Mechanical Engineering for Sustainable Development

State-of-the-Art Research

C. S. P. Rao | G. Amba Prasad Rao | N. Selvaraj
P. S. C. Bose | V. P. Chandramohan

Editors

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ABBREVIATIONS

2D	two-dimensional
3D	three-dimensional
AC	air-conditioner
AC	air-conditioning
AC	alternating current
AD	anaerobic digestion
ADI	alternating direction implicit
ADVISOR	advanced vehicle simulator
AFC	alkaline-based fuel cell
AGVs	automatic-guided vehicles
AI	artificial intelligence
AISI	American Iron and Steel Institute
AM	averaged Mises
ANFIS	adaptive network-based fuzzy inference system
ANN	artificial neural network
ANOVA	analysis of variance
APF	artificial potential field
AR	aspect ratio
ASTM	American society for testing and materials
AWH	air water heater
B&K	Brüel & Kjær
BCP	biphasic calcium phosphate
BD	biodiesel
BF	barrier following
BL	blends
BM	base metal
BP	brake power
BSFC	brake specific fuel consumption
BT	braking torque
bTDC	before top dead center
BTE	brake thermal efficiency
CA	crank angle
CAD	computer-aided design
CAD	crank angle degree

CCC	cylindrical combustion chamber
CFD	computational fluid dynamics
CHB	conventional hydraulic brake
CHB	conventional hydraulic braking system
CI	carbonyl iron
CI	compression ignition
CL	catalyst layer
CMM	coordinate measuring machine
CNC	computer numerical control
CNT	carbon nanotube
COD	chemical oxygen demand
COP	coefficient of performance
CR	compression ratio
CVD	chemical vapor deposition
CVI	chemical vapor infiltration
DARS-TIF	digital analysis of reaction system–transient interactive flamelets model
DC	direct current
DI	direct injection
DMA	dimethylaniline
DMRL	Defense Metallurgical Research Laboratory
DoE	design of experiment
DOE	design of experiments
DOF	degrees of freedom
DS	digested slurry
ECFM-3Z	three-zone extended coherent flame combustion model
ECFM-CLEH	extended coherent flame model-combustion limited by equilibrium enthalpy
ECN	epoxy-clay nanocomposites
EDM	electrical discharge machining
EDS	energy dispersive spectroscopy
EGR	exhaust gas recirculation
EI	electrolytic irons
EL	elongation
ESR	equivalent series resistor
FC	fuel cell
FDM	finite difference method
FE	finite element
FEM	finite element method
FFA	free fatty acid

FFT	fast Fourier transform
FGM	functionally graded materials
FIS	fuzzy inference system
FIV	flow-induced vibration
FLC	fuzzy logic controller
FOD	front obstacle distance
FSP	friction stir processing
FSW	friction stir welding
F-test	Fisher's test
FVM	finite volume method
FYM	farmyard manure
GCI	grid convergence index
GDL	gas diffusion layer
GFRG	grey fuzzy reasoning grade
GRA	grey relational analysis
GRC	grey relational coefficient
GRG	grey relational grade
GUI	graphical user interface
HA	hydroxyapatite
HAZ	heat-affected zone
HCC	hemispherical combustion chamber
HCCI	homogeneous charge compression ignition
HcHCr	high carbon high chromium
HC	hydrocarbon
HFC	hydrogen fluoride hydrocarbon
HIFP	heated inclined finned plate
HRB	Rockwell hardness number
HRR	heat release rate
HSD	honest significant difference
HWFET	highway fuel economy test
HWT	hypersonic wind tunnel
ICEM	integrated computer-aided engineering and manufacturing
IC	internal combustion
ID	industrial dynamics
IEEE	Institute of Electrical and Electronics Engineers
ILSS	interlaminar shear strength
ISFC	indicated specific fuel consumption
ISI	Institute for Scientific Information
IT	injection timing
IUTM	Instron universal testing machine

JIT	Just-In-Time
KH	Kelvin Helmholtz
KOME	karanja oil methyl esters
KSTePS	Karnataka Science and Technology Promoting Society
LDC	lid-driven cavity
LOD	left obstacle distance
LPG	liquefied petroleum gas
LTC	low-temperature combustion
LUA	limited under aging
MAM	methacrylamide
MBAM	N, N′-methylenebisacrylamide
MCFC	molten carbonate-based FC
MEKP	methyl ethyl ketone peroxide
MF	membership function
MGT	mean gas temperature
MHD	magnetohydrodynamics
MH	manual handling
MIG	metal inert gas
MIT	Massachusetts Institute of Technology
MMCs	metal matrix composites
MME	mahua methyl ester
MMT	montmorillonite
MRB	magneto rheological brake
MRF	magneto rheological fluid
MR	magneto rheological
MRR	material removal rate
MSE	mean squared error
MWCNT	multiwall carbon nanotube
MWCNTs	multiwall CNTs
MWNTs	multiwall nanotubes
Ni–MH	nickel–metal hydride
NN	non-negativeness
NOME	neem oil methyl esters
NURBS	nonuniform rational basis spline
OA	obstacle avoidance
OA	orthogonal array
OA	over aging
OFAT	one-factor-at-a-time
OM	optical metallography
PAFC	phosphoric acid-based FC

