Researcher Links UK-Russia Workshop

Scientific and Technical Grounds of Future Low-Carbon Propulsion

19th - 22nd November 2018, Northumbria University at Newcastle, UK

Local heat exchange in the combustion engine of hydrogen diesel engine

Vladimir Krasnov

FSUE NAMI

PhD

Northumbria University NEWCASTLE · NAMI · Newcastle University · University of Sunderland · BRITISH COUNCIL

Local heat exchange issue

Piston engine – the main consumer of C_xH_y fuels and the main pollutant of environment.

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Most effective and ecological - CH_4 (1nd stage) and H_2 (2nd stage)

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New heat exchange and workflow conditions – new heat stress statement of engine parts

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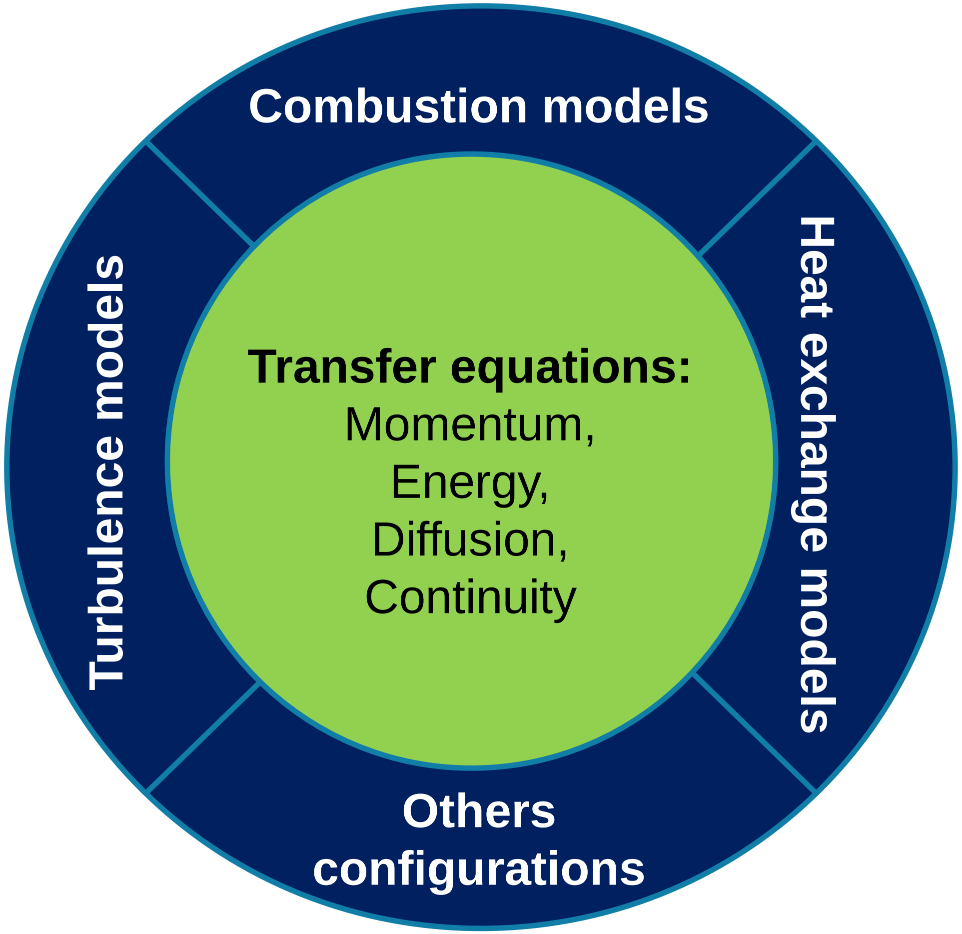
Most effective and ecological - CH_4 (1nd stage) and H_2 (2nd stage)

New heat exchange and workflow conditions – new heat stress statement of engine parts

Local heat exchange of converted engines should be researched

Workflow mathematic model

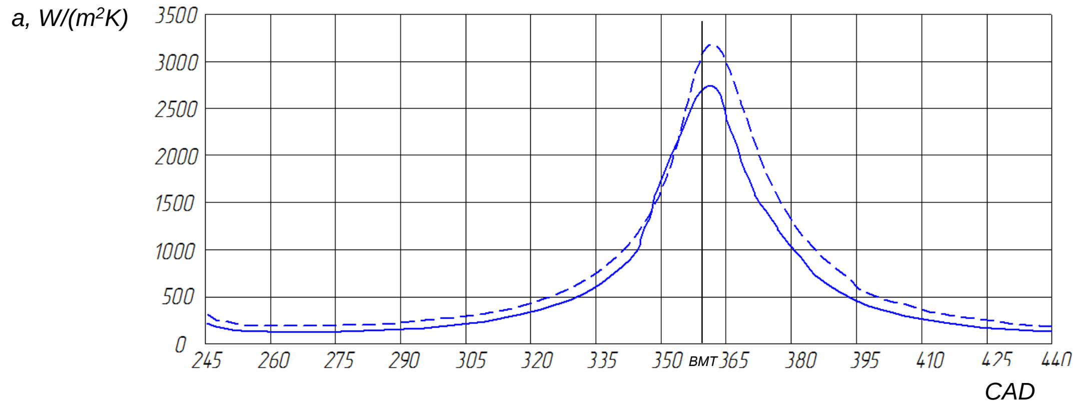


3D CFD-code FIRE, by AVL List GmbH.
Advanced algorithm SIMPLE, developed (by B. Spalding)

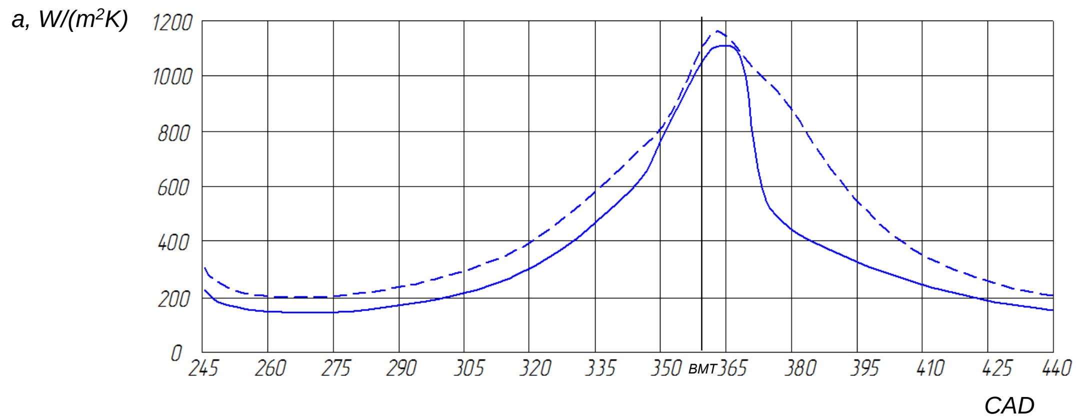
AVL

Comparison of values of averaged over the surface area of the cylinder cover heat transfer coefficients for basic and hydrogen diesel engines

