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List of Acronyms

ARC .... *Active Radical Combustion*

ASC .... *Ammonia Slip Catalyst*

ATAC .... *Active Thermo-Atmosphere Combustion*

ATS .... *After-treatment System*

BAS .... *Belt Alternator Starter*

BEV .... *Battery Electric Vehicle*

BMEP .... *Brake Mean Effective Pressure*

BSCO .... *Brake Specific CO Emissions*

BSFC .... *Brake Specific Fuel Consumption*

BSG .... *Belt-driven Starter Generator*

BSHC .... *Brake Specific Hydrocarbons Emissions*

$BSNO_x$ .... *Brake Specific NO_x Emissions*

BSPM .... *Brake Specific Particulate Matter Emissions*

BSPN .... *Brake Specific Particle Number Emissions*

$C_{10}H_{22}$ .... *Decane*

C_2H_4 .... *Ethylene*, from the group of alkenes

C_2H_6 .... *Ethane*, from the group of alkanes

C_3H_6 .... *Propene*, from the group of alkenes

1,3-C_4H_6 ...... *Butadiene*, from the group of allenes

C_6H_6 .... *Benzene*, an aromatic hydrocarbon

C_7H_8 .... *Toluene*, an aromatic hydrocarbon

C_8H_{18} .... *2,2,4-Trimethylpentane*, also referred to as *Isooctane*

CA_{10} .... *Crank Angle Degree at which 10% of combustion has occurred. Normally associated with combustion start*

CA_{50} .... *Crank Angle Degree at which 50% of combustion has occurred. Normally referred to as combustion phasing*

CA_{90} .... *Crank Angle Degree at which 90% of combustion has occurred. Normally associated with combustion end*

CACG .... *Crank Angle Degree of the combuston Center of Gravity. Normally referred to as the combustion centroid*