PA	peak aging
PEMFC	polymer electrolyte membrane-based FC
PEM	proton exchange membrane
PID	proportional integral derivative
PMEDM	powder-mixed electric discharge machining
PME	palm methyl ester
PM	particulate matter
PM	performance measurement
POC	poly(1,8-octanediol–co-citrate)
POME	pongamia oil methyl esters
PPF	poly(propylene fumarate)
RC	resistor capacitor
RC	roller conveyor
ROD	right obstacle distance
RON	research octane number
RP	rapid prototyping
RSAH	regenerative storage air heater
RSM	response surface methodology
RT	Rayleigh–Taylor
S/N	signal to noise
SAIF	Sophisticated Analytical Instrument Facility
SCM	supply chain management
SCPM	supply chain performance measurement
SC	supply chain
SD	synchronous dynamic
SD	system dynamics
SEM-EDS	scanning electron microscopy-energy dispersive spectroscopy
SEM	scanning electron microscopy
SENB	single edge notched beam
SFC	specific fuel consumption
SiCp	sillicon carbide particles
SI	International System of Units
SI	spark ignition
SMAC	semi-implicit marker and cell
SME	small manufacturing enterprises
SN	sum normalization
SOC	state of charge
SOFC	solid oxide-based FC
SOI	start of injection

SPH	smooth particle hydrodynamics
SQL	structured query language
SR	surface roughness
SST	shear stress transport
SUV	sport-utility vehicle
SVD	singular value decomposition
SVM	support vector machine
SZ	stir zone
TA	turning angle
TEMED	tetramethylethylenediammine
TEM	transmission electron microscopy
TG-DTA	thermogravimetric/differential thermal analysis
TIF	transient interactive flamelet
TMT	thermo mechanical treated
TO	topology optimization
TQM	Total Quality Management
TS	target seeking
TS	tensile strength
TWR	tool wear rate
UA	under aging
UBHC	unburnt hydrocarbon
UDDS	urban dynamometer driving schedule
UHC	unburned hydrocarbon
UP	unsaturated polyester
UTM	universal testing machine
UTS	ultimate tensile strength
VARS	vapor absorption refrigeration system
VCC	vapor compression cycle
VCR	variable compression ratio
VC	vapor compression
VHN	Vickers Hardness Number
VREP	virtual robot experimentation platform
WC	tungsten carbide
WZ	weld zone
XRD	X-ray diffraction
YS	yield strength

PREFACE

The faculty of mechanical engineering is a versatile branch among the various disciplines of engineering. It works hand in hand with interdisciplinary subjects such as electronics, computer science, automatic controls, environment, management, and so forth, in addition to its own core subjects. These are embedded into each other. The subject can especially be seen in practice in the field of automotive engineering where it has undergone a multitude of developments to meet customer demand and satisfaction in terms of safety, automation, economics, and so forth. Of late, the field of mechanical engineering has seen substantial growth and interest to attain sustainable development.

The book is a compilation of selected research papers prepared and presented at the First International and Eighteenth National Conference of the Indian Society of Mechanical Engineers held at NIT Warangal February 23–25, 2017. The theme of the conference was “Advances in Mechanical Engineering: Enabling Sustainable Development.” The broad objective of bringing out such a compendium is to provide some insight into the topics related to mechanical engineering and the state-of-the-art of work that is being carried out across the world by budding researchers and scientists with the help of eminent experts.

Broadly, the theme is subdivided into three divisions: machine design, materials and manufacturing, and thermal engineering. The papers presented are both experimental and numerical (computational/simulation) in nature. The area of thermal engineering broadly covers the use of alternate fuels such as biodiesel, etc., with an objective of reducing the burden on petroleum reserves and the environment. Also, the researchers are focusing on making use of a split injection strategy with the aim of mitigating harmful emissions from existing engines with conventional fuels. The conference also witnessed works related to combustion so as to achieve sustained supersonic combustion and to obtain and maintain hot air for such types of combustion. The use of new combustion strategies such as homogeneous charge compression ignition (HCCI) is being explored in depth. These days, fuel cells are emerging as a viable alternate power source either fully or in hybrid vehicles.

Nowadays, many researchers specialized in heat transfer are working in the area of numerical heat transfer with applications for cooling of electronic equipment. The works deal with the different configurations of sources of heat in order to dissipate or maximize the heat transfer with reduced energy consumption. Research includes reports on the use of nanofluids to enhance the rate of heat transfer.

Materials technology is growing at a faster pace, such as with nanomaterials, composite materials, functional-graded materials, in addition to developments in the use of optimization tools in cutting and forming processes. Materials characterization has become an important tool in assessing proper materials for application-oriented jobs. Unconventional machining processes, such as electro discharge machining (EDM), are emerging in addition to friction stir welding and forming processes. There is also new development in design engineering, especially of new products, use of new tools for assessing proper designs, rapid prototyping tools, and so forth.