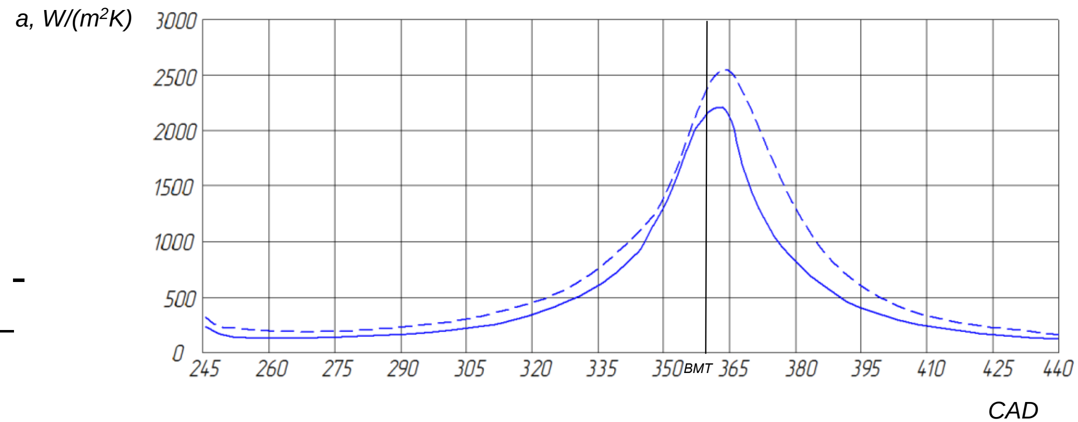
Head



Liner



Piston

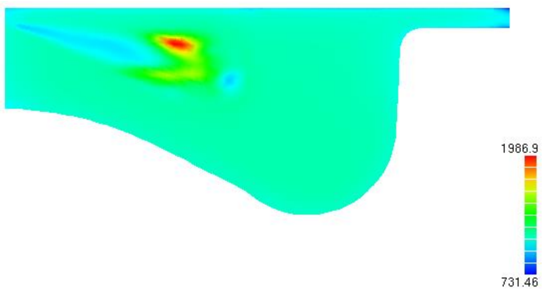


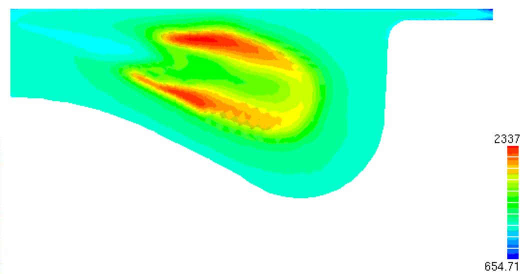
Hydrogen diesel engine - - -

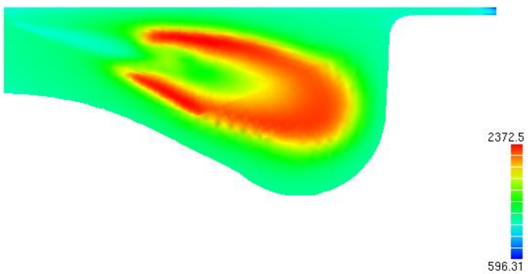
Basic diesel engine ———

Comparison of the temperature fields of the basic diesel engine and the hydrogen analogue with different CAD

basic diesel engine

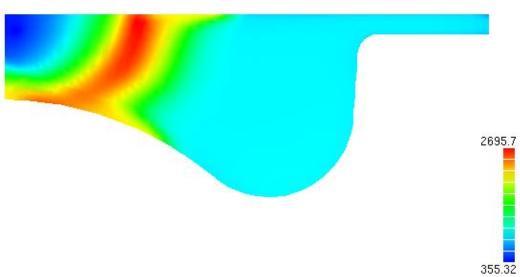


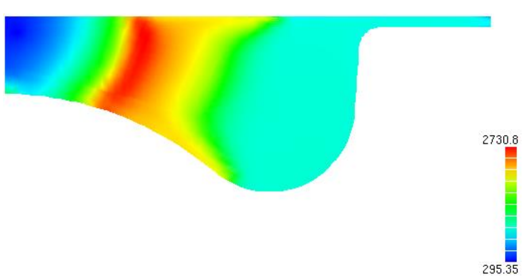


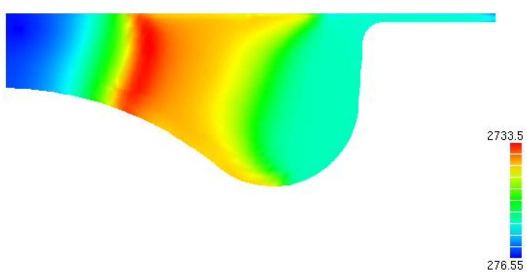


$\varphi = 350^{o}$ $\varphi = 355^{o}$ $\varphi = 360^{o}$

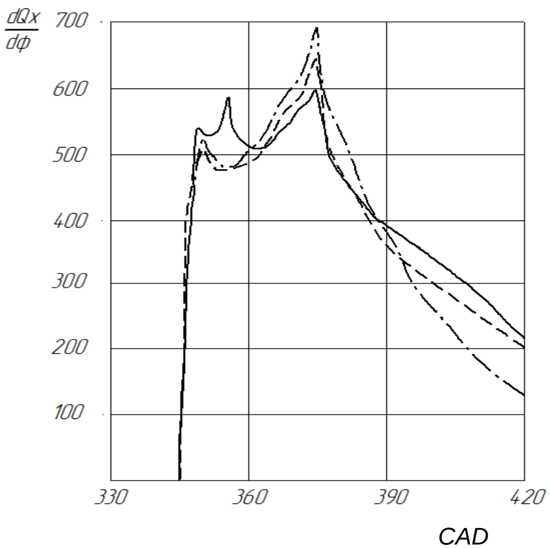
hydrogen analogue



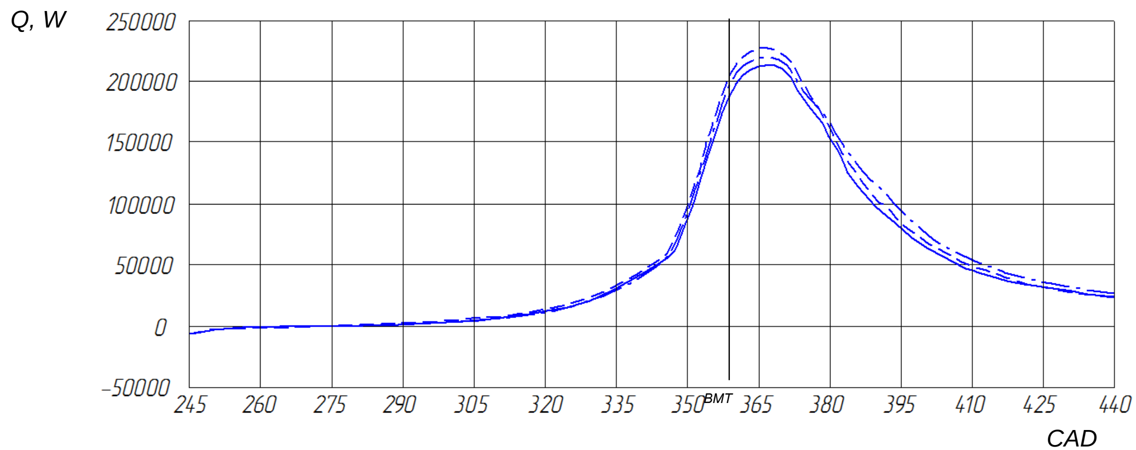




The effect of the intensity of the swirl number in a cylinder on the local heat exchange of a hydrogen diesel



Change in heat release rate

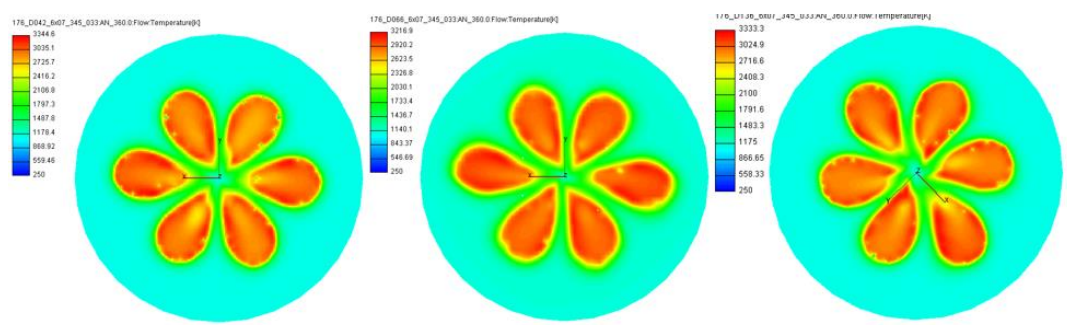


The total heat flux into the walls of the combustion chamber of a hydrogen diesel engine

——————— $D_{n\ cp}$ = 0,42

— — — — $D_{n\ cp}$ = 0,66

— · — · — $D_{n\ cp}$ = 1,36;

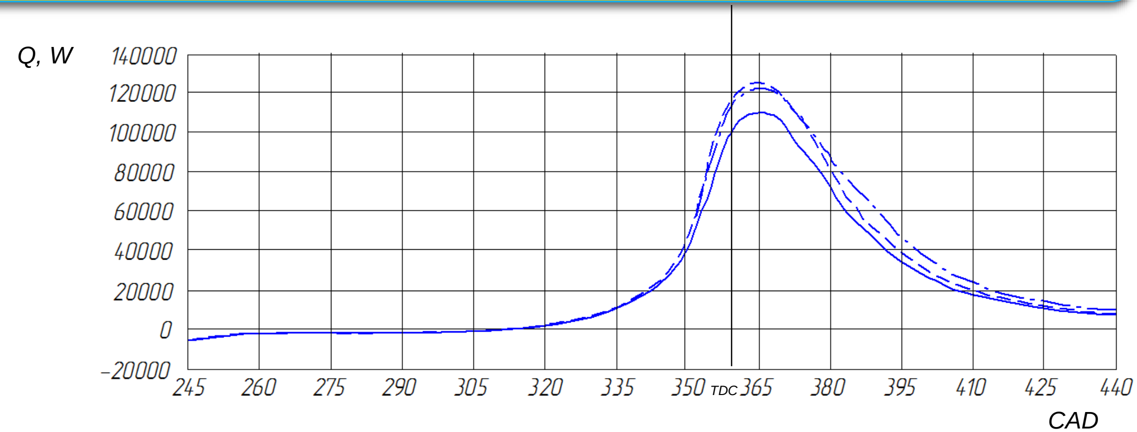


$D_{n\ cp}$ = 0,42; $D_{n\ cp}$ = 0,66; $D_{n\ cp}$ = 1,36.

