An Effective Overview to a Homogeneous Charge Compression Ignition Engine

B. Shiva & K. Ranadheer Raju

1M.Tech (CAD/CAM), Dept. of Mechanical Engineering, Balaji Institute of Technology & Science, Warangal Rural, Telangana, India
2Asst. Professor, Dept. of Mechanical Engineering, Balaji Institute of Technology & Science, Warangal Rural, Telangana, India

Abstract: Homogeneous charge compression ignition (HCCI) engine technology is comparatively new and has not developed adequately to be commercialised related with conventional engines. It can use spark ignition or compression ignition engine configurations, exploiting on the compensations of both: high engine efficiency with low emissions levels. HCCI engines can use a extensive range of fuels with low emissions levels. Due to these benefits, HCCI engines are appropriate for use in a hybrid engine configuration, where they can decrease the fuel consumption even more. On the other hand, HCCI engines have some drawbacks, such as knocking and a low to medium operating load range, which need to be resolved before the engine can be commercialised.

Keywords - Diesel; HCCI; gasoline; natural gas; hydrogen

1. INTRODUCTION

Environmental security is a giant growth market for the longer term. Within the years ahead, “inexperienced” applied sciences that support enhance energy efficiency or reduce emissions will be principal development. With the appearance of increasingly stringent gasoline consumption and emissions requirements, engine producers face the difficult task of supplying traditional cars that abide by the aid of these rules. HCCI combustion has the capabilities to be totally effective and to provide low emissions. HCCI engines can have efficiencies as high as compression-ignition, direct-injection (CIDI) engines (a sophisticated version of the most of the time identified diesel engine), even as producing extremely-low oxides of nitrogen (NOx) and particulate topic (PM) emissions. HCCI engines can operate on fuel, diesel gasoline, and most alternative fuels. While HCCI has been validated and recognized for relatively a while, simplest the up to date creation of digital sensors and controls has made HCCI engines an expertise functional reality.

HCCI represents the subsequent major step beyond high efficiency CIDI and spark-ignition, direct injection (SIDI) engines for use in transportation cars. In some regards, HCCI engines incorporate the high-quality elements of each spark ignition (SI) gas engines and CIDI engines. Like an SI engine, the charge is well blended which minimizes particulate emissions, and like a CIDI engine it’s compression ignited and has no throttling losses, which results in excessive efficiency. However, in contrast to both of these conventional engines, combustion occurs concurrently for the duration of the cylinder volume alternatively than in a flame front. HCCI engines have the talents to reduce cost than CIDI engines for the reason that they would possibly use a cut-down pressure fuel-injection procedure. The emission management programs for HCCI engines have the capabilities to be much less luxurious and no more based on scarce valuable metals than either SI or CIDI engines. HCCI engines possibly commercialized in mild-responsibility passenger cars and as a lot as a half-million barrels of principal oil per day may be stored.

HCCI is potentially relevant to both light and heavy-obligation engines. Light-responsibility HCCI engines can run on gas and have the knowledge to match or exceed the efficiency of diesel-fueled CIDI engines, without the fundamental task of NOx and PM emission manipulate or impacting gasoline-refining capacity. For heavy-obligation vehicles, successful the progress of the diesel-fueled HCCI engine is a major alternative technique within the event that CIDI engines cannot acquire future NOx and PM emissions necessities.

Actually, HCCI technology would be scaled to nearly every size-class of transportation engines from small bike
to tremendous transport engines. HCCI can also be applied to piston engines used outside the transportation sector such as those used for electrical energy new release and pipeline pumping. HCCI engines are notably well proper to series hybrid automobile functions when we consider that the engine can be optimized for operation over an extra restricted the range of speeds and masses in comparison with primary engines used with conventional automobiles. Use of HCCI engines in sequence hybrid automobiles might extra leverage the advantages of HCCI to create extremely gasoline-efficient cars.

II. FUNDAMENTALS OF HCCI COMBUSTION

In HCCI mode of combustion, the fuel and air are mixed prior to the start of combustion and the mixture is auto-ignited spontaneously at multiple sites throughout the charge volume due to increase in temperature in the compression stroke [4, 6, 7]. In this mode, the combustion process is arranged in such a way that the combustion takes place under very lean and dilute mixture conditions, which results in comparatively lower bulk temperature and localised combustion temperature, which therefore, considerably reduces the NOx emissions. Furthermore, unlike conventional CI combustion, in HCCI mode the fuel and air is well mixed (homogeneous). So, the absence of fuel rich regions in the combustion chamber results in considerable reduction in PM generation. Therefore, due to absence of locally high temperatures and a rich fuel-air mixture during combustion process, the simultaneous reduction of NOx and PM emissions is made possible.

