in ports, specifics of the port's design, the influence of the neighboring cylinders and the design features of the pulse converter. The two-stroke engine scavenging model is based on the perfect gas mixing law and the perfect displacement and short circuit hypotheses. This model allows engineers to numerically optimize the port timing and also the design configuration of intake and exhaust ports of two-stroke engines.

■ DIESEL-RK supports modeling and analysis of engines with two-stage turbocharging, Hyperbar concept, etc., and can be used for matching characteristics of piston engines with turbine and compressor maps.

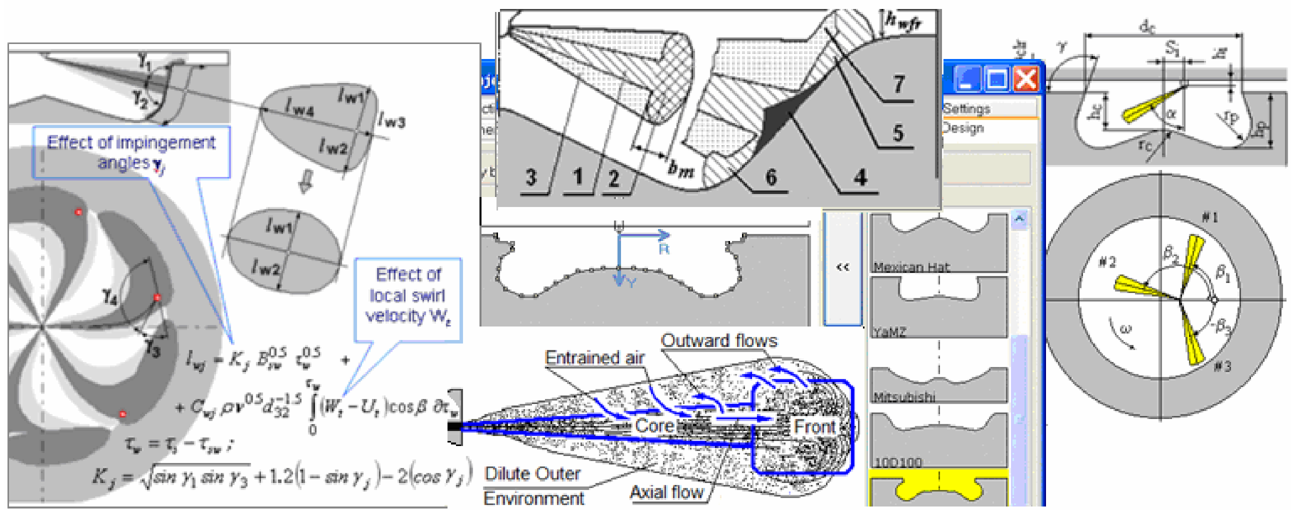
■ The DIESEL-RK solver may be run under the control of an external code. In that case the interface of the program includes input & output text files. Templates of these files are generated automatically.

DIESEL-RK has the following novel advanced features:

1. Multi-zone spatial diesel spray combustion model (RK-model) takes into account:

- piston bowl shape: any geometrical shapes can be modeled and saved into the piston bowl data base which already includes the most common geometries;
- dynamics and profile of swirl;
- sprayer location: central, non-central, side injection;
- number, diameter and directions of nozzle holes;
- shape of injection profile including **multiple injection**;
- drop sizes and dynamics of fuel sprays evolution due to swirl & walls;
- interaction of the sprays with walls and with other sprays: as spatial as near walls.