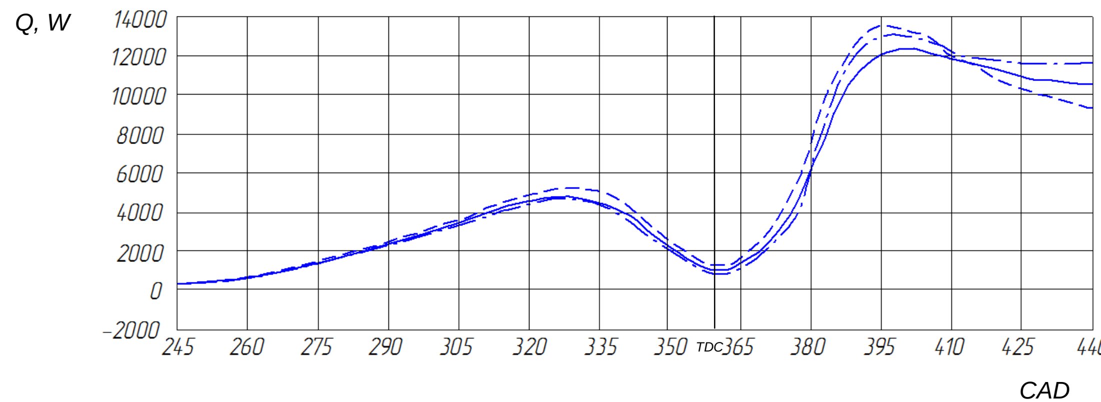
Temperature fields for φ= 360º

The effect of the intensity of the swirl number on the total area heat flows in hydrogen diesel engine