The purpose of this book is, therefore, to present new technologies and the development scenario, and not to give any indication about the direction that should be given to the research in this complex and multidisciplinary challenging field.

The editors take this opportunity to thank all the chapter contributors for sharing their works. The editors are also grateful to Apple Academic Press, especially Mr. Ashish Kumar, Mr. Rakesh Kumar, and Ms. Sandra Sickels, for extending their cooperation in bringing out this compendium. They are also thankful for the cooperation extended by authorities of NIT Warangal and governing body of ISME for their support.

PART I

Machine Design (MD)

CHAPTER 29

COMBINED EFFECT OF CYLINDRICAL COMBUSTION CHAMBER SHAPE AND NOZZLE GEOMETRY ON THE PERFORMANCE AND EMISSION CHARACTERISTICS OF A COMPRESSION IGNITION ENGINE OPERATED ON PONGAMIA

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ABSTRACT

The use of biodiesel in the diesel engine decreases the exhaust emissions but the performance of the engine is found to decrease. This is due improper mixing of air and inadequate turbulence. The performance of the engine can be improved by improving the mixing quality of biodiesel spray with air which can be achieved by modifying the combustion chamber shape and nozzle geometries. The present work investigates the combined effect of cylindrical combustion chamber (CCC) shape and five-hole nozzle geometry on the performance and emission characteristics of biodiesel operated diesel engine with baseline diesel fuel. Engine tests were carried out on a single-cylinder four-stroke direct injection (DI) diesel engines using various blends of Pongamia oil methyl esters (POME) with standard diesel as a fuel and compared with modified combined CCC shape and five-hole nozzle geometry. For comparison, the compression ratio of the engine is kept constant. The experimental results depict that brake thermal efficiency increases up to B60 blend of POME in both baseline diesel engine and modified diesel engine geometry. A drastic reduction in unburnt hydrocarbons and oxides of nitrogen (NO_x) emissions was observed with modified diesel engine geometry as compared to baseline diesel engine. The percentage of carbon monoxide (CO) emissions decreases more with increasing the percentage of POME in modified diesel engine geometry up to B40 blend, thereafter increase in carbon monoxide emissions as increases in blend in modified diesel engine geometry compared with baseline diesel engine. However, the percentage of carbon dioxide emission (CO_2) is more in modified diesel engine geometry as compare with baseline diesel engine for injection pressure 205 bars. The experiment is repeated with increase in injection pressure.

29.1 INTRODUCTION

The diesel and petrol fuels are vanishing spontaneously and the costs of the fossil fuels are increasing day by day. Hence, renewable fuels have been focused more on its capacity to replace the fossil fuels. However, due to environmental considerations, more attention is given to the use of biofuels. The main problem of vegetable oils of usage in internal combustion engine is with their higher viscosity, from 15 to 20 times higher than the regular diesel fuel. Many techniques such as blending with standard diesel fuel, micro-emulsification with methanol, thermal cracking, and conversion of vegetable oils into biodiesels by transesterification process are used to reduce the viscosity of the vegetable oils. All of the above, transesterification process is most commonly used for reducing the viscosity of oil. To improve the performance of diesel engine operated with biodiesel in comparing the conventional diesel engine with diesel fuel, there in need of altering the fuel properties, engine design parameters, and engine operating parameters. To enhance the performance and reduce the emissions, quick and improved air–biodiesel mixing is the essential condition. To improve the air and fuel mixing, quality of the biodiesel spray with air can be enhanced by the selection of appropriate nozzle injection pressure and suitable combustion chamber shape.

