

DIESEL - RK

Software for engine simulation and optimization

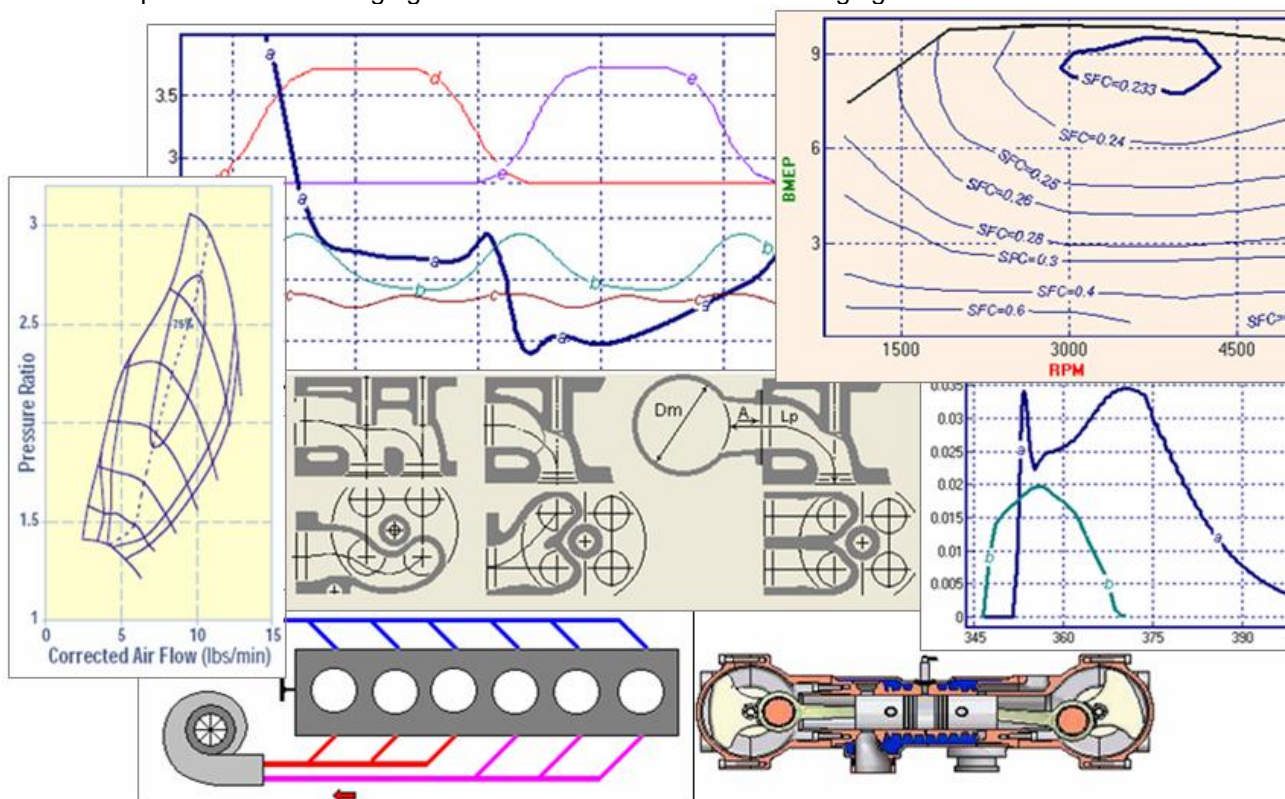
www.diesel-rk.bmstu.ru

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.
- SI petrol engines.
- SI gas engines including prechamber systems.

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

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



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.