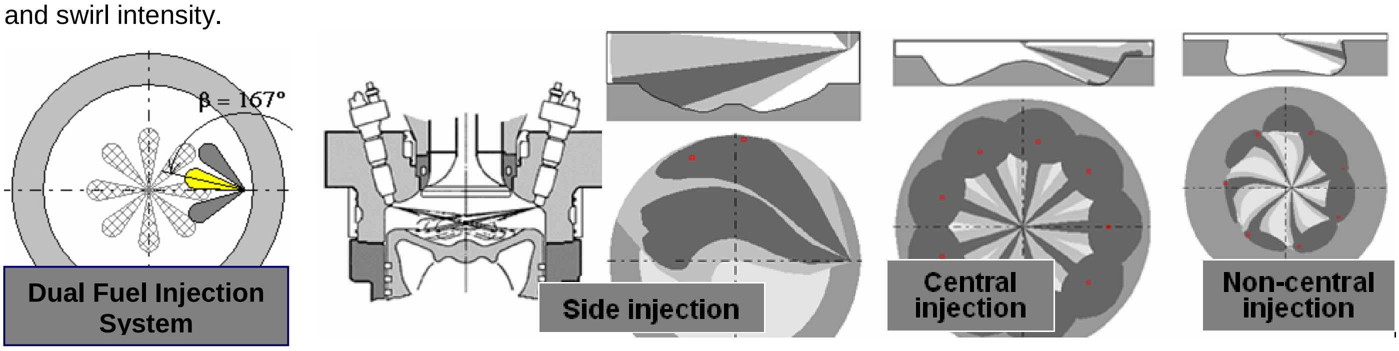
Publications:
SAE Paper No 2005-01-2119, 2005
SAE Paper No 2006-01-1385, 2006
SAE Paper No 2007-01-1908, 2007
SAE Paper No 2009-01-1956, 2009
SAE Paper No 2010-01-1960, 2010
SAE Paper No 2013-01-0882, 2013
ASME ICEF2014 – 5700, 2014
SAE Paper No 2015-01-1791, 2015
SAE Paper No 2015-01-1859, 2015



The RK-model has a capability to optimize the piston bowl shape and fuel injection system parameters (nozzle holes directions, diameter and number of holes) as well as to develop multiple injection strategy and the Common Rail controlling algorithm together with EGR strategy over the whole operating range.

2. Fuel Spray Visualization code.

This code allows engineers to present results of modeling of interaction of the fuel spray with combustion chamber walls, air swirl and neighboring sprays in the animation picture format. The code assists in choosing the best shape of the piston bowl and select the diameter, the number and the directions of nozzle holes for a given injection duration and swirl intensity.

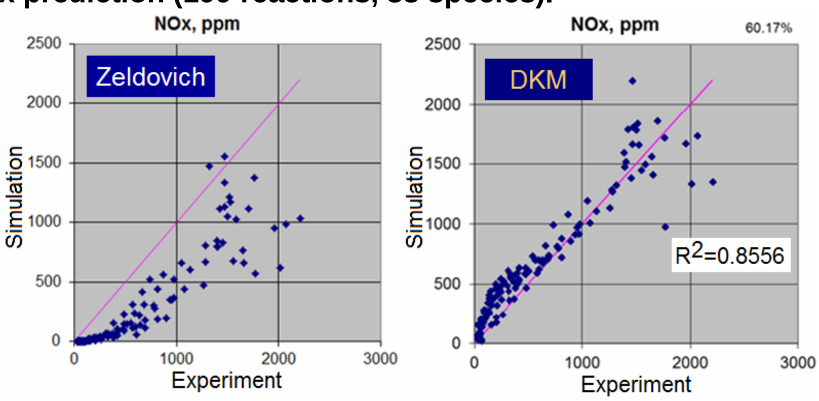


3. Detailed Kinetic Mechanism for the NOx prediction (199 reactions, 33 species).

User can select the NOx formation model:

- Zeldovich's mechanism for conventional diesels (the mechanism accounts 18 species).

- Detailed Kinetic Mechanism for the correct prediction of NOx emissions in the engine with a massive EGR, multiple injection and PCCI/HCCI (the mechanism includes 199 reactions, 33 species).



4. DIESEL-RK preprocessor is user-friendly and very easy in use.

The DIESEL-RK, which is an industrial standard level professional tool, can also be quickly learned and successfully used by beginner-level users. To significantly simplify creation of a new study case and corresponding data input process, the special ***Wizard of New Project Creation*** has been developed. This tool creates input data file by using generic information about the engine and default data on the most commonly used technical solutions accepted in the subject field. Thus, both the process of data input and the calibration of the engine model become significantly easier. This is especially important for researchers who are working on projects with a great time constraints and lack of experimental data to perform rapid analysis of the engine being investigated or developed.

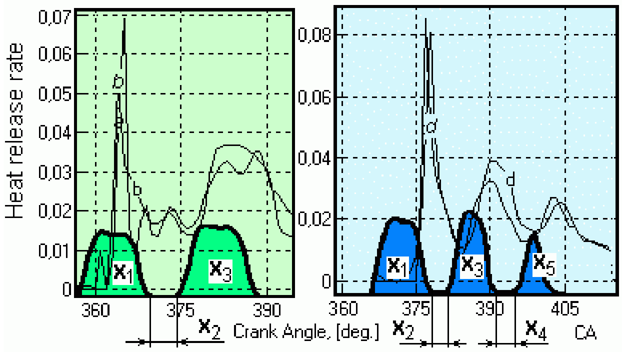
5. Optimization of the multiple injection strategy where target includes SFC, NOx and PM.