Jaichandar and Annamalai[1] investigated the performance and emission characteristics of various shapes of combustion chamber such as toroidal, shallow depth, and hemispherical combustion chamber (HCC) shapes by using 20% Pongamia oil methyl esters (POME) in standard diesel without changing the compression ratio (CR) of the engine. The result show that the toroidal combustion chamber shape shows higher brake thermal efficiency (BTE) compared to other two combustion chamber shapes and also observed that there is significant reduction of particulates, carbon monoxide (CO), and unburnt hydrocarbons (UBHCs) for toroidal combustion chamber shape compare to other two shapes but oxides of nitrogen (NO_x) in increased for toroidal combustion chamber shape. Jaichandar and Annamalai[2] conducted an experiment on diesel engine by using the toroidal reentrant and HCC shapes with varying the nozzle opening pressure for 20% POME in standard diesel fuel. The result revealed that the performance parameters such as BTE and specific fuel consumption (SFC) are improved for toroidal reentrant combustion chamber shape compared to baseline shape at high nozzle injection pressure and also observed reduction in emission characteristics but increase in oxides of nitrogen for toroidal reentrant combustion chamber shape at higher nozzle injection pressure as compared to baseline shape. Jaichandar et al.[3] show that the BTE is improved by 5.64% and the SFC is reduced by 4.6 but 11% of oxides of nitrogen has been increased for toroidal reentrant combustion chamber shape as compared to diesel engine operated with *ultra-low-sulfur diesel* due to appropriate air–fuel mixing and reduce injection timing. Rajashekhar et al.[4] investigated the combined effect of multichambered combustion chamber shape and nozzle injection pressure by using Jatropha as a biodiesel in diesel engine and results showed that the both performance and emission characteristics were optimum at 200-bar injection pressure. Karra and Kong[5] studies show that the nozzle size of 10-hole nozzle geometry gives lesser pressure drop and also performs better atomization, maximum air utilization, and reduction in oxides of nitrogen at full load condition of diesel engine. The experimental result by Saravanan et al.[6] reveals that by modification of combustion process, the oxides of nitrogen, and carbon monoxides emissions are highly reduced but increase in the BTE and UBHC emission with increase in the smoke density in biodiesel-fueled diesel engine. Lahane and Subramanian[7] suggested that varying the number of holes in nozzle injector reduces the oxides of nitrogen in biodiesel-fueled diesel engine and wall impingement minimizes the UBHC, carbon monoxide, and brake SFC (BSFC). The experimental work by Mobasheri and Peng[8] showed that by changing the combustion chamber shape, the emission characteristics are reduced but performance parameters remain the same. The experimental work by Balaji and Cheralathan[9] was carried out to observe the effect of nozzle injector pressure on DI diesel engine with neem methyl ester. The result showed that the performance characteristics such as BTE increases with decrease in BSFC and emission characteristics such as carbon monoxide, carbon dioxide, hydrocarbon, nitrogen oxides, and smoke intensity are reduced at optimum nozzle injection pressure for 240 bar. The experimental result by Khandal et al.[10] reveals that varying the injection timing, injection pressure, CR, and nozzle holes leads to enhanced performance parameters like BTE and meanwhile reduce the emission characteristics in biodiesel-fueled diesel engine; however, oxides of nitrogen emission increases as the number of holes increase in injector nozzle. Banapurmath et al.[11] studied the various combustion chamber shapes such as cylindrical, trapezoidal, and toroidal combustion chamber shapes in diesel engine. The results showed that toroidal combustion chamber shape showed higher performance parameters with reduced emission characteristics compared to remaining two combustion chamber shapes.

From the above summary of literature review, we found that there was minimum research work carried on combined effect of combustion chamber shape and nozzle geometries in the biodiesel-fueled diesel engine, hence analyzing the best and suitable combination of modified geometries that are studied in reference to performance and emission characteristics with consideration of cylindrical combustion shape and five-hole nozzle geometry in diesel engine fueled with POME.

29.2 PROPERTIES OF FUEL

All over India, the production of nonedible is increasing as the usage is increasing day by day because the availability of petroleum products are decreasing as the cost of production is more. Out of all nonedible oils, Jatropha and Pongamia have more importance in research activities. *Pongamia pinnata*, an essential plant having natural importance across the world and also one of the best potential biofuel crops, can grow anywhere in the waste lands. *P. pinnata* having higher potential exists everywhere in our country to bring the higher plantation growth. Basically, Pongamia seed contains 30–35% of the oil. POME has to be prepared usually by transesterification process. The properties of diesel, blends, and POME are as follows in Table 29.1.

TABLE 29.1 The Properties of Diesel, Blends, and Pongamia Oil Methyl Esters.

Properties	Blends					
	Diesel	**B20**	**B40**	**B60**	**B80**	**B100**
Density (kg/m^3)	830	820	842	851	868	894
Specific gravity	0.83	0.82	0.842	0.851	0.868	0.894
Flash point (°C)	63	83	89	110	118	180
Fire point (°C)	66	95	100	124	145	195
Calorific value (kJ/kg)	42,000	41,618	39,380	38,100	37,880	37,150

29.3 EXPERIMENTAL METHODOLOGY

The engine selected for experimentation was a single-cylinder, compression ignition, and direct injection (DI) engine. It was a naturally aspirated, four-stroke, water-cooled, and vertical engine. As shown in Figure 29.1 experimental setup, it is made to work under higher pressures and is widely used in agriculture and industrial sectors. The engine runs at a constant speed of 1500 rpm. The engine has overhead valve arrangement. The valves are controlled by push rods and a camshaft. The water required for the cooling of the engine is obtained by forced circulation of water from water pump through the water jacket. The specification of the engine is shown in Table 29.2.

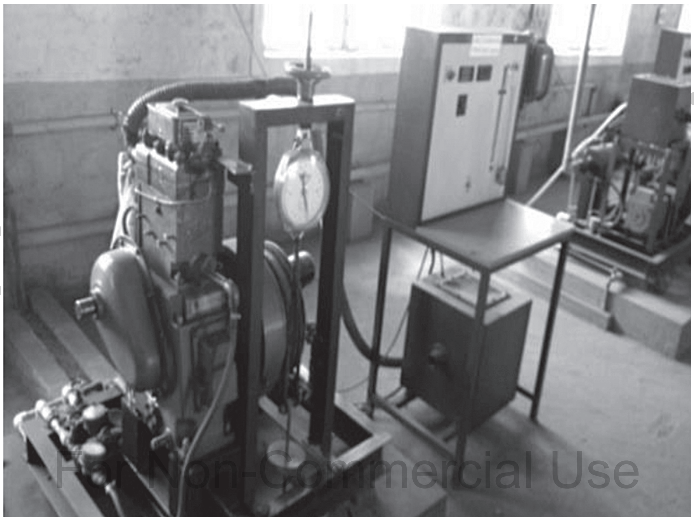

FIGURE 29.1 Experimental test engine.