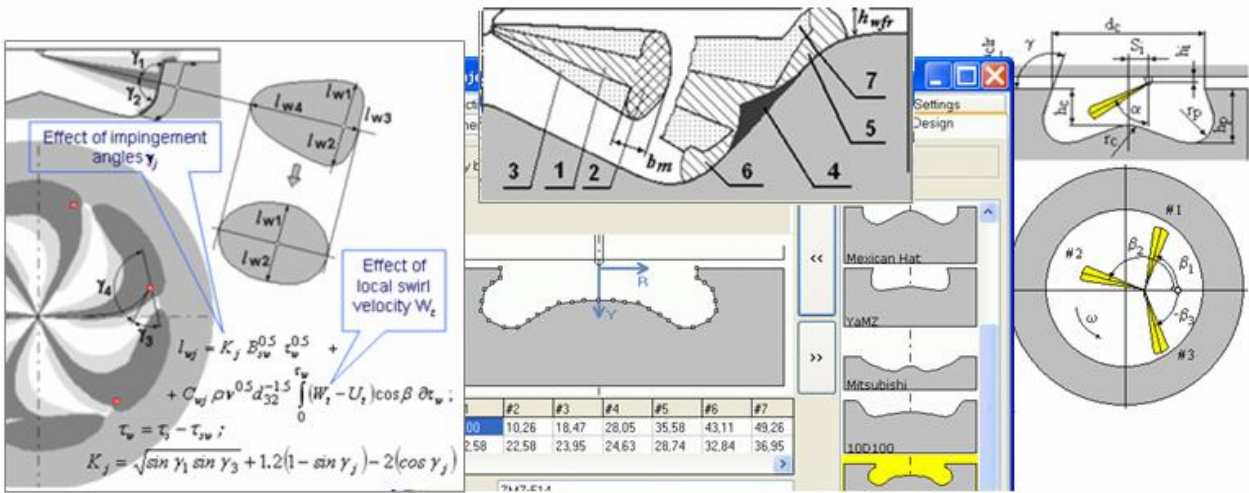
- The parameters of the gas in cylinders and manifolds of the engine are defined by step-by-step solution of the system of governing differential equations of conservation of energy, mass and state equation written for open thermodynamic systems.
- A model of the gas exchange takes into account the non-steady 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. Such the model allows engineers to numerically optimize the valve 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 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 include the most common geometries;
- dynamics and profile of swirl;
- sprayer location: central, non-central, side injection;
- number, diameter and directions of sprayer nozzles;
- shape of injection profile including **multiple injection**;
- drop sizes and dynamics of evolution of fuel sprays;
- interaction of the spray with walls and other neighboring sprays.

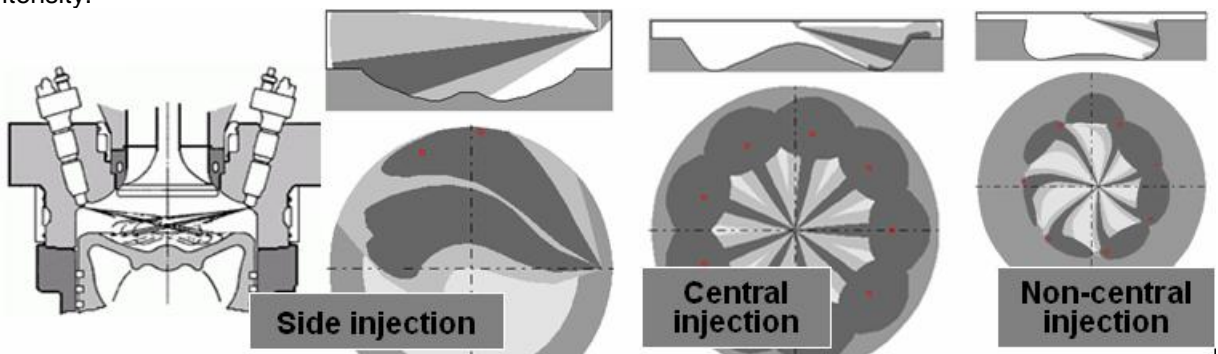
- Publications:
- SAE Paper No 2005-01-2119, 2005
 - SAE Paper No 2006-01-1385, 2006
 - SAE Paper No 2007-01-1908, 2007
 - SAE Paper No 2009-01-1956, 2009



The RK-model has a capability to optimize the piston bowl shape and fuel injection system parameters (sprays directions, diameter and number of nozzles) as well as to develop multiple injection strategy and the Common Rail controlling algorithm 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 injector nozzles 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 considerable EGR, multiple injection and HCCI (the mechanism accounts 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 radically 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