The program allows engineers:
- to carry out automatic optimization of the multiple injection strategy taking into account the influence of EGR.
- to optimize the fuel fractions X_1, X_3, X_5 and separations X_2, X_4 for each injected fuel portion; as well as X_6=EGR for every operating mode.

Target function may be SFC = *f* (X_1, X_2, …X_n) or complex

$$SE = MAX\left(1,\frac{NOx}{NOx_0}\right)^{k1} + MAX\left(1,\frac{PM}{PM_0}\right)^{k2} + \left(\frac{SFC}{SFC_0}\right)^{k3}.$$

where: *NOx = f (X_1, X_2, …X_n)*, PM=f(X_1, X_2, …X_n), etc.



Number of injected fuel portions is limited to 20.

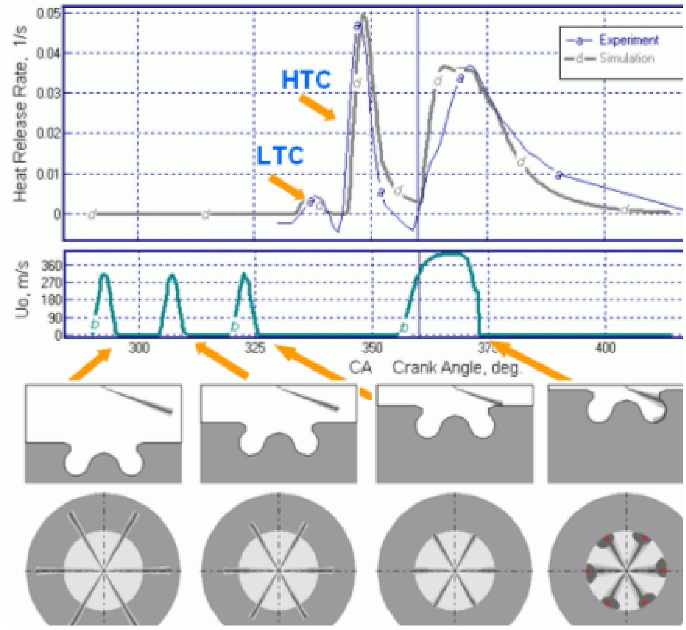
6. Premixed Charge Compression Ignition (PCCI) analysis and HCCI analysis.

All calibration coefficients used for PCCI/HCCI and for conventional engines are identical.

Ignition delay is calculated using Detail Chemistry and accounts EGR. The Lawrence Livermore National Laboratory mechanism which includes 1540 reactions and 160 species is implemented. The TABKIN methodology with Livengood-Wu integral is used.

The advanced combustion model is combined with Detailed Kinetic Mechanism of NOx formation, which allows engineers to optimize the PCCI strategy. Low Temperature Combustion (LTC) is accounted.

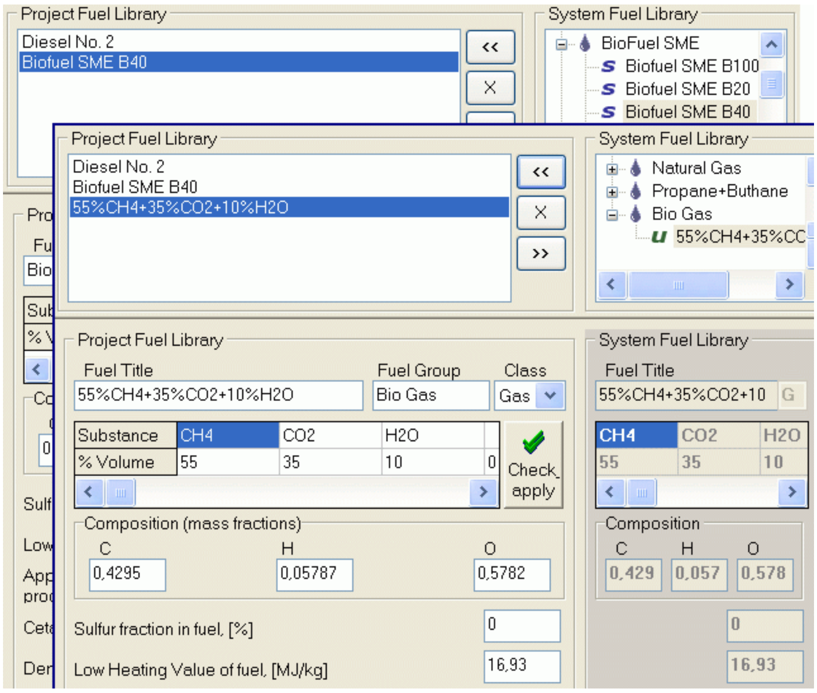
(The diagram shows the sprays evolution process. Each picture corresponds to the end of injection of each fuel portion.)