TABLE 29.2 Engine Specifications.

Engine parameter	Specifications
Engine	Kirloskar single-cylinder four-stroke direct injection (DI) diesel engine
Nozzle opening pressure	200–205 bar
Rated power	5 HP at 1500 rpm
Bore	80 mm
Stroke length	110 mm
Compression ratio	17.5:1
Displacement volume	660 cm^3
Arrangement of valves	Overhead
Combustion chamber	Open chamber (DI)
Cooling type	Water cooled
Loading	Mechanical-type loading dynamometer

The selection of biodiesel is usually based on the availability of biodiesel; the Pongamia methyl ester is used for the experimentation. The various blends such as B20, B40, B60, B80, and B100 are prepared in laboratory; we found the various fuel properties of prepared blends and standard diesel in laboratory using Abel's apparatus and Saybolt's viscometer. The experimentations are carried out with HCC shape and three-hole nozzle geometry for standard diesel, B20, B40, B60, B80, and B100 fuels with 0, 25, 50, 75, and 100% engine loading with help of mechanical loading type of dynamometer and emission readings are noted with help of gas analyzer. The piston shape is changed to cylindrical shape without altering the volume by filling the molten aluminum and machining process. The cylindrical combustion chamber (CCC) shape and five-hole nozzle geometry assembled into baseline engine setup. The same experimentation will be repeated with CCC shape and five-hole nozzle geometry as carried to HCC shape without changing the CR. Finally, the performance and emission characteristics of modified geometries were compared with baseline hemispherical piston geometry. The hemispherical and CCC shapes are shown in Figure 29.2. The three-hole injector nozzle and five-hole injector nozzle geometries are as shown in Figure 29.3.

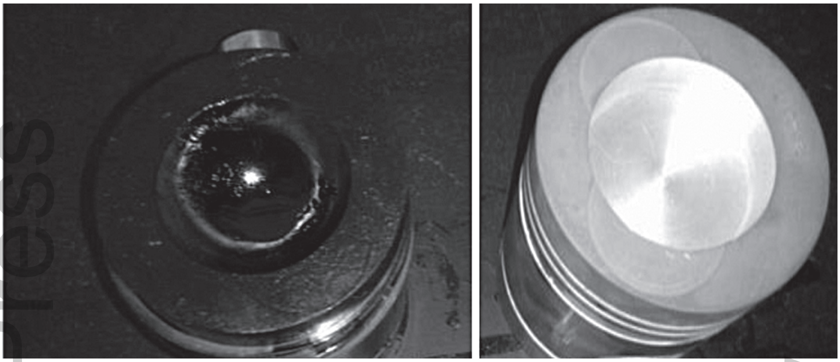

FIGURE 29.2 Hemispherical and cylindrical combustion chamber shapes.

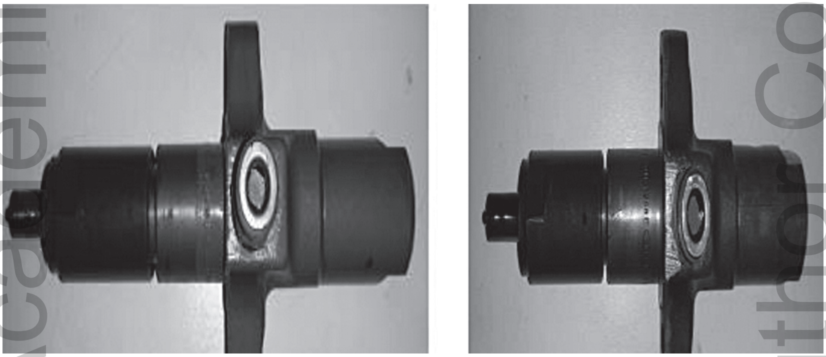

FIGURE 29.3 Three-hole and five-hole nozzle geometries.

29.4 RESULTS AND DISCUSSION

In this experiment, we investigated the comparison between the baseline geometry of HCC shape and three-hole nozzle geometry and modified geometry of CCC shape and five-hole nozzle geometry with reference to performance characteristics and emission characteristics without changing the CR at full load condition of diesel engine are as follows.

29.4.1 SPECIFIC FUEL CONSUMPTION

From Figures 29.4 and 29.5, we observed that the variation of SFC with brake power (BP) for baseline and modified engine geometries. The SFC increases from 0.26 to 0.29 kg/kW·h with increase in the blend for baseline geometry and for modified geometry, it varies from 0.28 to 0.35 kg/kW·h with increasing the blend. The SFC increases for biodiesel in both the shapes due to lesser calorific value. However, the SFC is more in modified geometry compared to baseline geometry due to poor mixing quality in modified shape.

