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List of Acronyms

ARC	<i>Active Radical Combustion</i>
ASC	<i>Ammonia Slip Catalyst</i>
ATAC.....	<i>Active Thermo-Atmosphere Combustion</i>
ATS.....	<i>After-treatment System</i>
BAS	<i>Belt Alternator Starter</i>
BEV	<i>Battery Electric Vehicle</i>
BMEP.....	<i>Brake Mean Effective Pressure</i>
BSCO.....	<i>Brake Specific CO Emissions</i>
BSFC.....	<i>Brake Specific Fuel Consumption</i>
BSG	<i>Belt-driven Starter Generator</i>
BSHC.....	<i>Brake Specific Hydrocarbons Emissions</i>
BSNO _x	<i>Brake Specific NO_x Emissions</i>
BSPM.....	<i>Brake Specific Particulate Matter Emissions</i>
BSPN.....	<i>Brake Specific Particle Number Emissions</i>
C ₁₀ H ₂₂	<i>Decane</i>
C ₂ H ₄	<i>Ethylene, from the group of alkenes</i>
C ₂ H ₆	<i>Ethane, from the group of alkanes</i>
C ₃ H ₆	<i>Propene, from the group of alkenes</i>
1,3-C ₄ H ₆	<i>Butadiene, from the group of allenes</i>
C ₆ H ₆	<i>Benzene, an aromatic hydrocarbon</i>
C ₇ H ₈	<i>Toluene, an aromatic hydrocarbon</i>

C_8H_{18}	<i>2,2,4-Trimethylpentane, also referred to as Isooctane</i>
CA_{10}	<i>Crank Angle Degree at which 10% of combustion has occurred. Normally associated with combustion start</i>
CA_{50}	<i>Crank Angle Degree at which 50% of combustion has occurred. Normally referred to as combustion phasing</i>
CA_{90}	<i>Crank Angle Degree at which 90% of combustion has occurred. Normally associated with combustion end</i>
CACG	<i>Crank Angle Degree of the combuston Center of Gravity. Normally referred to as the combustion centroid</i>
CAD	<i>Crank Angle Degree</i>
CARB	<i>California Air Resources Board</i>
CCS	<i>Carbon Capture and Storage</i>
CDC	<i>Conventional Diesel Combustion</i>
CFD	<i>Computational Fluid Dynamics</i>
CH_3CHO	<i>Acetaldehyde, from the aldehyde group</i>
CH_3COCH_3 ..	<i>Acetone, from the group of ketones</i>
CH_4	<i>Methane</i>
CI	<i>Compression Ignition Engine</i>
CIHC	<i>Compression-Ignited Homogeneous Charge</i>
CLS	<i>Chemiluminescence Detection</i>
CNG	<i>Compressed Natural Gas</i>
CO	<i>Carbon Monoxide</i>
CO_2	<i>Carbon Dioxide</i>
CPC	<i>Condensation Particle Counter</i>
CR	<i>Compression Ratio</i>
DACC	<i>Direct Air Carbon Capture</i>
DAQ	<i>Data Acquisition System</i>
DDFS	<i>Direct Dual Fuel Stratification</i>

DEF	<i>Diesel Exhaust Fluid</i>
DI.....	<i>Direct Injection System</i>
DI-HCCI	<i>Direct Injection Homogeneous Charge Compression Ignition</i>
DMA	<i>Differential Mobility Analyzer</i>
DMDF	<i>Dual-Mode Dual-Fuel</i>
DME.....	<i>Dimethyl Ether</i>
DOC.....	<i>Diesel Oxidation Catalyst</i>
DPF	<i>Diesel Particulate Filter</i>
EAS	<i>Electrical Aerosol Spectrometer</i>
ECU	<i>Engine Control Unit</i>
EEPS.....	<i>Engine Exhaust Particle Sizer</i>
EGR.....	<i>Exhaust Gas Recirculation</i>
EHC	<i>Electrically Heated Catalyst</i>
EPA	<i>Environmental Protection Agency</i>
ESC.....	<i>European Stationary Cycle</i>
FCV	<i>Fuel Cell Vehicle</i>
FFT	<i>Fast Fourier Transform</i>
FHEV	<i>Full Hybrid Electric Vehicle</i>
FID	<i>Flame Ionization Detector</i>
FIS	<i>Fuel Injection System</i>
FPGA	<i>Field-Programmable Gate Arrays</i>
FSN.....	<i>Filter Smoke Number</i>
FTIR	<i>Fourier Transform InfraRed Spectroscopy</i>
FTP	<i>Federal Test Procedure</i>
GA.....	<i>Genetic Algorithm</i>
GCI.....	<i>Gasoline Compression Ignition</i>