7. Simulation and analysis of Bio-fueled diesel engines and Gas engines.

The DIESEL-RK supports the library of different fuels including different blends of biofuels with diesel oil for diesel combustion and arbitrary mixtures of gases for gas engine. User-Defined Fuels properties are saved in internal database of the project. Different types of fuels can be specified for a certain mode of engine's operation.

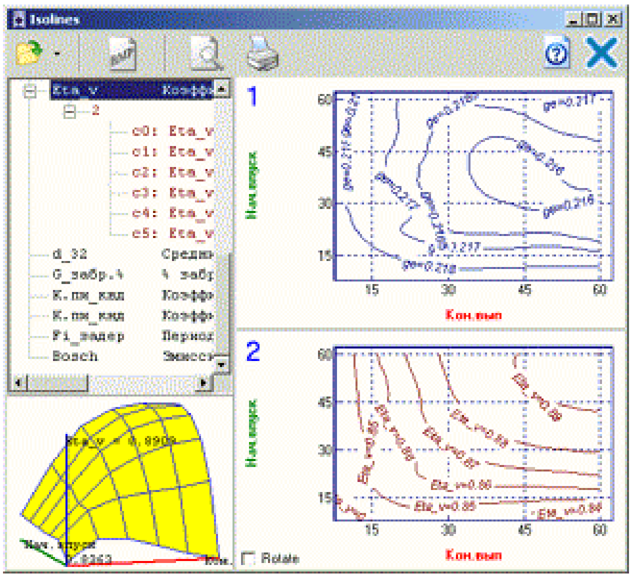
Physical properties of biofuel blends are used in the spray evolution simulations and in modeling the evaporation and combustion processes. Properties of gas mixture of gas engine are calculated automatically depending on gas composition. Fuel gas may be an arbitrary mixture of: **H2, O2, N2, H2O, CO2, CH4, C2H6, C3H8, C4H10, CH3OH, CH3-O-CH3, C2H5OH, CO.** This list may be extended easily.



8. Multiparametric optimization and 1D & 2D parametrical research procedures.

To perform optimization calculations the DIESEL-RK is equipped with a **built-in procedure of multiparametric optimization** which includes **15 methods of nonlinear optimization search and stochastic methods (PSO)**. There is also a possibility to perform 1D and 2D parametrical search investigations.

Optimization tools with **multithreading** allow considerably increasing the efficiency of computational researches focused on improvement the engine performances.

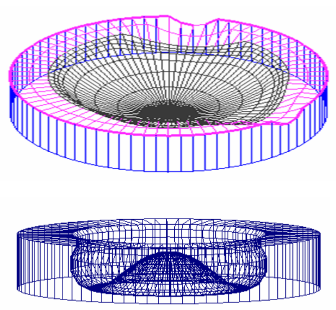


When dealing with problems related to a search for optimal combinations of various engine parameters such as compression ratio, injection timing, diameter, number and direction of nozzle holes, combustion chamber shape, valve timing, turbocharging parameters etc., it is often difficult to plan and run a new experiment and process experimental results because of a large number of variable factors. Very effective way to overcome such the problem is using a multiparametric optimization technique. The optimizing procedure uses the engine's mathematical model together with a specified goal function and restrictions to find a set of optimal design parameters. Due to the high computational speed of DIESEL-RK, the optimization procedure is carried out very rapidly without the use of significant resources. The target function including list of engine parameters may be calculated in DIESEL-RK or by User Model DLL being linked to DIESEL-RK kernel.