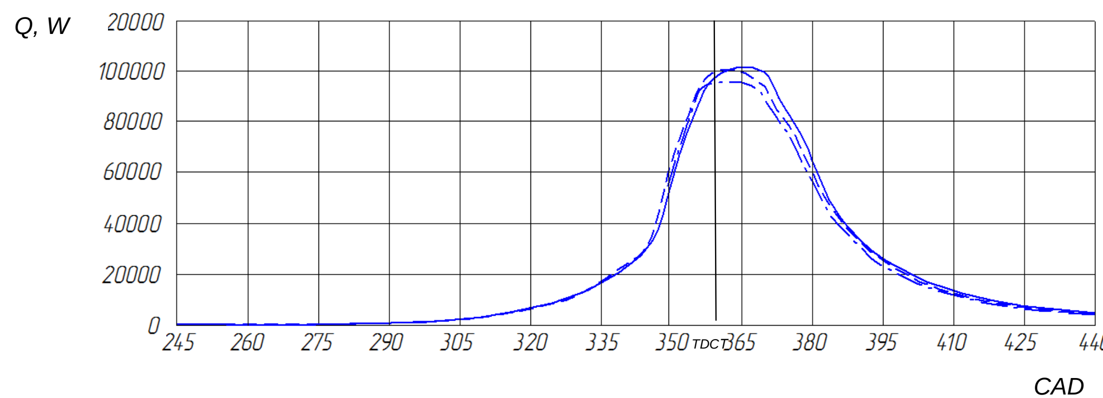
Piston



Liner



Head

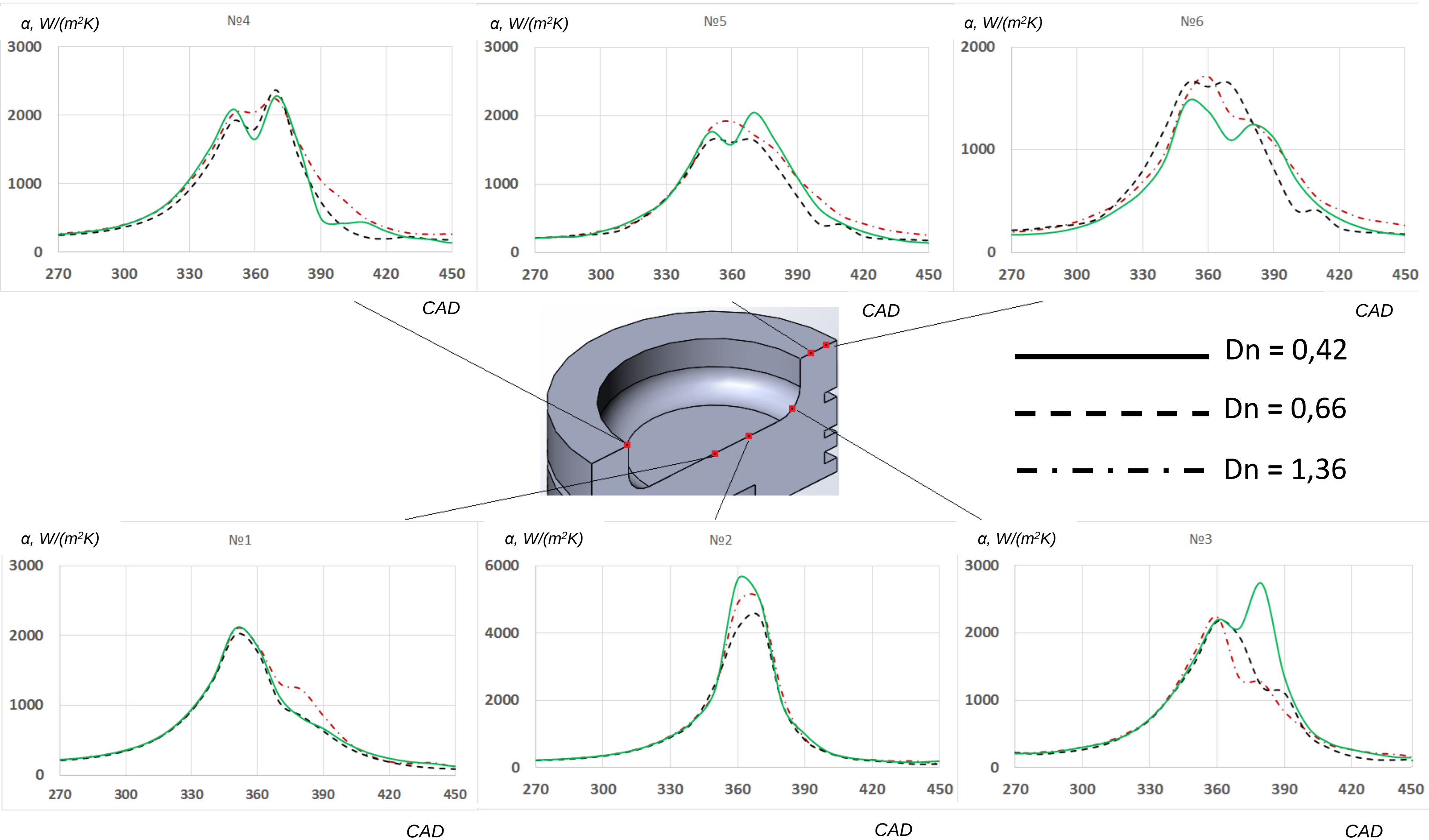


———— $D_n = 0{,}42$

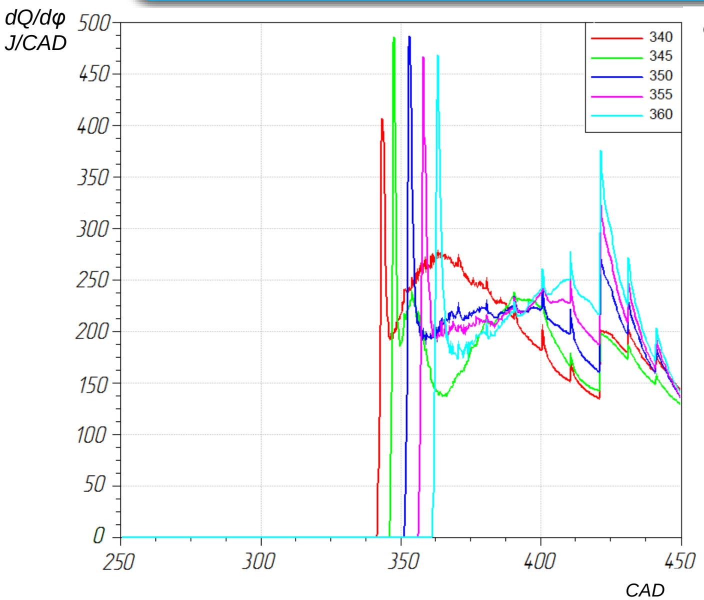
– – – – $D_n = 0{,}66$

– · – · $D_n = 1{,}36$

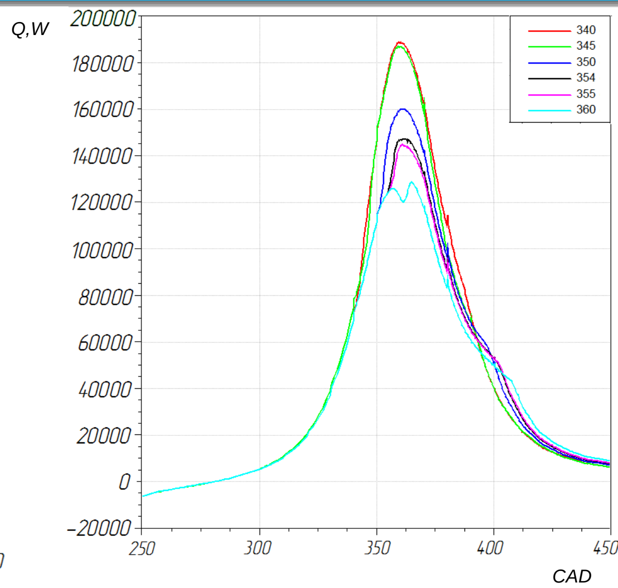
Local heat transfer coefficients on the piston surface depending on the swirl number



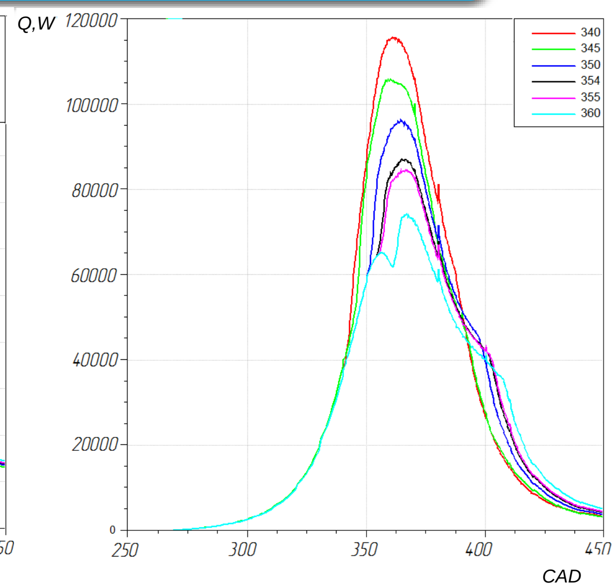
The influence of the injection advance angle on the local heat transfer of a hydrogen diesel engine



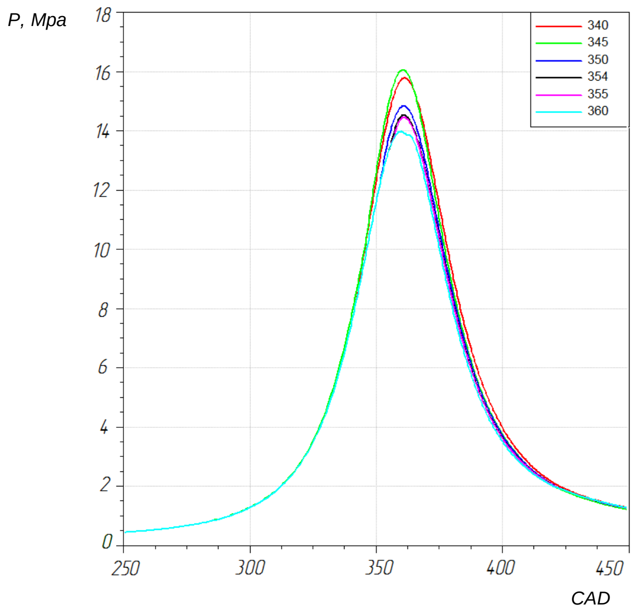
Heat release



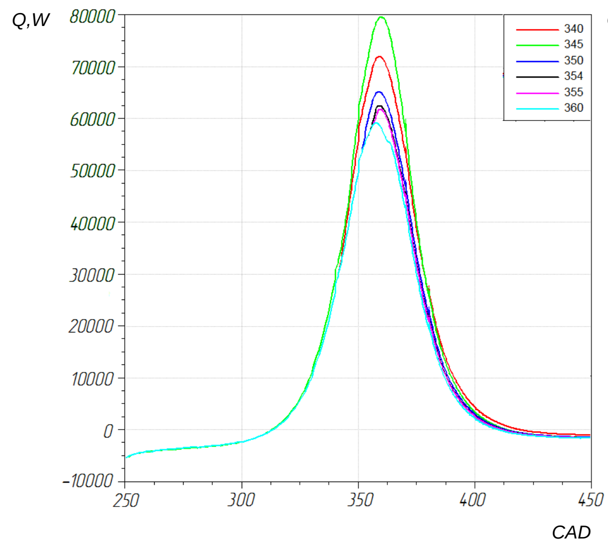
Total heat flux



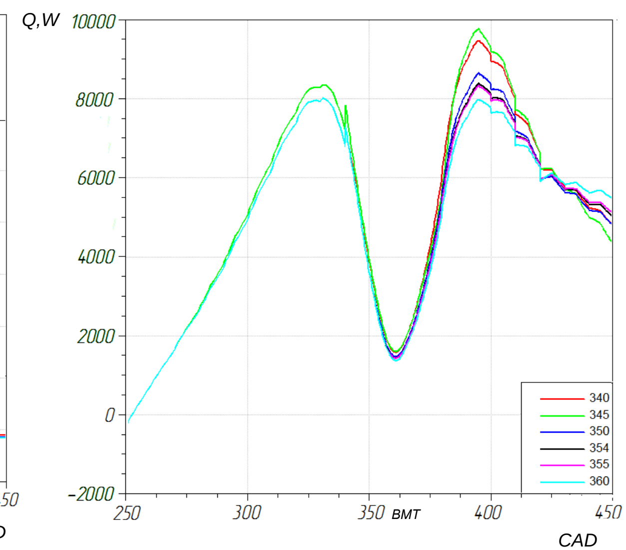
Head heat flux



Indicator diagrams



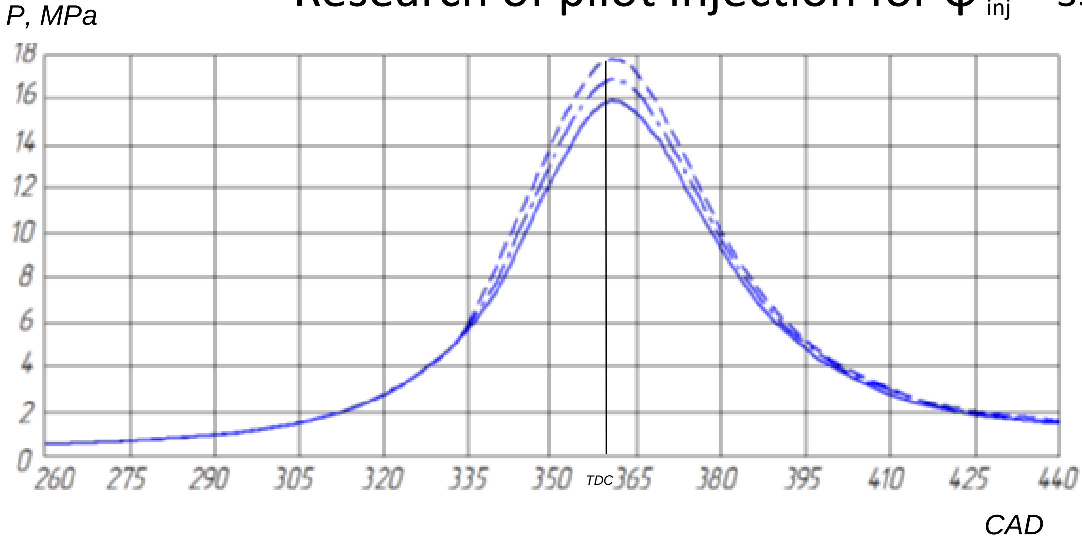
Piston heat flux



Liner heat flux

The effect of hydrogen pilot injection on local heat transfer of a hydrogen diesel