GDCI.....	<i>Gasoline Direct Compression Ignition</i>
GF.....	<i>Gasoline Fraction</i>
GHG.....	<i>Greenhouse Gases</i>
GMD.....	<i>Geometric Mean Diameter</i>
GPF.....	<i>Gasoline Particulate Filter</i>
H ₂	<i>Hydrogen</i>
H ₂ O.....	<i>Water</i>
HC.....	<i>Hydrocarbon species</i>
HCCI.....	<i>Homogeneous Charge Compression Ignition</i>
HCHO.....	<i>Formaldehyde, from the group of aldehydes</i>
HCOOH.....	<i>Formic Acid</i>
HEV.....	<i>Hybrid Electric Vehicle</i>
HiMICS.....	<i>Homogeneous charge intelligent Multiple Injection Combustion System</i>
HP-EGR.....	<i>High Pressure Exhaust Gas Recirculation</i>
HPDI.....	<i>High Pressure Direct Injection</i>
HRF.....	<i>High Reactivity Fuel</i>
HVO.....	<i>Hydrogenated Vegetable Oil</i>
ICCI.....	<i>Intelligent Control Compression Ignition</i>
ICE.....	<i>Internal Combustion Engine</i>
IMEP.....	<i>Indicated Mean Effective Pressure</i>
iso-C ₄ H ₈	<i>Isobutylene, an olefin from the alkene group</i>
JCCI.....	<i>Jet Controlled Compression Ignition</i>
LCA.....	<i>Life Cycle Analysis</i>
LHV.....	<i>Lower Heating Value</i>
LMTD.....	<i>Logarithmic Mean Temperature Difference</i>
LP-EGR.....	<i>Low Pressure Exhaust Gas Recirculation</i>

LPG	<i>Liquefied Petroleum Gas</i>
LRF	<i>Low Reactivity Fuel</i>
LTC	<i>Low Temperature Combustion</i>
LTDC.....	<i>Low Temperature Diesel Combustion</i>
MCE.....	<i>Multi-Cylinder Engine</i>
MHEV.....	<i>Mild Hybrid Electric Vehicle</i>
MKC.....	<i>Modulated Kinetics Combustion</i>
MPD.....	<i>Magneto-Pneumatic Detector</i>
MULDIC	<i>MULTiple stage DIesel Combustion</i>
N ₂	<i>Nitrogen</i>
N ₂ O.....	<i>Nitrous Oxide</i>
NADI.....	<i>Narrow Angle Direct Injection</i>
NDA	<i>Non-Disclosure Agreement</i>
NDIR.....	<i>Non-Dispersive Infrared</i>
NET	<i>Not Exceed Threshold</i>
NH ₃	<i>Ammonia</i>
NMOG	<i>Non-Methane and Oxygenated Hydrocarbons</i>
NO.....	<i>Nitrogen Monoxide</i>
NO ₂	<i>Nitrogen Dioxide</i>
NO _x	<i>Oxides of Nitrogen</i>
O ₂	<i>Oxygen</i>
O ₃	<i>Ozone</i>
ODE.....	<i>Ordinary Differential Equation</i>
OEM.....	<i>Original Equipment Manufacturer</i>
OME _x	<i>Polyoxymethylene Dimethyl Ethers</i>
PAH	<i>Polycyclic Aromatic Hydrocarbons</i>
PCCI.....	<i>Premixed Charge Compression Ignition</i>

