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ORIGINAL ARTICLE

Influence of compression ratio on combustion and performance characteristics of direct injection compression ignition engine

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Delay period

Abstract The importance of diesel engines for human application is growing day by day. The engine operating parameters also play a key role in tuning the engine conforming to the better performance and emission standards. The effect of varying the compression ratios has more impact on the performance, emission and combustion parameters. In this study, single cylinder direct injection CI engine was tested on varying the compression ratios of 18, 17 and 16 at varying loads. The combustion and performance variation on reducing the compression ratios were investigated clearly. Reduction in brake thermal efficiency and increase in exhaust gas temperatures were observed when compression ratio was reduced from 18 to 16. The brake specific fuel consumption was increased on reducing the compression ratio. Reduction of peak cylinder pressure was observed on reduction of compression ratio and the ignition delay period increased on reducing the compression ratio. The peak heat release rate was closer to TDC on increasing compression ratios from 16 to 18. The rate of pressure rise was also investigated and showed maximum of 5.38 bar/°CA and minimum of 0.78 bar/°CA on above compression ratios. Cumulative heat release was also evaluated in this study showing higher heat energy for higher loads and compression ratios. The performance and combustion parameters on the useful compression ratio of 18 were also justified.

1. Introduction

Internal combustion engines gained impetus when Otto developed the first petrol engine followed by the development of diesel engine by Rudolph Diesel in the late 19th century. Drastic improvements and modifications have been made in the field of Internal combustion engineering till today and they serve mankind in Transportation and Power generation [2–4,10]. Diesel engines find more application in the current world compared to SI engines. The higher torque and efficiency due to the increased compression ratio enable the humans favouring the diesel engines for variety of applications. Day by day very strict emission regulations have been imposed on the

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Nomenclature

Abbreviations

BTE	brake thermal efficiency
BMEP	brake mean effective pressure
BSFC	brake specific fuel consumption
CR	compression ratio
CA	crank angle
CI	compression ignition
IT	injection timing
NHR	net heat release
CHR	cumulative heat release
EGT	exhaust gas temperature
RTD	resistance temperature detector
bTDC	before top dead centre
DI	direct injection
IDI	indirect injection
J/°CA	Joules per degree crank angle
bar/°CA	bar per degree crank angle

vehicles and constant speed engines marking various technological advancements. In order to improve the performance and comply with emissions, several test parameters such as adjustment of Injection timing, Compression ratio, and injection pressures have been carried out by various researchers [1,7,8]. Diesel engine combustion chambers can be classified into direct type or Open combustion chamber and indirect injection combustion chamber or turbulent swirl chamber. Entire combustion is concentrated in the main cylinder combustion chamber in case of DI engine and IDI engine incorporates combustion in main cylinder and cylinder head [13]. In general, the diesel engine combustion is said to be complex and can be categorized into Ignition delay, premixed combustion phase, Rate controlled combustion phase and late combustion phase. The delay occurring between start of fuel injection and start of combustion refers to ignition delay. The occurrence of rapid combustion involving high heat release is observed in premixed phase. In controlled combustion, the burning rate is controlled by the rate of burning mixture and late combustion phase or the afterburning zone involves continuation of heat release at a lower rate [9].

Performance, emission and combustion characteristics were evaluated at varying compression ratios with 50% load for diesel and WCO Biodiesel where the results showed that exhaust gas Temperature increased with higher compression ratios. The mechanical efficiency gradually decreased with increasing Compression ratio. The brake thermal efficiency increased and brake specific fuel consumption reduced on increasing CR. The Peak cylinder pressure also increased with increase of CR. Heat release rate reduced with increase of Compression ratio and the Heat release rate of standard diesel was found higher than the blends [14,15]. Experimental investigations were carried out on a variable speed engine at varying compression ratios operated with diesel and biodiesel blends which revealed the increase of engine torque with increasing compression ratio at all speeds. At full load conditions, an increase in torque was about 15% and reduction of brake specific fuel consumption was about 17.3% when compression ratio was increased from 14 to 18 for standard diesel. The brake thermal efficiency increased for diesel and other blends on increasing the compression ratio. The average increase of cylinder pressure was about 8.4% on increasing the compression ratio and this was observed at all speeds. The delay period reduced with increasing compression ratio which was also observed at all speeds. Significant reduction was observed in the delay period which could be due to early combustion on increasing compression ratios [16]. The effect of compression ratios on performance, combustion and emission characteristics was studied on a dual fuel engine operated on raw biogas. Compression ratios were reduced from 18 to 16 for varying loads at spill setting of 23°bTDC. The brake thermal efficiency in dual mode improved for increasing compression ratios which could be due to complete combustion of biogas and the exhaust gas Temperature reduced for increasing compression ratio at all loads. The volumetric efficiency also exhibited a gradual reduction on reduction of compression ratio at all loads. The peak cylinder pressure reduced with reduction of compression ratio and moved closer to TDC. The heat release also increased on increasing the compression ratio. The ignition delay reduced with increasing compression ratio for all loads. Maximum ignition delay occurred for lowest compression ratio at minimum load [5].

In the present study, performance and combustion characteristics were evaluated for standard diesel at all loads and compression ratio of 18, 17 and 16 were operated for the study. Lower compression ratios were neglected which resulted in low brake thermal efficiency and the maximum CR limit is 18. Performance parameters such as brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature were studied at all loads and combustion parameters such as cylinder pressure, rate of pressure rise, net heat release and cumulative heat release were investigated.

2. Materials and methods

2.1. Experimental set up and methodology

The diesel engine test set up comprises of single cylinder, four stroke, and direct injection engine of Kirloskar make. The engine is water cooled with Power rating of 3.5 kW at 1500 rpm and the schematic layout can be seen from Fig. 1. The other detailed specifications can be referred from Table 1 where the engine displacement capacity is 661 cc. Engine is also equipped with a Rotameter enabling the engine cooling operating at the range between 40 and 400 L per hour and enhances calorimeter cooling in the range of 25–250 L per hour. Since the ranges of temperature measurement used in various parts are different, varieties of thermocouples such as RTD, PT 100 and K type thermocouple are employed in the engine for the measurement of engine water temperatures and exhaust temperatures. Pressure measurement for measuring the combustion pressure and fuel inlet pressure are used in the set up where the piezo electric sensor is used with a low noise cable in the range of 5000 PSI. The piezo electric