9. Simulation of combustion in engine with few fuel systems

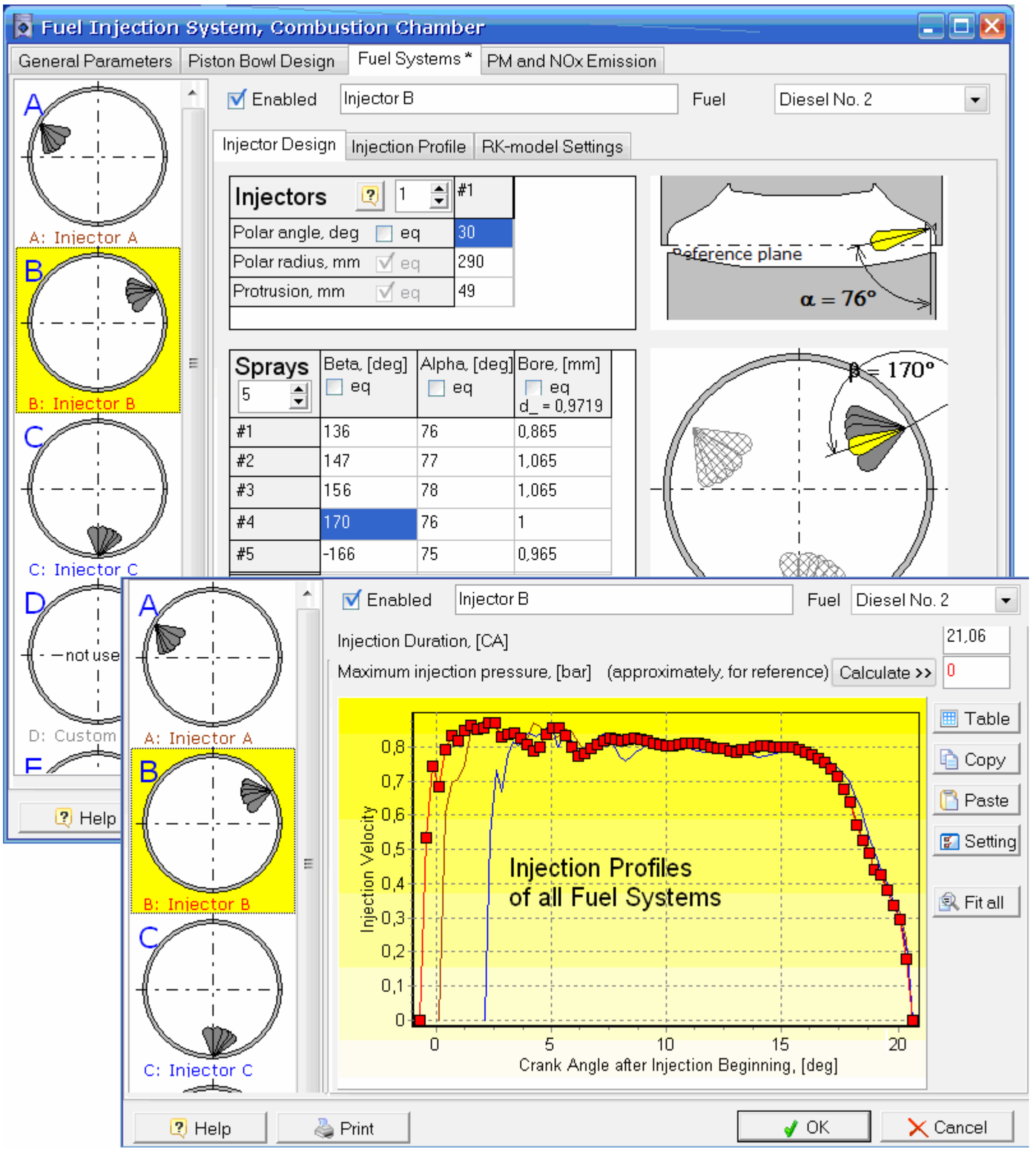
Combustion model allows specification of few independently working fuel injection systems named as A, B, C, D, E in one cylinder. Each system may include few injectors and may supply own fuel with independent control. The injectors may have nozzles with arbitrary orientation and having different diameters.

3D mesh is used for piston bowl and spray zones interpretation.