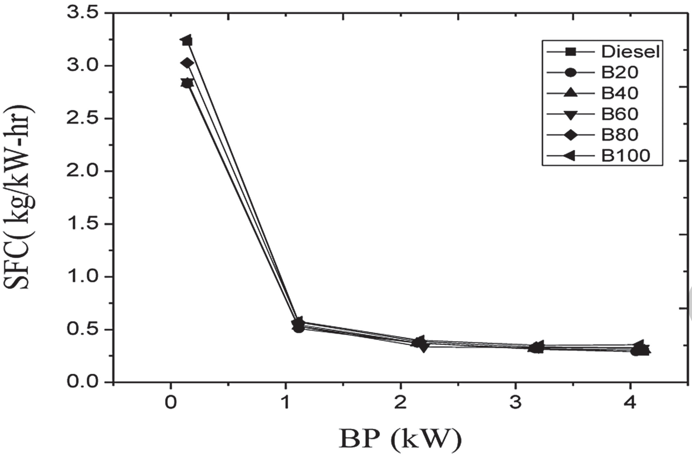

FIGURE 29.4 Variation of specific fuel consumption (SFC) with brake power (BP) for baseline geometry.

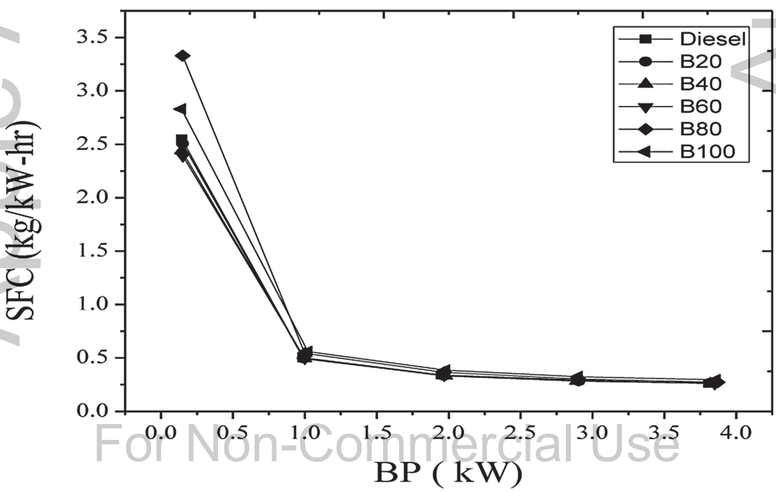

FIGURE 29.5 Variation of SFC with BP for modified geometry.

29.4.2 BRAKE THERMAL EFFICIENCY

From Figures 29.6 and 29.7, we observed that the variation of BTE with BP for baseline and modified engine geometries. The BTE increases from 32.79 to 34.69% with increase in the blend for baseline geometry, and it increases from 29.58 to 29.83% for modified engine geometry; however, the decrease in BTE is observed for modified geometry for pure biodiesel (B100). This is due to improved combustion characteristics in baseline geometry.

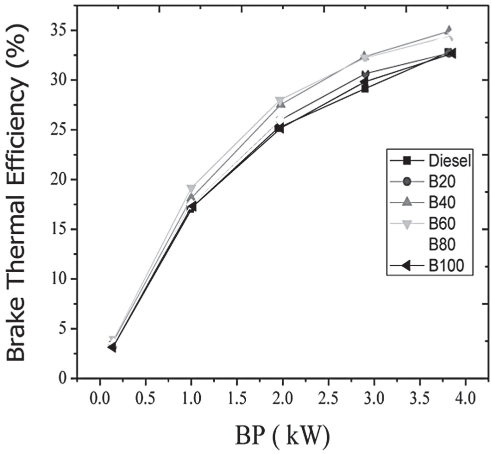

FIGURE 29.6 Variation of BTE with BP for baseline geometry.

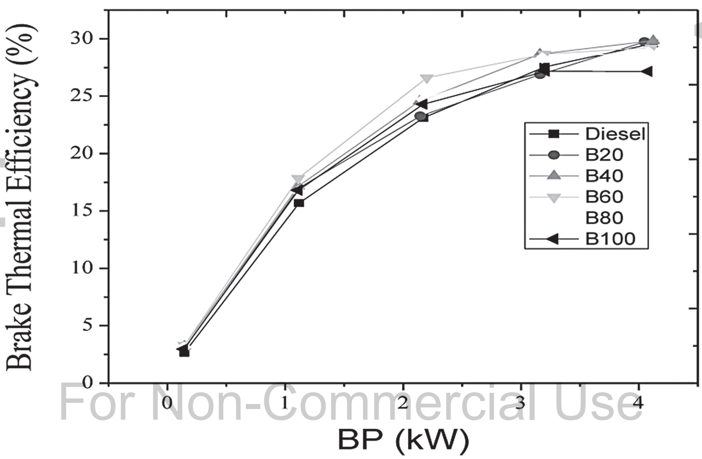

FIGURE 29.7 Variation of BTE with BP for modified geometry.