As it is evident from Fig. 1 that for conventional diesel combustion, the adiabatic flame temperature in air stretches through both the soot and NOx generation regions. Conceptually, in a conventional diesel combustion, the fuel and air charge undergoes rich combustion of about Θ=4 at the end of the adiabatic mixing process during the ignition delay period, and then combustion moves to completion in a stoichiometric (Θ=1) diffusion flame. This rich combustion may cause soot production depending upon the soot formation tendency of the fuel and the Θ-T distribution during the pre-mixed combustion period. Once the combustion of the fuel prepared to flammability limits during the ignition delay period is over, the rate of combustion further depends on a mixing controlled basis. In the conventional diesel combustion, thermal NOx is produced when the local in-cylinder temperatures are in excess of 1800-2000K and there is enough oxygen available. Considering approximately adiabatic combustion, these combustion regions fall in soot and NOx regions respectively, resulting in high levels of emissions. SI combustion also generates significant amount of NOx emissions, but they are removed by modern three-way catalysts.

Fig. 1 - Conventional combustion & variants of diesel combustion on T-Θ space [22]

As it is clear from Fig. 2 that the HCCI combustion falls outside the soot and NOx islands. In HCCI combustion as the flame temperatures are considerably lower than the conventional diesel combustion due to lean or dilute mixture, the NOx emissions are low. Furthermore, the well premixed charge present in the cylinder leads to lower soot emissions as well. However, it is not necessary for combustion process to happen specifically in the HCCI region to avoid NOx and soot formation. Low Temperature Combustion (LTC) takes benefit of this fact by adjusting combustion to take place anywhere in the gray shaded region, while making effort to ensure that most of the fuel is mixed to Θ≤1 (the HCCI region), before the reactions are quenched by expansion for maintaining good combustion efficiency. Therefore, though diesel LTC combustion is not fully premixed, it employs necessarily the same principles as HCCI to achieve low emissions.

III. HOMOGENEOUS CHARGE COMPRESSION IGNITION ENGINES
IC engines are wide employed in various applications: vehicle engines, power generation and ships. The emissions generated from these applications have a significant impact on the environment, therefore different solutions are investigated to attain low emissions levels [2, 3, 8-11]. a replacement mode of combustion is being sought-after so as to cut back the emissions levels from these engines: a possible candidate is that the homogeneous ChargeCompression Ignition (HCCI) engine. Figure two shows the variations among SI, CI and HCCI engines, wherever SI engines have a sparking plug to initiate combustion with a flamefront propagating across the combustion chamber. CI engines have a fuel injector to inject the diesel and combustion takes place during a compressed hot air region. HCCI engines, on the opposite hand, don't have any spark plug or fuel injector and therefore the combustion starts spontaneously in multiple locations. High engine potency are often achieved with lowNOx and soot emissions. In HCCI combustion, a homogenous mixture of air and fuel is compressed till auto-ignition happens close to the tip of the compression stroke, followed by a combustion method that's considerably quicker than either CI or SI combustion [11-14].

Since the mixture is lean and is fully controlled by chemical kinetics, there are new challenges in developing HCCI engines: difficulty controlling the auto-ignition of the mixture and the heat release rate at high load operation, achieving a cold start, meeting emission standards and controlling knock [19, 20]. The advantages of using HCCI technology in IC engines are:

1. High efficiency relative to SI engines - approaching the efficiency of CI engines due to the ability of these engines to use a high compression ratio (CR) and fast combustion

2. The ability to operate with a wide range of fuels and

3. The ability to be used in any engine configuration: automobile engines, stationary engines, heavy duty engines or small engines.

On the other hand, HCCI engines have some disadvantages such as high levels of unburned hydrocarbons (UHC) and carbon monoxide (CO). Knocking also occurs under certain operating conditions and reduces the operating range of the engine. Emissions regulations are becoming more stringent and NOx and soot emissions levels in HCCI engines have been greatly reduced without sacrificing efficiency, which is close to that of CI engines.

The combination of natural gas or hydrogen with diesel is reported to yield low emissions and to some extent increase the engine efficiency, either in HCCI or CI combustion model. Diesel alone is not suitable for HCCI engines due to its low volatility and high propensity to auto-ignite, while natural gas has a high resistance to auto-ignition, as reported by Kong [64]. Combinations of high octane number fuels (such as natural gas and hydrogen) with high cetane number fuels (such as diesel) are able to increase the engine durability, and under certain operating conditions reduce emissions levels such as soot, HC, CO and NOx. It was also reported that these combinations have a high thermal efficiency under early injection timing. Fuels with a higher octane number have better resistance to knocking, while fuels with a higher cetane number have a shorter ignition delay time, thus providing more time for the fuel to complete the combustion. Therefore, a combination of both (high cetane number fuels and high octane number fuels) provides a soft engine run, whereby the mixture can be operated at high CR and has a longer combustion duration.

Table 1. Characteristics of gasoline and diesel fuels