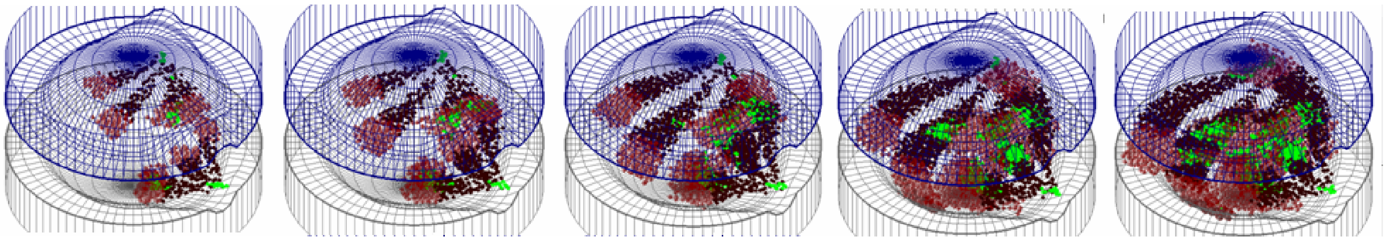


It is non-CFD simulation: the balance equations are resolved for clusters of cells. **Computational time is 1 ... 2 min** on conventional PC.

3D visualization of spray behavior allows analysis of sprays spatial & near wall intersection.



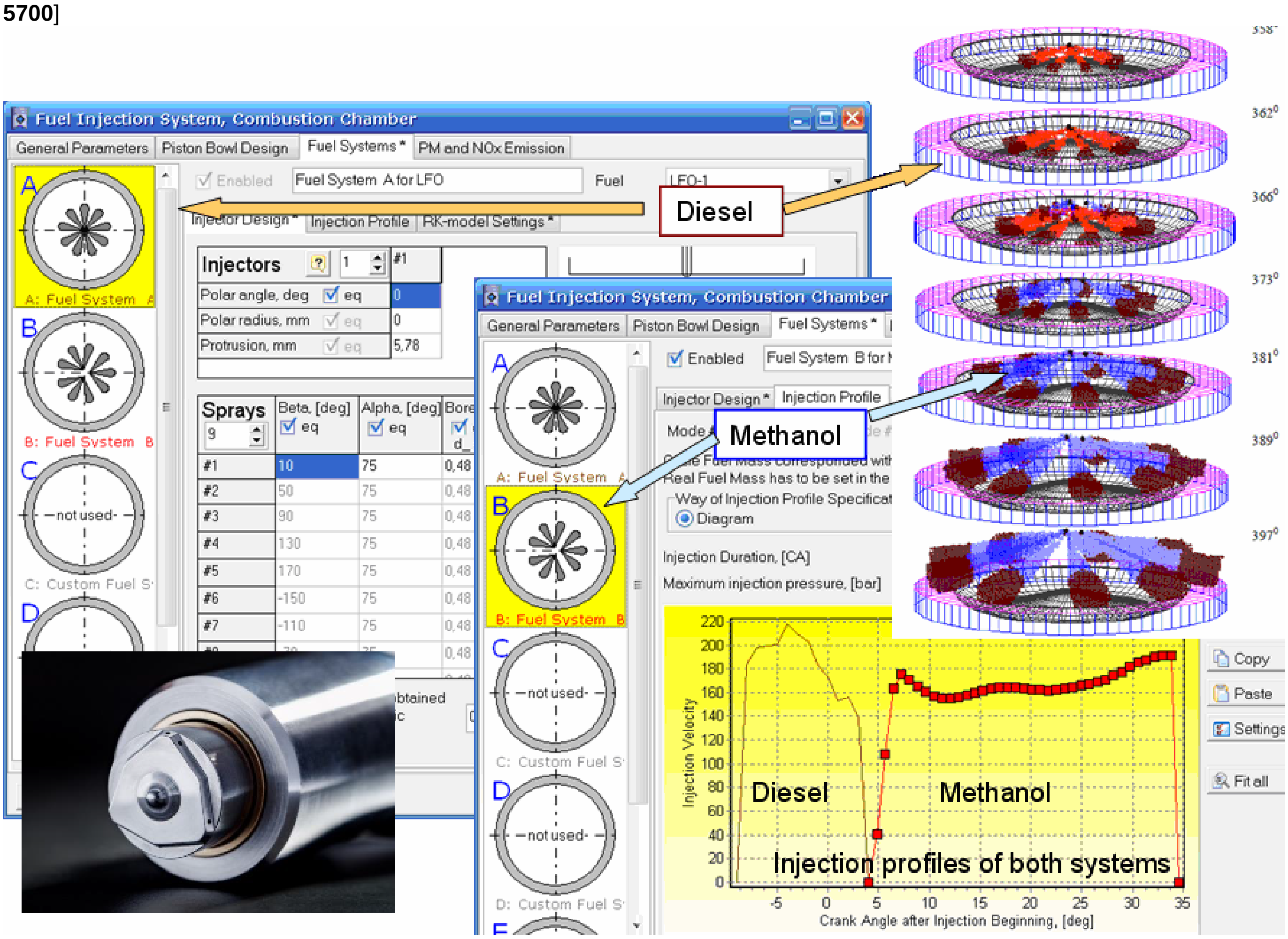
10. 3D simulation of fuel sprays evolution and spatial intersections.