29.4.3 CARBON MONOXIDE

From Figures 29.8 and 29.9, we observed that the variation of carbon monoxide with BP for baseline and modified engine geometries. The percentage of CO emission decreases from 0.225 to 0.009 for baseline geometry, for modified geometry, it varies from 0.743 to 0.672 but the percentage of CO emission decreases up to B40 blend and thereafter it increases with increasing the blend for baseline geometry, whereas the percentage of CO emission increases up to B80 blend and thereafter it decreases with the B100 blend for modified geometry. However, the percentage of CO is more in baseline geometry compared to modified geometry at 50% load condition due to lower temperature in modified geometry at full load condition.

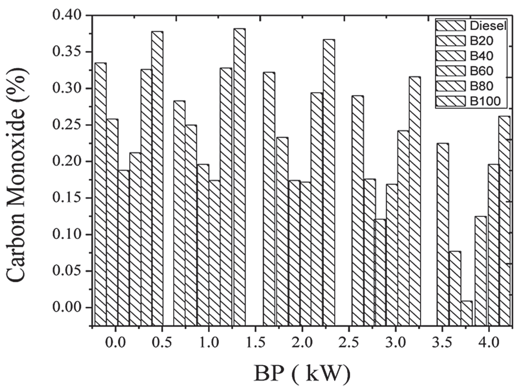

FIGURE 29.8 Variation of CO with BP for baseline geometry.

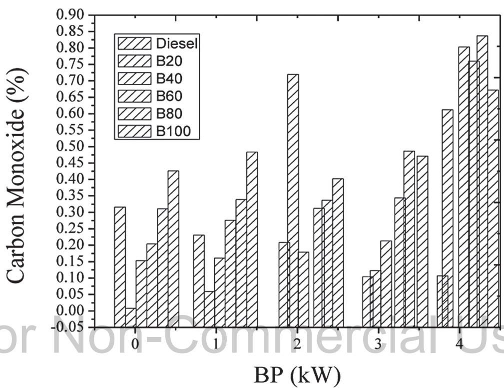

FIGURE 29.9 Variation of CO with BP for modified geometry.

29.4.4 CARBON DIOXIDE

From Figures 29.10 and 29.11, we observed that the variation of carbon dioxide with BP for baseline and modified engine geometries. The percentage of CO_2 varies from 7.55 to 6.03% in baseline geometry, but for modified geometry, it varies from 7.33 to 10.83%; however, the percentage of CO2 is more in modified geometry compared to baseline geometry due to improved combustion in HCC shape.

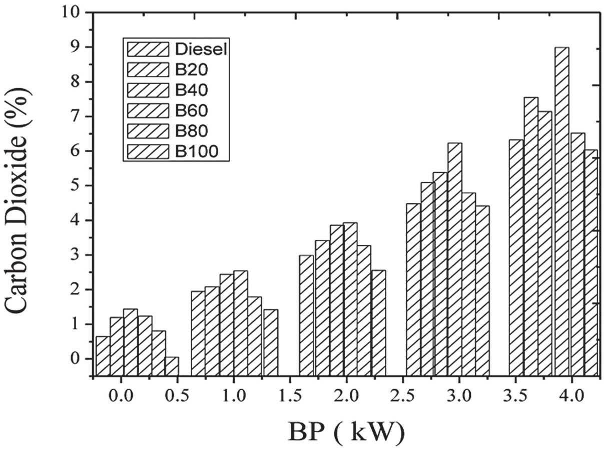

FIGURE 29.10 Variation of CO_2 with BP for baseline geometry.

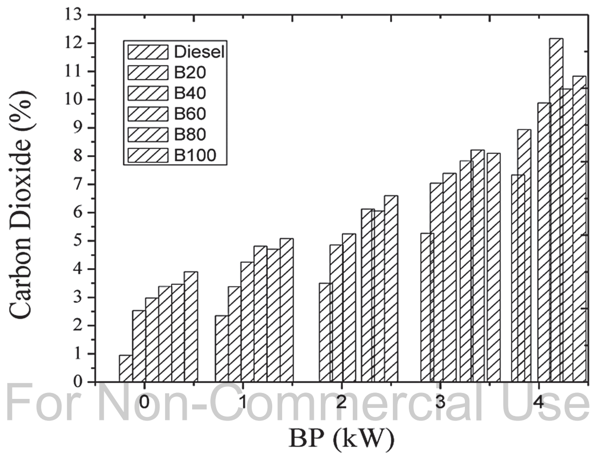

FIGURE 29.11 Variation of CO_2 with BP for modified geometry.

29.4.5 UNBURNT HYDROCARBONS

From Figures 29.12 and 29.13, we observed that the variation of UBHCs with BP for baseline and modified engine geometries. The UBHC emission decreases as load increases in both geometries due to the high content of oxygen in Pongamia biodiesel and better air swirl but comparatively UBHC emission reduces up to 50% load condition and thereafter increases in modified geometry and also lower UBHC are observed for modified shape than the baseline geometry.