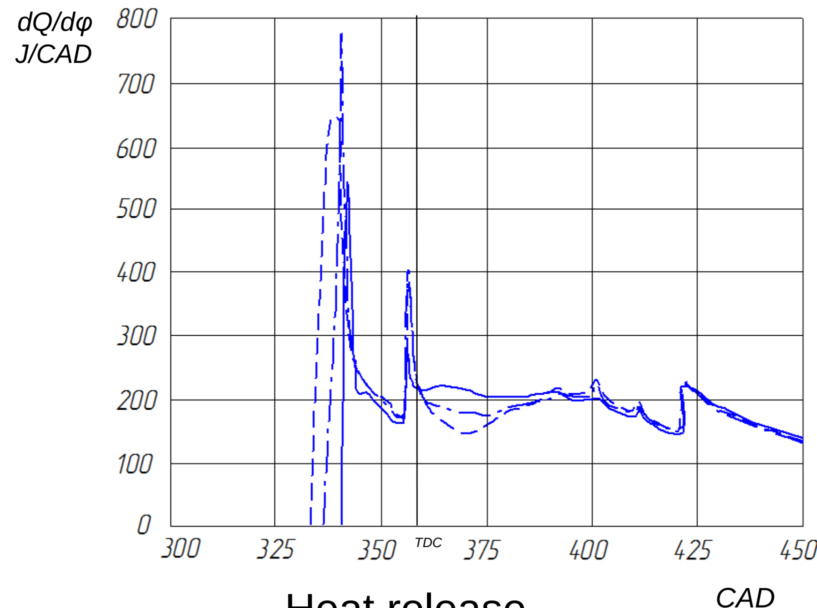
Research of pilot injection for $\varphi_{inj} = 354^o$



Indicator diagrams

$\varphi_{p.inj}=330^o$ (- - -)
$\varphi_{p.inj}=334^o$ (–·–)
$\varphi_{p.inj.}=338^o$ (——)

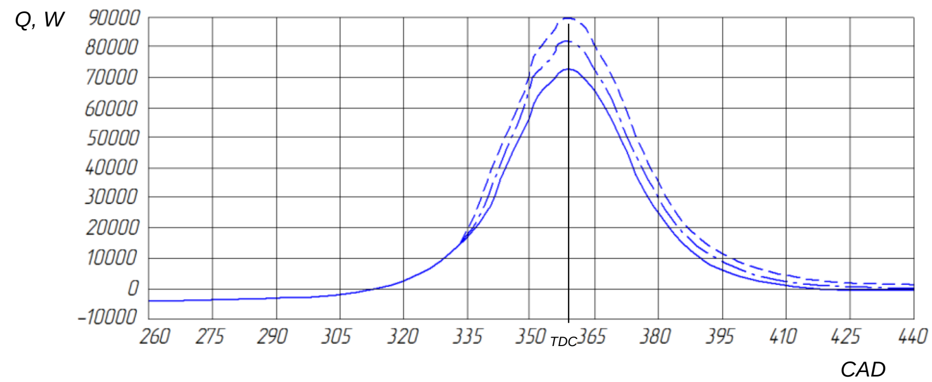
Main injection start angle φ_{inj}, CAD	6		
Pilot injection portion	20%		
Pilot injection duration $\Delta\varphi_{p.inj}$	8		
Pilot injection start $\varphi_{p.inj}$, CAD	330	334	338



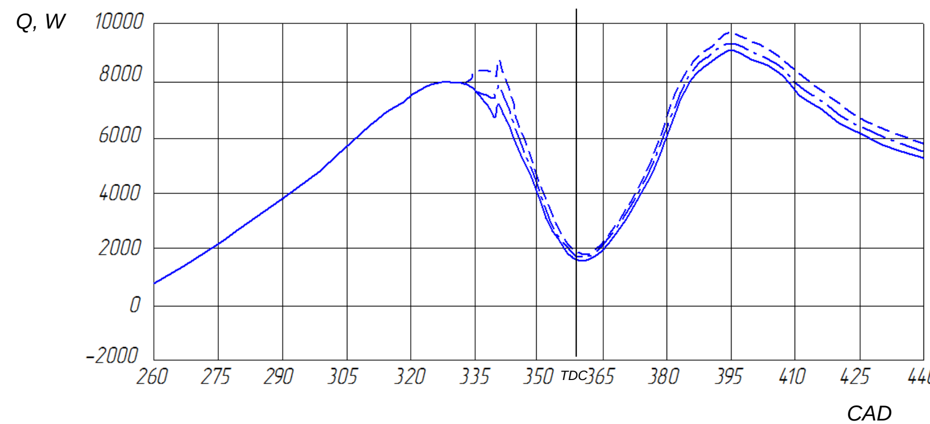
Heat release

Impact of hydrogen pilot injection on local heat transfer in hydrogen diesel engine