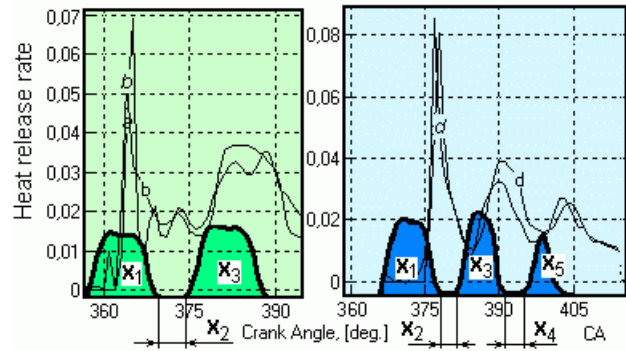
subject field. Thus, both the process of data input and the calibration of the engine model become significantly easier. This is especially important for researchers who are working on projects with a great time constraint and lack of experimental data to perform rapid analysis of the engine being investigated or developed.

5. Optimization of multiple injection strategy.

The program allows engineers:

- to carry out automatic optimization of 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.

Goal function used is $SFC = f(X_1, X_2, \dots, X_n)$.
 Restrictions applied are: $NO = f(X_1, X_2, \dots, X_n)$,
 $Soot = f(X_1, X_2, \dots, X_n)$, etc.
 Number of injected fuel portions is limited to 20.

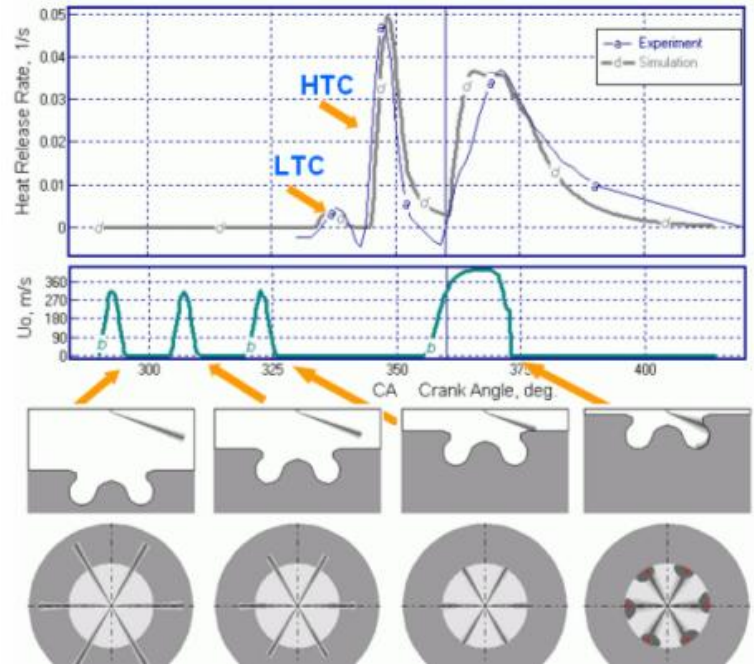


6. Premixed Charge Compression Ignition (PCCI) analysis.

All calibration coefficients used for PCCI and for conventional engines are identical. Ignition delay is calculated using Detail Chemistry of fuel, air and EGR. The Lawrence Livermore National Laboratory mechanism which considers 1540 reactions between 160 species is implemented.

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 spray evolution process. Each picture is for the instance of the time corresponding 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 data base 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 fueled engine are calculated automatically depending on different gas fractions in the mixture. List of supported