CAD .... *Crank Angle Degree*

CARB .... *California Air Resources Board*

CCS .... *Carbon Capture and Storage*

CDC .... *Conventional Diesel Combustion*

CFD .... *Computational Fluid Dynamics*

CH_3CHO ..... *Acetaldehyde*, from the aldehyde group

CH_3COCH_3 .. *Acetone*, from the group of ketones

CH_4 .... *Methane*

CI............. *Compression Ignition Engine*

CIHC .... *Compression-Ignited Homogeneous Charge*

CLS .... *Chemiluminescence Detection*

CNG .... *Compressed Natural Gas*

CO .... *Carbon Monoxide*

CO_2 .... *Carbon Dioxide*

CPC .... *Condensation Particle Counter*

CR .... *Compression Ratio*

DACC .... *Direct Air Carbon Capture*

DAQ .... *Data Acquisition System*

DDFS......... *Direct Dual Fuel Stratification*

DEF .... *Diesel Exhaust Fluid*

DI............. *Direct Injection System*

DI-HCCI ..... *Direct Injection Homogeneous Charge Compression Ignition*

DMA .... *Differential Mobility Analyzer*

DMDF........ *Dual-Mode Dual-Fuel*

DME.......... *Dimethyl Ether*

DOC.......... *Diesel Oxidation Catalyst*

DPF .... *Diesel Particulate Filter*

EAS .... *Electrical Aerosol Spectrometer*

ECU .... *Engine Control Unit*

EEPS......... *Engine Exhaust Particle Sizer*

EGR.......... *Exhaust Gas Recirculation*

EHC .... *Electrically Heated Catalyst*

EPA .... *Environmental Protection Agency*

ESC........... *European Stationary Cycle*

FCV .... *Fuel Cell Vehicle*

FFT .... *Fast Fourier Transform*

FHEV .... *Full Hybrid Electric Vehicle*

FID........... *Flame Ionization Detector*

FIS .... *Fuel Injection System*

FPGA .... *Field-Programmable Gate Arrays*

FSN........... *Filter Smoke Number*

FTIR......... *Fourier Transform InfraRed Spectroscopy*

FTP .... *Federal Test Procedure*

GA............ *Genetic Algorithm*

GCI........... *Gasoline Compression Ignition*

GDCI .... *Gasoline Direct Compression Ignition*

GF .... *Gasoline Fraction*

GHG .... *Greenhouse Gases*

GMD .... *Geometric Mean Diameter*

GPF .... *Gasoline Particulate Filter*

H_2 .... *Hydrogen*

H_2O .... *Water*

HC .... *Hydrocarbon species*

HCCI .... *Homogeneous Charge Compression Ignition*

HCHO .... *Formaldehyde*, from the group of aldehydes

HCOOH ...... *Formic Acid*

HEV .... *Hybrid Electric Vehicle*

HiMICS .... *Homogeneous charge intelligent Multiple Injection Combustion System*