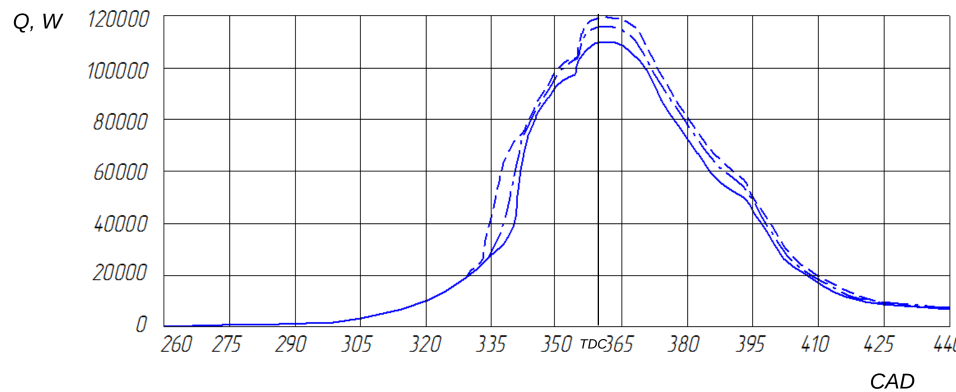
Piston heatflow



Liner heatflow



Head heatflow

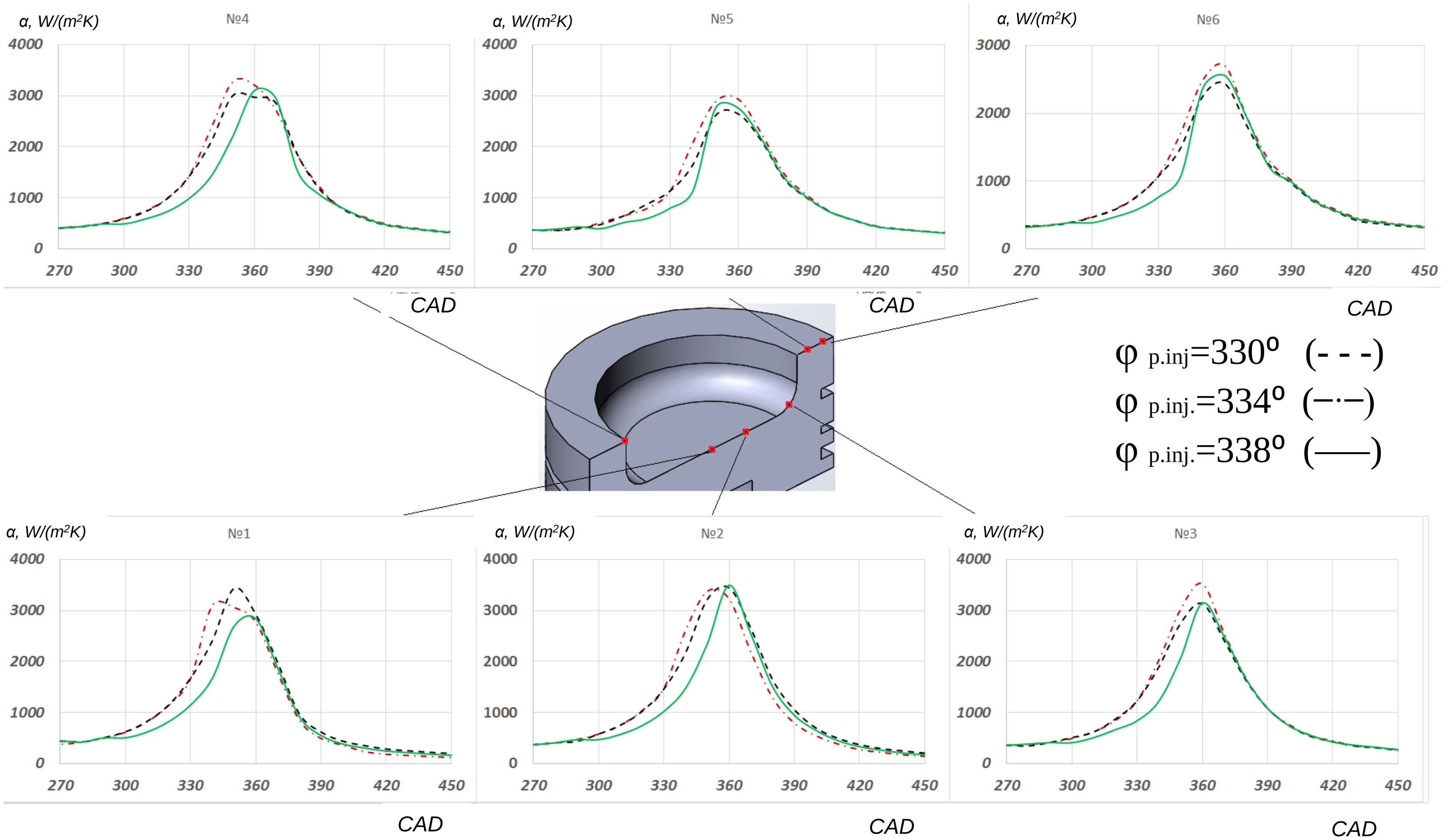


$\varphi_{p.inj}=330^o$ (- - -)

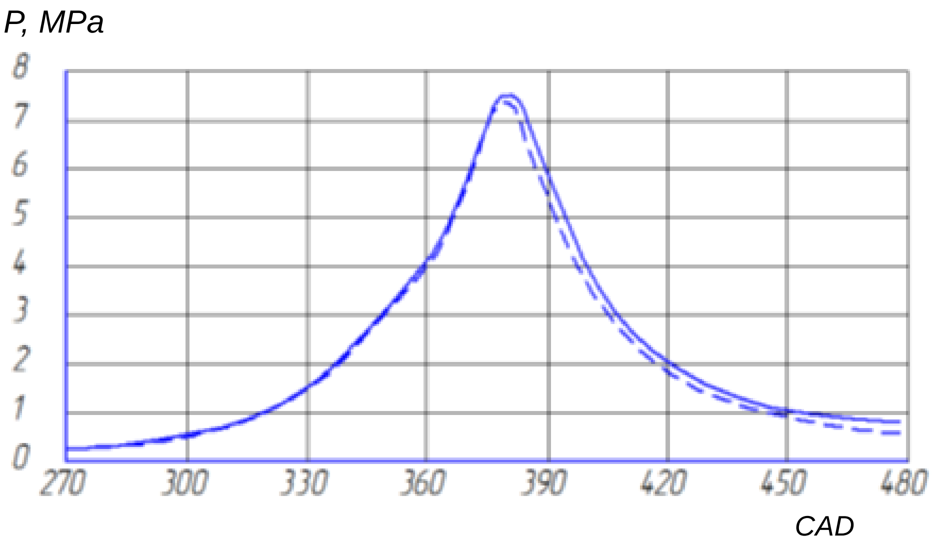
$\varphi_{p.inj.}=334^o$ (−·−)

$\varphi_{p.inj.}=338^o$ (——)

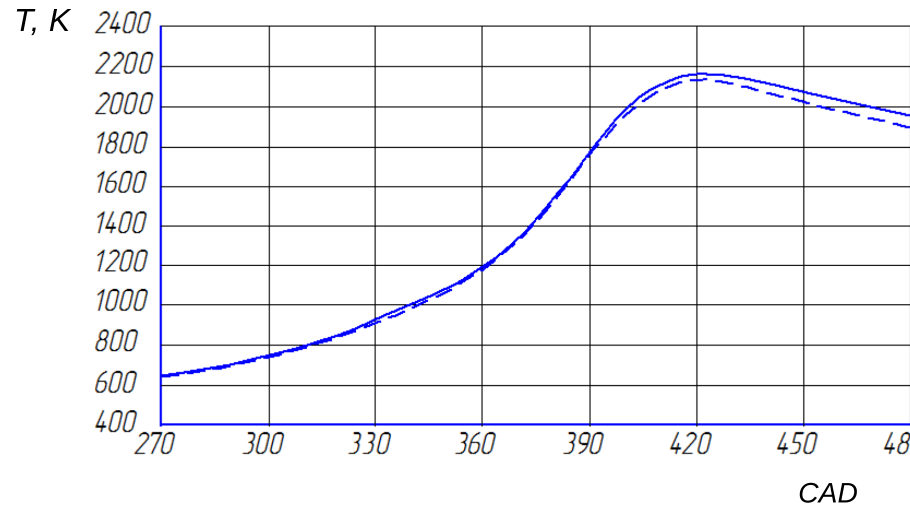
Local heat transfer coefficients on the surface of the piston depending on the moment of pilot injection of hydrogen



Computational and experimental study of the working process and local heat exchange in the combustion chamber of gas and hydrogen engines with spark ignition converted to hydrogen



Comparison of the calculated and experimental indicator diagrams of a gas engine with spark ignition

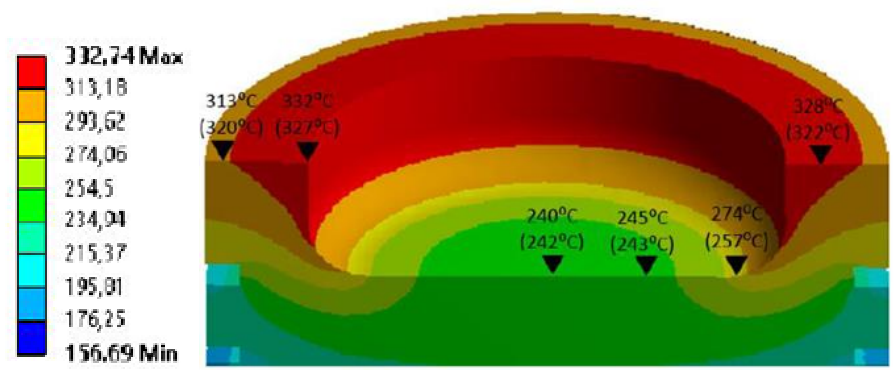


Comparison of average-mass temperature charts with spark ignition

Simulation (——) Experiment (- - -)

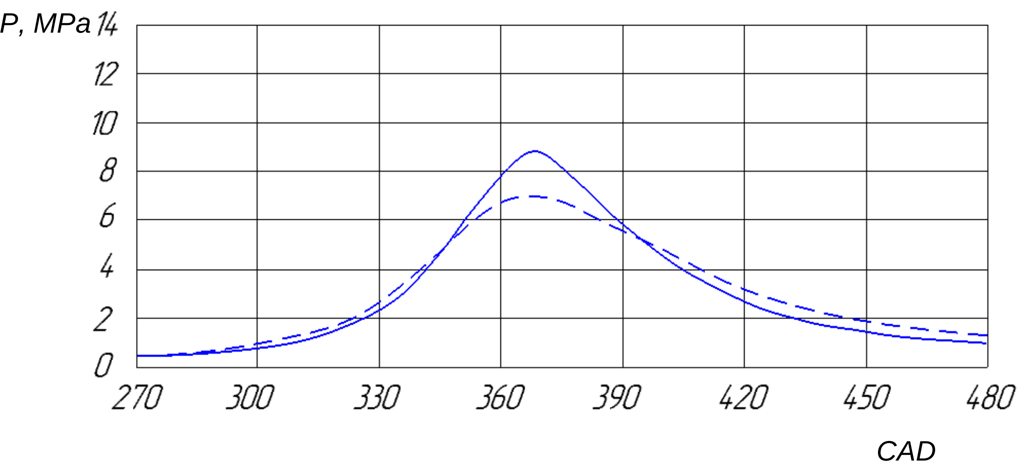
Cylinder diameter *D*, mm	120
Stroke *S*, mm	120
Frequency *n*, min $^{-1}$	2200
Compression ration ε	11,53
Boost pressure p_k, bar	1,5
Injection start angle φ_{inj} [CAD to TDC]	24
Equivalence ratio, α	1,33