Substance	CH4	CO2	H2O
% Volume	55	35	10

Composition (mass fractions)		
C	H	O
0,4295	0,05787	0,5782

Composition		
C	H	O
0,429	0,057	0,578

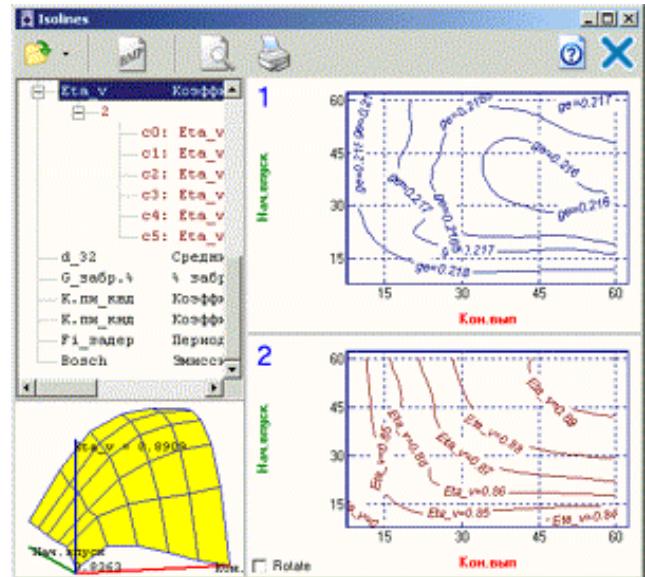
gases includes 12 items and may be extended easily.

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

To perform optimization calculations the DIESEL-RK is equipped with a **built-in procedure of multiparametric optimization** which includes 14 methods of nonlinear optimization search. There is also a possibility to perform 1D and 2D parametrical search investigations.

Optimization tools allow engineers to considerably increase the efficiency of computational research provide effective ways to improve the engine design.

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 injector nozzles, 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.

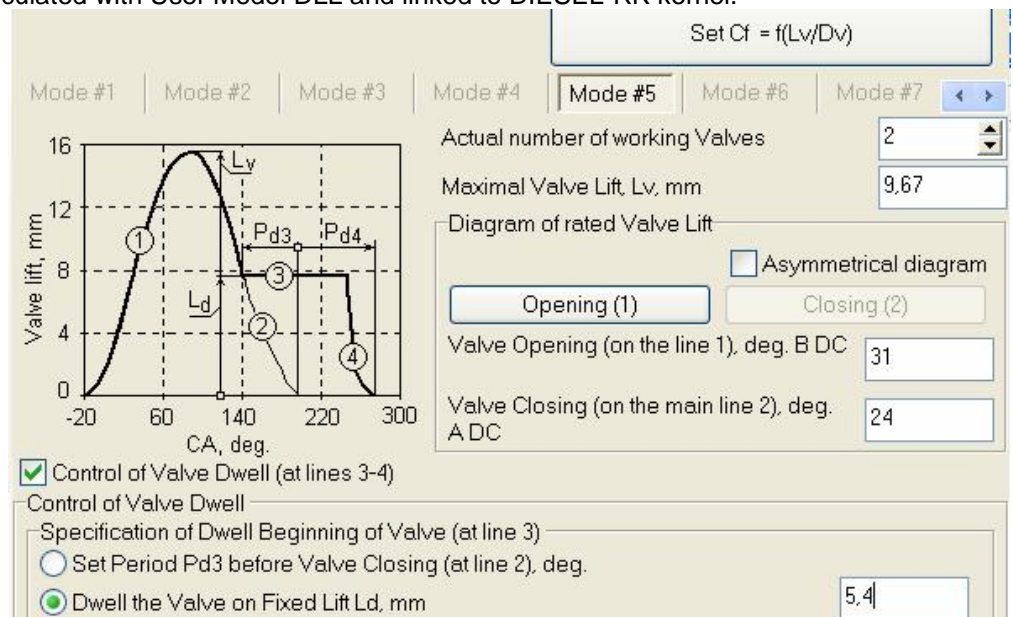


The optimizing procedure uses the engine's mathematical model together with the specified goal function and restrictions to find a set of optimal design parameters. Because of the high computational speed of DIESEL-RK, the optimization procedure is carried out very rapidly without use of significant resources. The target function including list of engine parameters may be calculated with User Model DLL and linked to DIESEL-RK kernel.

9. Variable Valve Actuation analysis.

Valve Lift Diagram with variable valve actuation can be setup and optimized individually for every operating mode.

The Valve Dwell optimization takes also into account the duration and valve lift of the dwell.



10. Coupled simulation of the mixture formation and combustion and prediction of the thermal state of engine components.

Fuel evaporation and combustion as well as heat losses to the walls are calculated using local wall temperatures obtained with the use of Finite Element Model of main engine parts. Boundary conditions depend on the cooling system design.

The program includes data base of geometry of pistons, liners and cylinder heads which will be reflected by a preprocessor