PCI.....	<i>Premixed Compression Ignited combustion</i>
PDF	<i>Probability Density Function</i>
PER	<i>Premixed Energy Ratio</i>
PFI.....	<i>Port Fuel Injection System</i>
PHEV	<i>Plug-in Hybrid Electric Vehicle</i>
PID.....	<i>Proportional - Integral - Differential</i>
PM	<i>Particulate Matter</i>
PMEP	<i>Pumping losses Mean Effective Pressure</i>
PN.....	<i>Particulate Number</i>
PPCI.....	<i>Partially Premixed Compression Ignition</i>
PPLCCI.....	<i>Partially Premixed Lean Charge Compression Ignition</i>
PREDIC.....	<i>PREmixed DIEsel Combustion</i>
PRR.....	<i>Pressure Rise Rate</i>
PSD	<i>Particle Size Distribution</i>
RCCI.....	<i>Reactivity-Controlled Compression Ignition</i>
RDE.....	<i>Real Driving Emissions</i>
RoHR.....	<i>Rate of Heat Release</i>
RON.....	<i>Research Octane Number</i>
SCCI.....	<i>Stratified Charge Compression Ignition</i>
SCE.....	<i>Single-Cylinder Engine</i>
SCR	<i>Selective Catalyst Reducer</i>
SET.....	<i>Supplemental Emissions Test</i>
SGCI.....	<i>Stratified Gasoline Compression Ignition</i>
SI.....	<i>Spark Ignition Engine</i>
SMD	<i>Sauter Mean Diameter</i>
SMPS.....	<i>Scanning Mobility Particle Sizer</i>
SMR.....	<i>Steam Methane Reforming</i>

SO ₂	<i>Sulphur Dioxide</i>
SOC	<i>State of Charge</i>
SOF	<i>Soluble Organic Fraction</i>
<i>SoI</i>	<i>Start of Injection</i>
SPCCI	<i>Spark-Controlled Compression Ignition</i>
SPPCCI	<i>Spark-Controlled Premixed Compression Ignition</i>
TCO	<i>Total Cost of Ownership</i>
TDC	<i>Top Dead Center</i>
THC	<i>Total Hydrocarbons</i>
TRL	<i>Technology Readiness Level</i>
TSC	<i>Toyota-Soken Combustion</i>
TSCI	<i>Thermally Stratified Compression Ignition</i>
TTW	<i>Tank to Wheel</i>
UHC	<i>Unburned Hydrocarbons</i>
UNIBUS	<i>UNIform BULky combustion System</i>
VGT	<i>Variable Geometry Turbine</i>
VVL	<i>Variable Valve Lift</i>
VVT	<i>Variable Valve Time</i>
WHSC	<i>World Harmonized Stationary Cycle</i>
WHTC	<i>World Harmonized Transient Cycle</i>
WHVC	<i>World Harmonized Vehicle Cycle</i>
WI	<i>Water Injection</i>
WTT	<i>Well to Tank</i>
WTW	<i>Well to Wheel</i>

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

H	Enthalpy	kJ
I	Irradiance or infrared light intensity	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}	Equilibrium constant for NO oxidation	
K_{soot}	Correlation coefficient in the soot formation model	
L	Length	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^z	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	$\text{kg m}^{-1} \text{s}$
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
<i>a, air</i>	Referred to air
<i>amb</i>	Referred to ambient conditions
<i>b</i>	Referred to burned gases
<i>bb</i>	Referred to blow-by gases
<i>cyl</i>	Referred to in-cylinder conditions

EGR	Referred to EGR gases
eq	Referred to equivalent value or normalization
exh	Referred to exhaust conditions
$f, fuel$	Referred to fuel
ht	Referred to a heat transfer 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 unbred gases

Universal constant Numbers

e	Elementary electrical charge	$1.602 \cdot 10^{-19} \text{ C}$
g	Gravity acceleration	9.81 m/s^2
h_p	Plan constant	$6.626 \cdot 10^{-34} \text{ J s}$
N_A	Avogadro constant	$6.022 \cdot 10^{23} \text{ mol}^{-1}$
R_u	Ideal gas constant	$8.31446 \text{ J mol}^{-1} \text{ K}$
π	Pi Number	$3.141592\dots$
σ_{SB}	Stefan-Boltzman constant	$5.67 \cdot 10^{-8} \text{ W/m}^2 \text{ K}^4$

Non-dimensional Numbers

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

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	$We = \frac{\rho_a u D}{\sigma_l}$