Spark ignition gas engine parameters

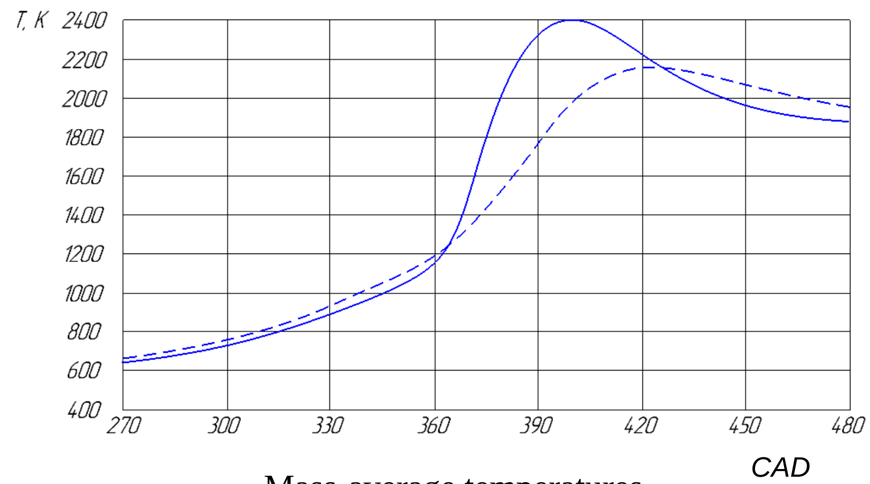


Piston temperature field for spark ignition gas engine

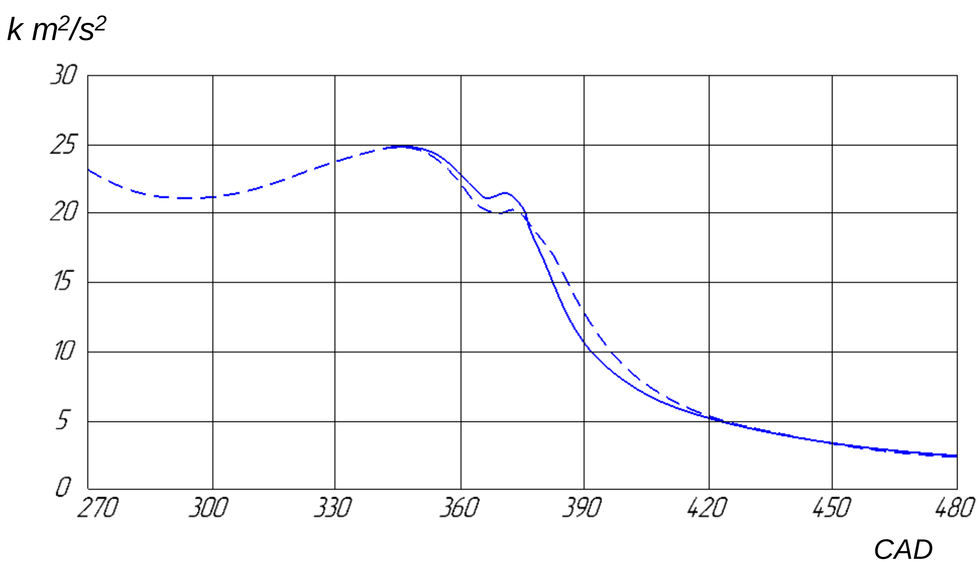
Computational experimental research of workflow and local heat exchange in combustion chambers of natural gas engine and hydrogen engine with spark ignition



Indicator diagrams



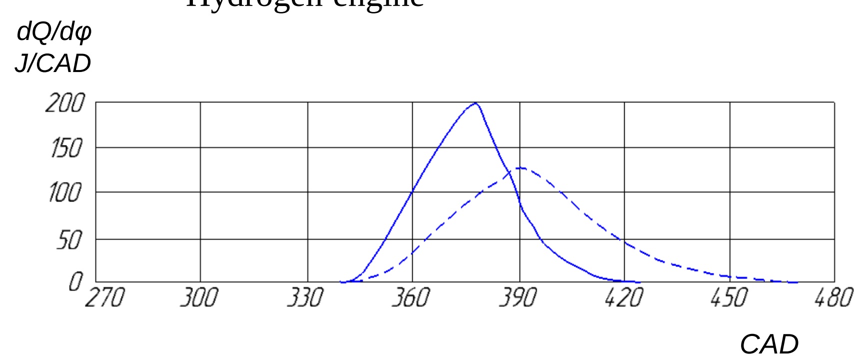
Mass-average temperatures



The change in the average kinetic energy of turbulence in the combustion chamber of a gas engine and a hydrogen engine