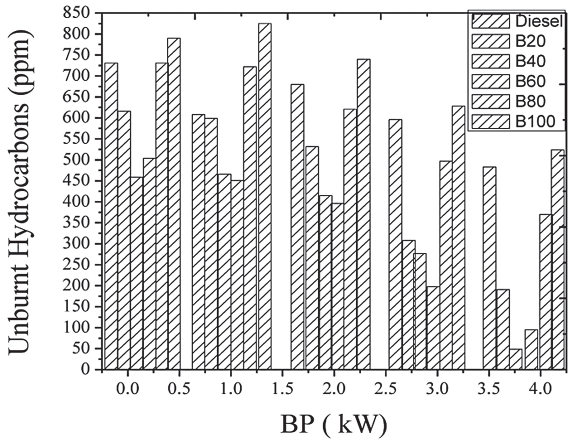

FIGURE 29.12 Variation of unburnt hydrocarbons (UHC) with BP for baseline geometry.

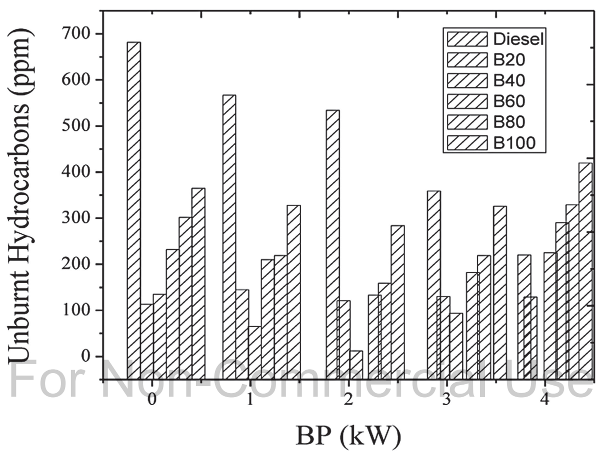

FIGURE 29.13 Variation of UHC with BP for modified geometry.

29.4.6 OXIDES OF NITROGEN

From Figures 29.14 and 29.15, we observed that the variation of oxides of nitrogen with BP for baseline and modified engine geometries. The better mixing of fuel and air and faster burning process in both geometries NO_x level increases in both the shapes. The NO_x emission decreases from 2103 to 1914 ppm as blend increases for baseline geometry, and it varies from 1028 to 892 ppm as increase in the blend for modified shape. However, the 45% of NO_x emission has reduced in modified geometry comparatively baseline geometry due to low temperature attained in modified geometry.

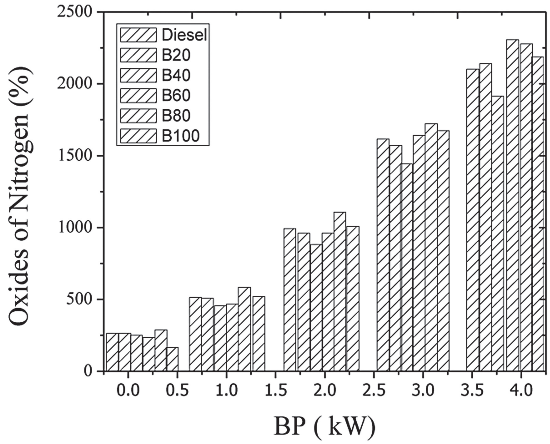

FIGURE 29.14 Variation of NO_x with BP for baseline geometry.

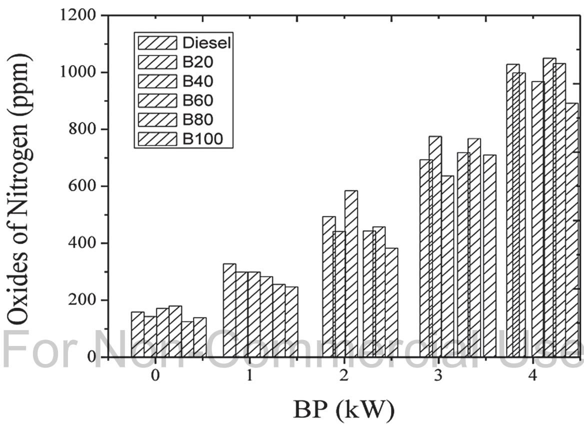

FIGURE 29.15 Variation of NO_x with BP for modified geometry.

29.5 CONCLUSIONS

The SFC has shown reduction with increase in BP for both geometries but it decreases in the case of baseline geometry due to improved combustion. BTE has improved with increase in BP for both geometries and it is observed that among all blends, B40 for baseline geometry and B40 for modified geometry give more efficiency. The BTE increases as blends increase in both geometries observed at all load. The modified geometry gives lower emissions as compared to baseline geometry especially there is a 45% of the reduction in the NO_x for modified geometry as compared to the baseline geometry. The modified geometry utilized more oxygen than that of baseline geometry due to complete combustion.

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KEYWORDS

- **combustion chamber shapes**
- **emission**
- **Pongamia**
- **biodiesel**
- **diesel engine**

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