HP-EGR ...... *High Pressure Exhaust Gas Recirculation*

HPDI .... *High Pressure Direct Injection*

HRF .... *High Reactivity Fuel*

HVO .... *Hydrogenated Vegetable Oil*

ICCI .... *Inteligent Control Compression Ignition*

ICE .... *Internal Combustion Engine*

IMEP .... *Indicated Mean Effective Pressure*

iso-C_4H_8 ...... *Isobutylene*, an olefin from the alkene group

JCCI .... *Jet Controlled Compression Ignition*

LCA .... *Life Cycle Analysis*

LHV .... *Lower Heating Value*

LMTD .... *Logarithmic Mean Temperature Difference*

LP-EGR ...... *Low Pressure Exhaust Gas Recirculation*

LPG .... *Liquefied Petroleum Gas*

LRF .... *Low Reactivity Fuel*

LTC .... *Low Temperature Combustion*

LTDC......... *Low Temperature Diesel Combustion*

MCE.......... *Multi-Cylinder Engine*

MHEV........ *Mild Hybrid Electric Vehicle*

MKC.......... *Modulated Kinetics Combustion*

MPD.......... *Magneto-Pneumatic Detector*

MULDIC ..... *MULtiple stage DIesel Combustion*

N_2............. *Nitrogen*

N_2O........... *Nitrous Oxide*

NADI......... *Narrow Angle Direct Injection*

NDA .... *Non-Disclosure Agreement*

NDIR......... *Non-Dispersive Infrared*

NET .... *Not Exceed Threshold*

NH_3........... *Ammonia*

NMOG .... *Non-Methane and Oxygenated Hydrocarbons*

NO............ *Nitrogen Monoxide*

NO_2........... *Nitrogen Dioxide*

NO_x........... *Oxides of Nitrogen*

O_2............. *Oxygen*

O_3............. *Ozone*

ODE.......... *Ordinary Differential Equation*

OEM.......... *Original Equipment Manufacturer*

OME_x .... *Polyoxymethylene Dimethyl Ethers*

PAH .... *Polycyclic Aromatic Hydrocarbons*

PCCI .... *Premixed Charge Compression Ignition*

PCI . . . . *Premixed Compression Ignited combustion*

PDF . . . . *Probability Density Function*

PER . . . . *Premixed Energy Ratio*

PFI . . . . *Port Fuel Injection System*

PHEV . . . . *Plug-in Hybrid Electric Vehicle*

PID . . . . *Proportional - Integral - Differential*

PM . . . . *Particulate Matter*

PMEP . . . . *Pumping losses Mean Effective Pressure*

PN . . . . *Particulate Number*

PPCI . . . . *Partially Premixed Compression Ignition*

PPLCCI . . . . . . *Partially Premixed Lean Charge Compression Ignition*

PREDIC . . . . . . *PREmixed DIesel Combustion*

PRR . . . . *Pressure Rise Rate*

PSD . . . . *Particle Size Distribution*

RCCI . . . . *Reactivity-Controlled Compression Ignition*

RDE . . . . *Real Driving Emissions*

RoHR . . . . *Rate of Heat Release*

RON . . . . *Research Octane Number*

SCCI . . . . *Stratified Charge Compression Ignition*

SCE . . . . *Single-Cylinder Engine*

SCR . . . . *Selective Catalyst Reducer*

SET . . . . *Supplemental Emissions Test*

SGCI . . . . *Stratified Gasoline Compression Ignition*

SI . . . . *Spark Ignition Engine*

SMD . . . . *Sauter Mean Diameter*

SMPS . . . . *Scanning Mobility Particle Sizer*

SMR . . . . *Steam Methane Reforming*

SO_2 .... *Sulphur Dioxide*

SOC .... *State of Charge*

SOF .... *Soluble Organic Fraction*

SoI .... *Start of Injection*

SPCCI .... *Spark-Controlled Compression Ignition*

SPPCCI .... *Spark-Controlled Premixed Compression Ignition*

TCO .... *Total Cost of Ownership*

TDC .... *Top Dead Center*

THC .... *Total Hydrocarbons*

TRL .... *Technology Readiness Level*

TSC .... *Toyota-Soken Combustion*

TSCI .... *Thermally Stratified Compression Ignition*

TtW .... *Tank to Wheel*

UHC .... *Unburned Hydrocarbons*

UNIBUS .... *UNIform BUlky combustion System*

VGT .... *Variable Geometry Turbine*

VVL .... *Variable Valve Lift*

VVT .... *Variable Valve Time*

WHSC .... *World Harmonized Stationary Cycle*

WHTC .... *World Harmonized Transient Cycle*

WHVC .... *World Harmonized Vehicle Cycle*

WI .... *Water Injection*

WtT .... *Well to Tank*

WtW .... *Well to Wheel*

List of Symbols

The following list of symbols, letters, and subindexes serve as a general guide. Specific nomenclature may be used on cited formulas. Specific explanations and references provided in the manuscript must be consulted for an adequate interpretation of symbols and equations.

Latin Letters

a	Acceleration	$\mathrm{m\,s^{-2}}$
A	Area	$\mathrm{m^2}$
B	Magnetif fueld strenght	$\mathrm{A\,m^{-1}}$
$BSFC$	Brake Specific fuel consumption	$\mathrm{g\,kW^{-1}\,h}$
$[c]$	Gas concentration	$\mathrm{mol\,m^{-3}}$
c_{bb}	Discharge coeffient for blow-by massflow	
c_m	Piston average speed	$\mathrm{m\,s^{-1}}$
c_D	Discharge coefficient	
c_p	Constant-pressure specific heat	$\mathrm{J\,mol^{-1}\,K^{-1}}$
c_v	Constant-volume specific heat	$\mathrm{J\,mol^{-1}\,K^{-1}}$
C	Carbon or soot concentration	$\mathrm{mg/m^3}$
d	Valve diameter	m
D	Piston diameter	m
D_p	Particle diameter	m
E	Young modulus	m
E_a	Activation energy	$\mathrm{kJ\,mol^{-1}}$
F	Force	N
$G(i)$	Inhibition function in Langmuir-Hinshelwood reaction model	
h	Specific enthalpy	$\mathrm{kJ\,kg^{-1}}$
h_exh	Intake port convective heat transfer coeffcient	$\mathrm{W/m^2K}$
h_int	Exhaust port convective heat transfer coeffcient	$\mathrm{W/m^2K}$
h_w	In-cylinder convective heat transfer coeffcient in Woschni model	$\mathrm{W/m^2K}$

H	Enthalpy	kJ
I	Irradiance or infrared light intenity	W/m^2
k	Absorption coefficient	m^-1
k_{th}	Thermal conductivity	$W\,m^{-1}\,K$
k_{sp}	Constant for spray velocity profile in gaussian distribution	
K_{def}	Piston deformation coefficient	
K_{eq}	Equiilibrium constant for NO oxidaton	
K_{soot}	Correlation coefficient in the soot formation model	
L	Lenght	m
L_i	Noise level on an octave third	dB
LHV	Lower heating value	$MJ\,kg^{-1}$
m	Mass	kg
$\dot{m}$	Mass flow rate	$kg\,h^{-1}$
MW	Molar weight	$g\,mol^{-1}$
n	Engine speed	rpm
N	Turbocharger speed	rpm
N_o	Opacity	%
p	Partial pressure	Pa
p_s	saturation vapor pressure	Pa
P	Pressure, normally used for in-cylinder pressure	bar
P_{inj}	Common rail injection pressure	bar
P^*	Critical pressure	bar
$P^{ž}$	Vapor pressure	Pa
Q	Heat	J
$\dot{Q}$	Heat flow rate	W
r	Radius	m
S	Stroke	m
T	Temperature	K
T_a	Reaction activation temperature	K
u	Gas velocity	$m\,s^{-1}$
v	Volume	m^3
$\dot{v}$	Volume flow rate	m^3/s
V	Voltage	V
W	Total work	kJ
$\dot{W}$	Power	kW
y	Combustion chamber height	m
Y	Mass fraction	
Z_p	Particle electrical mobility	m^2/Vs