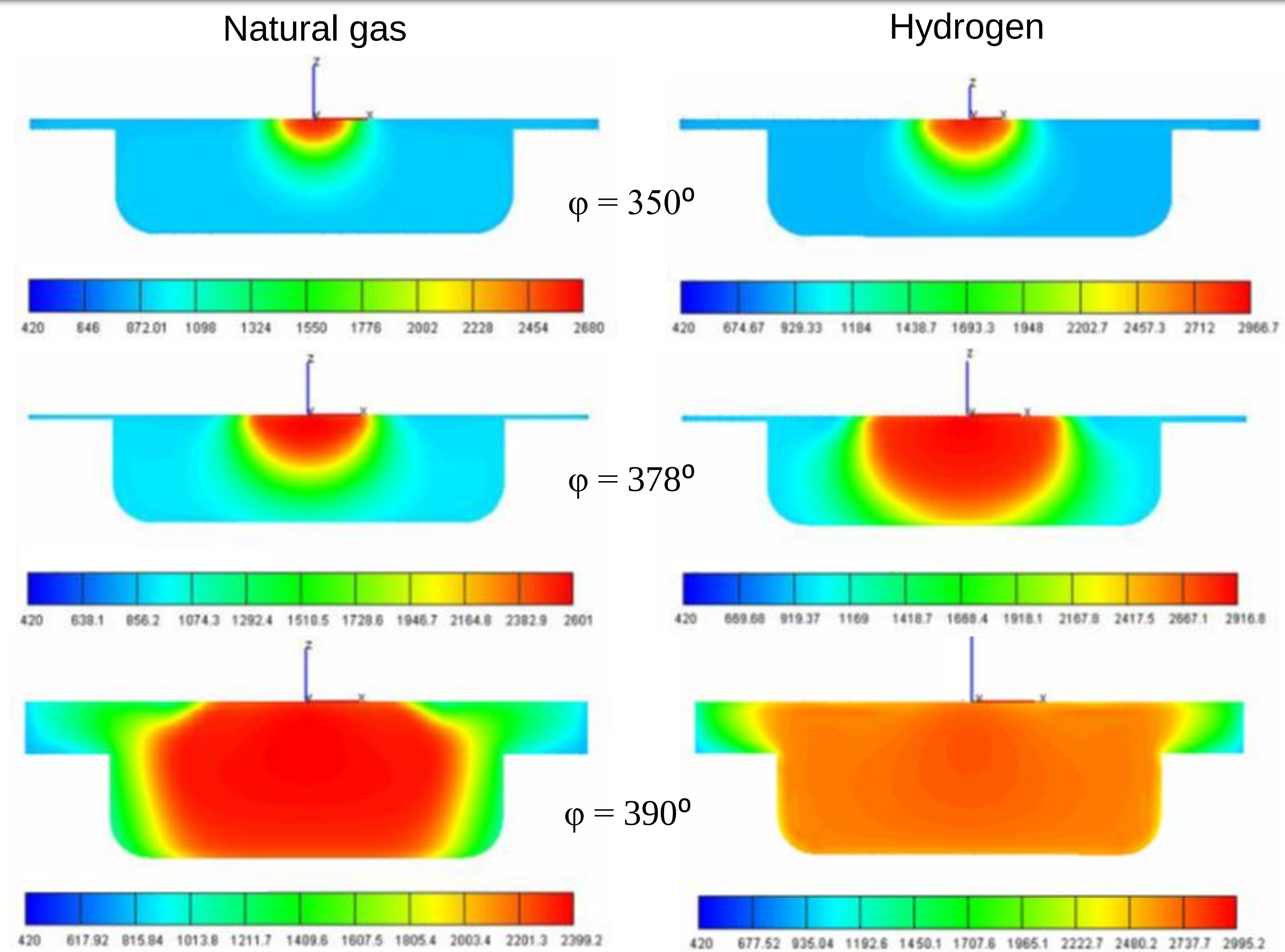
Natural gas engine - - -

Hydrogen engine ———

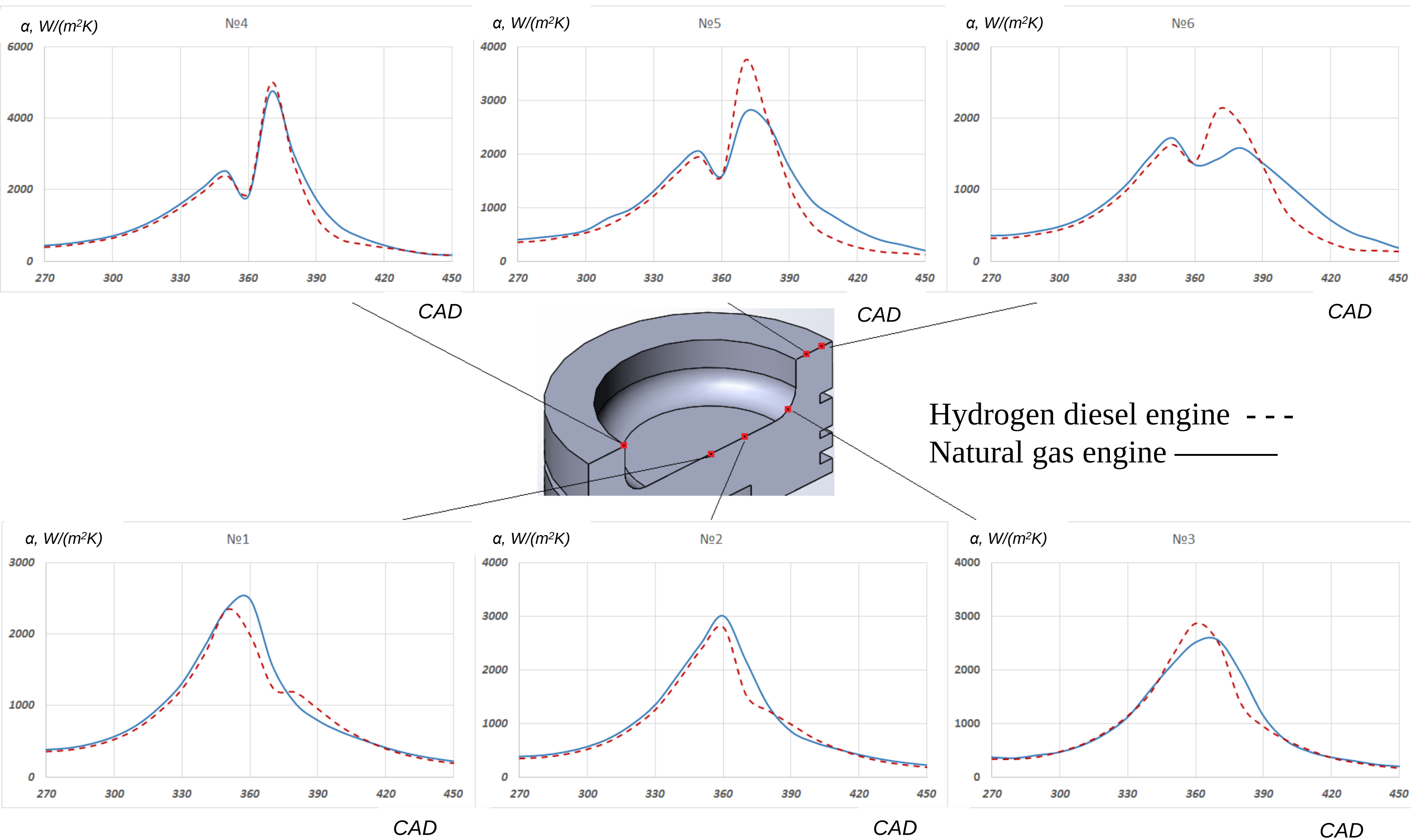


Heat release diagrams for gas engine and hydrogen engine

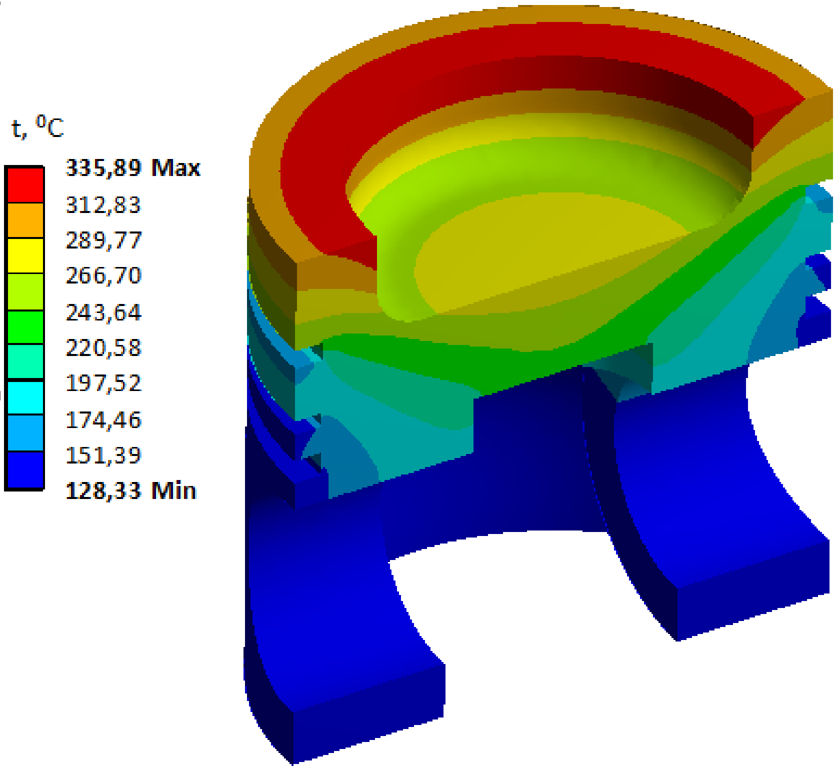
Temperature fields (K) of working fluid in combustion chamber for natural gas and hydrogen



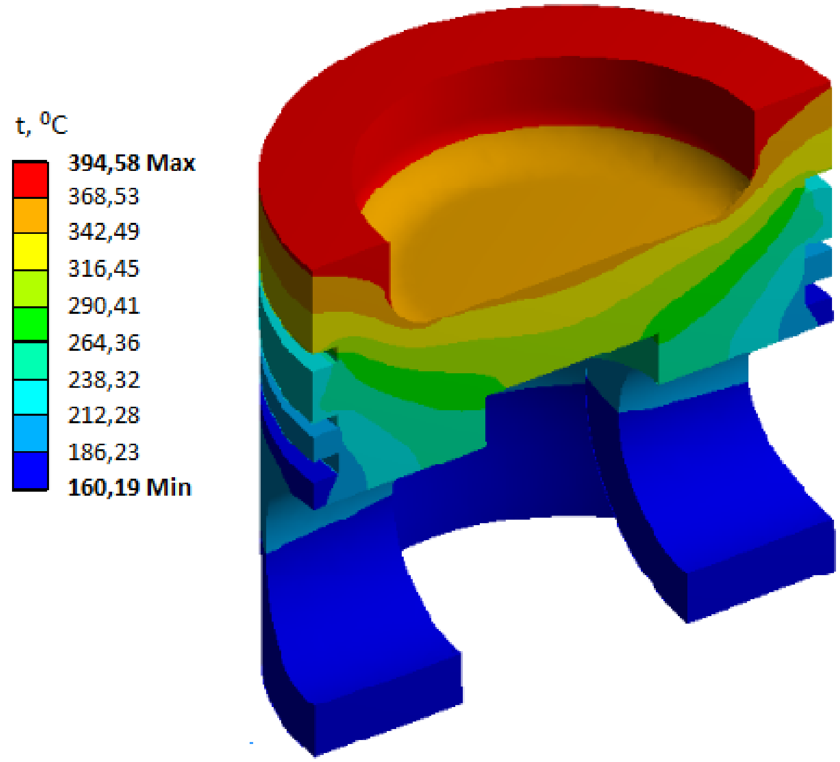
Natural gas engine and hydrogen diesel engine local heat flows comparison



Natural gas engine and hydrogen diesel engine temperature fields comparison



Natural gas engine



Hydrogen diesel engine

Due to relatively high temperatures around the upper compression ring (243-266°C - natural gas and 264-290°C -hydrogen), it is problematic to use as a lubricant mineral oils.

Summary

- Research of local heat exchange is necessary in case of converting to alternative fuels

- Reducing the compression ratio compared to the base diesel when converting to natural gas and hydrogen is necessary to prevent detonation.

- In General, a hydrogen-converted engine experiences higher thermal loads than a gas engine

- Introduce more intensive piston cooling in hydrogen engine compared to the base diesel

- New construction and lubricant materials should be selected for hydrogen engine

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Thank you for your attention

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