Spatial evolution of sprays from 2 injectors in cylinder of 2 stroke OP engine with side injection system.
Green bullets on figures indicate zones of sprays' spatial intersections which lead to local decrease of HRR. Fractions of intersection spray volumes for each pair of sprays are plotted as diagrams vs CA. It allows optimization of the nozzle directions and the diameter of some of them to avoid or minimize spatial sprays interaction. [**SAE 2015-01-1859**]

11. Dual Fuel engine simulation.

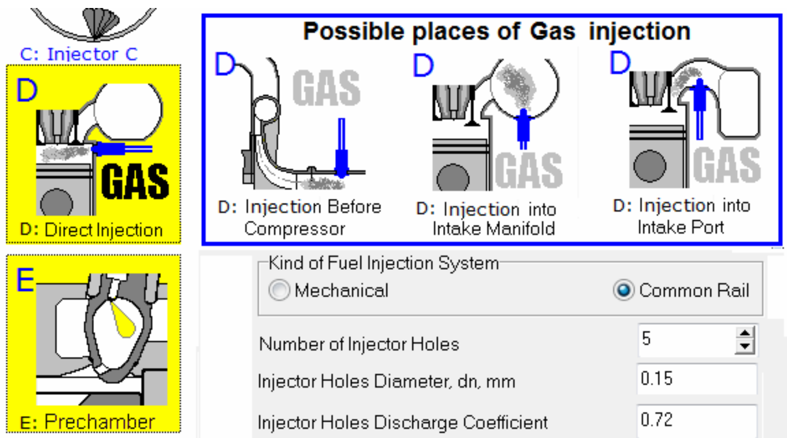
One fuel system may supply for example Methanol, and another Diesel oil. Interaction of sprays of different fuel systems is taken into account. Self-ignition of each fuel is calculated using detail chemistry simulation.[**ASME ICEF2014 – 5700**]



12. Analysis of Gas and DF engines with Pre-chamber ignition and with DI diesel pilot ignition.

Delivery of arbitrary composed gas into different parts of engine can be simulated. For this, one of the fuel systems should be assigned as **Gas**.

Ignition is possible to be modelled with the DI pilot diesel oil, and with the pre-chamber. In the last case the **Pre-chamber** should be assigned as one of fuel systems and its dimensions as well as injector parameters should be settled to calculate gas flow into the pre-chamber and combustion inside it.

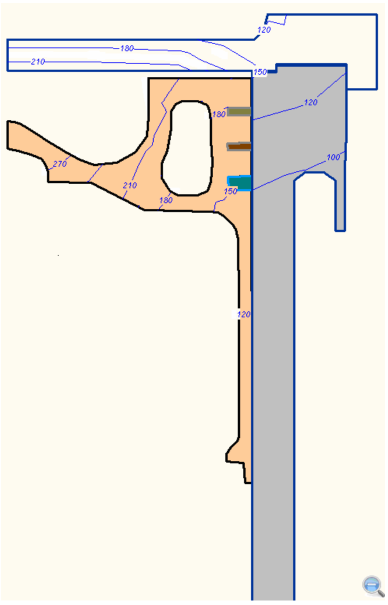


13. Common simulation of combustion and in-cylinder processes with Finite Element Analysis of temperature fields in engine parts.