Greek Letters

α	Crank angle	CAD
α_{th}	Thermal diffusivity	m^2/s
α_g	Absorption coefficient of a gas	$m\,mol^{-1}$
β	Ratio of con-rod mechanism	
γ	Ratio of heat capacities or isentropic exponent	
Δ	Difference, change, drop or increment	
$\Delta\alpha$	TDC angle correction	CAD
ε	Emisivity coefficient	
η	Efficiency	%
θ	Response time delay	s
$\theta(n)$	Low-pass frequency filter window	
$\Theta(i)$	Coverage expression in Langmuir-Hinshelwood reaction model	
κ	Polytropic coefficient of a gas	
λ	Wavelength	m
μ	Dynamic viscosity	$kg\,m^{-1}\,s$
ν	Kinematic viscosity	mm^2/s
Π_{cc}	Cross-correlation coefficient	
ρ	Density	$kg\,m^{-3}$
σ	Liquid surface tension	$N\,m^{-1}$
τ	Characteristic time	s
χ	Molar fraction	
ω	Angular velocity	$rad\,s^{-1}$

Subindexes

0	Referred to standard or stall conditions
01	Referred to stall conditions at compressor inlet
02	Referred to stall conditions at compressor outlet
03	Referred to stall conditions at turbine inlet
04	Referred to stall conditions at turbine outlet
a, air	Referred to air
amb	Referred to ambient conditions
b	Referred to burned gases
bb	Referred to blow-by gases
cyl	Referred to in-cylinder conditions

EGR	Referred toEGR gases
eq	Referred to equivalent value or normalization
exh	Referred to exhasut conditions
$f, fuel$	Referred to fuel
ht	Referred to a heat trasnfer process
int	Referred to intake conditions
p	Referred to particles
ref	Reference value
res	Referred to residual gases
s	Referred to saturation conditions
sc	Referred to short-circuit gases
th	Referred to theoretical value
ub	Referred to unbured gases

Universal constant Numbers

e	Elmentary electrical charge	$1.602{\cdot}10^{-19}$ C
g	Gravity acceleration	9.81 m/s^2
h_p	Plan constant	$6.626{\cdot}10^{-34}$ J s
N_A	Avogadro constant	$6.022{\cdot}10^{23}$ mol^{-1}
R_u	Ideal gas constant	8.31446 J mol^{-1} K
π	Pi Number	3.1415952...
σ_{SB}	Stefan-Boltzman constant	$5.67{\cdot}10^{-8}$ W/m^{2}K^4

Non-dimensional Numbers

Da	Damköhler Numbner	$Da = \dfrac{L_T/I}{\delta_r/u_{CL}}$
Ka	Karlovitz Numbner	$Ka = \dfrac{\delta_r/u_{CL}}{\lambda_k/I}$
Le	Lewis Numbner	$Le = \dfrac{k_{th}}{C_p \rho D_{f-a}}$

Nu	Nusselt Numbner	$Nu = \frac{hL}{k}$
Pr	Prandtl Numbner	$Pr = \frac{c_p \mu}{k_{th}}$
Re	Reynolds Numbner	$Re = \frac{\rho u L}{\mu}$
Sc	Schmidt Numbner	$Sc = \frac{\mu}{\rho D_{f-a}}$
Sh	Sherwood Numbner	$Sh = \frac{K_c L}{D_{a-b}}$
Stk	Stokes Number	$\frac{\tau u_0}{d_p}$
We	Weber Number	$We = \frac{\rho_a u D}{\sigma_l}$