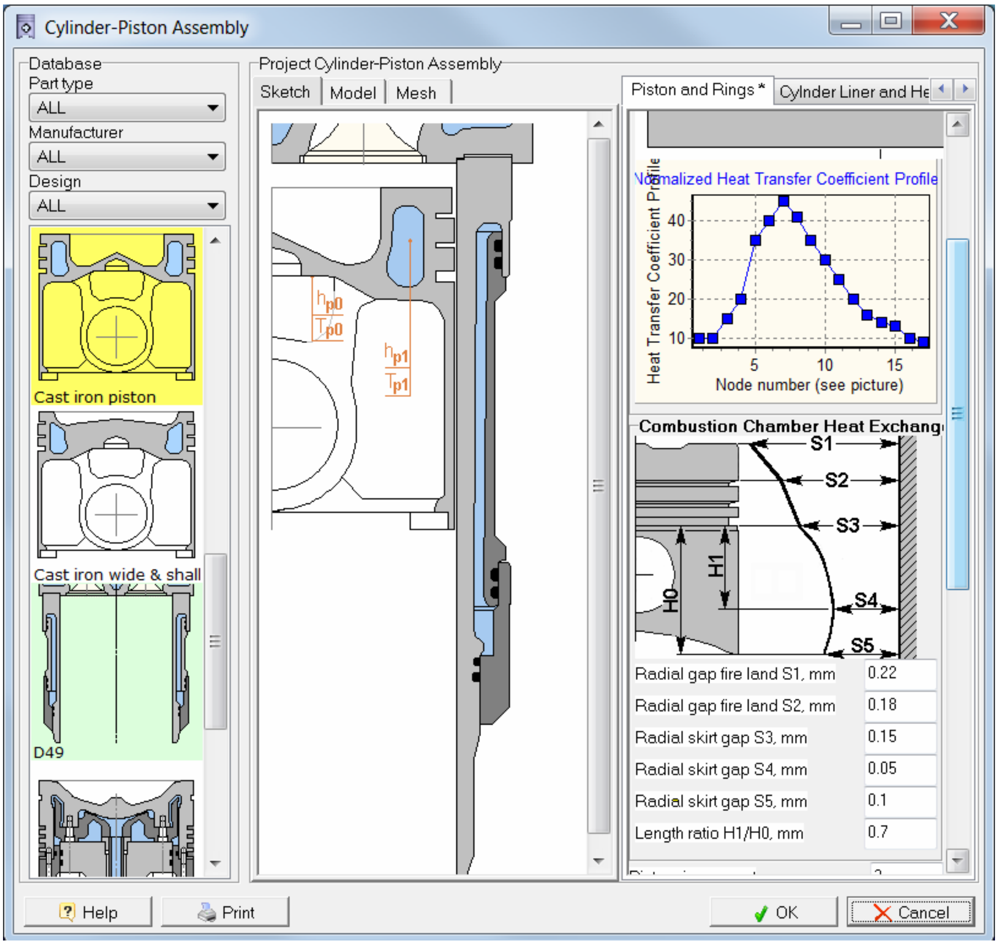
Diesel-RK has built-in databases of:
- Typical pistons, liners and cylinder heads being used in different engines.
- Properties of materials being used for pistons (skirt, rings and head), cylinder heads and liners, gaskets, etc.
- Boundary conditions for contacts of different parts, cooling in crank case, cooling in galleries, distributions of heat transfer along surfaces, etc.

User can select any parts (they fit each other automatically) and test any concept / combination of piston-cylinder design and analyze a temperature state of engine.
Finite element mesh is created automatically with accounts of the actual piston bowl shape. Heat transfer between piston and liner is simulated with accounts of the motion, lubricating oil properties and the piston skirt profile.
Results of temperature distribution are obtained while simulating the heat exchange, and simulating the fuel droplets evaporation near the walls where spray impinges the wall. The obtained temperatures in critical places (first piston ring, maximum temperature of piston crown surface) are used as limitations for engine optimization.

The database of engine parts and material properties may be expanded on customer requirements.
Computational time is quite short, so the engine optimization can be performed within the acceptable time period.



Resulted temperature field in the engine parts.



14. Simulation of engines with water injection.

One of the fuel systems can be assigned as Water Injection System (system D in the figure below). There is a possibility to select the location of H2O injection, cycle mass, timing and duration of water injection. DIESEL-RK will simulate condensation and evaporation of water in all engine's gas flow path including cooler, manifold, ports and cylinder. Effect of water injection is taken into account in NOx formation model which uses Detail Kinetic Mechanism. In the output data the mass fractions of liquid water and water steam are presented as diagrams vs CA and as integral parameters.