Cylinder deactivation technique in multi-cylinder engines for fuel consumption reduction

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Abstract. Cylinder deactivation is well-known in spark-ignited (SI) engines and compression-ignited (CI) engines. The major reason why the efficiency of these engines is decreased at part load is due to flow restriction in the intake system caused by partially closing throttle valves, which causes increased pumping losses. In order to resolve this issue, the cylinder deactivation system can be implemented in SI engines with four cylinders by developing a suitable control system. Half of the engine's cylinders had their fuel injectors and valve trains turned off, enabling cylinder deactivation (CDA). Fuel consumption was reduced by reducing engine impelling work and decreasing heat transmission to the walls of the cylinder. CDA techniques are tested for their impact on in-cylinder pressure and pumping loss. This work reveals that all of these cylinder deactivation solutions minimize pumping losses and fuel consumption thereby enhancing the engine's thermal efficiency. These findings suggest that closing both intake and exhaust valves is the most effective way of triggering CDA, and lowering BSFC (Brake-specific fuel consumption).

1. Introduction

In SI and CI engines, cylinder deactivation, also known as CDA, shuts down valves and cuts off the fuel supply in order to deactivate cylinders. By regulating the intake valve, the goal is to minimize the stroke volume rather than the fusion charge. These inactive cylinders also serve as an "air spring," performing compression and expansion cycles on a regular basis [1]. As a result, CDA is also thought to be an effective way for reducing pumping losses during part load conditions, quire driving torque. According to this study, cylinder mode provides the optimum fuel efficiency at low loads and cruising speeds. For larger loads, the mode of 4 cylinders is used, while standard engine operation is used for dynamic at full loads [2].

The researchers discovered that combining multiple approaches boosted engine efficiency, and they advised using both VVT and CDA procedures at the same time to improve fuel economy by 14-16 percent. A valve transit system is devised in this work to handle cylinder deactivation in SI engines, and it outperforms the current valve train system. Intake valve in the cylinder will be unlocked in all cycles to deactivate the cylinder. This effort will use the new valve train system to conduct one-cylinder and two-cylinder deactivation modes [3,4]. The unique design has a simple structure, is easy to regulate, and can fully meet the cylinder deactivation control techniques. Furthermore, the research optimizes CDA techniques for various engine load ranges [5].

One option for manufacturers to reduce fuel consumption is to reduce the size of the engines they offer. However, if the thermodynamically optimal volumetric capacity of 400 to 500 cm3 per cylinder is to be maintained, the volume of a cylinder can only be constrained to a certain amount. In the meanwhile, driver retains access to a powerful engine that provides the similar level of lashing pleasure and well-being in terms of acoustics and vibration characteristics [6]. Another significant success aspect that could help this technology become more widely used is its ability to be integrated into existing engine ideas at reasonable pricing [7]. The purpose of this topic is to reduce an internal combustion engine's fuel consumption.

- Inside the city, the power required is far lower than the peak power generated by the car.
- General Motors debuted this system in 1981.
- It continues to evolve as automobile manufacturers introduce new technologies [8].
Cylinder deactivation, which is utilized by automakers to progress fuel efficiency and diminish emissions, is based on this. While the details of how they work may vary, the underlying idea remains unchanged. When full power is not required, some of the cylinders are not powered. Deactivation is most commonly employed on V6 or V8 engines, thereby lessening the engine's displacement while it is running [9]. The engine produces greater power as soon as all cylinders are turned on, when some are shut off, the engine produces less power. Automakers prefer small turbocharged engines, which inject additional air and fuel into the engine as needed.

Variable Cylinder Management is a Honda mechanism that will switch an engine to run on 3 or 4 cylinders subjected to the driving conditions. During its pickup truck in 2019, General Motors adds a variable system, which currently switches off half of the cylinders on its engines. Similar systems are available from other vendors. Since 1981, when one was initially debuted on a Cadillac, the systems have come a long way. Modular Displacement was the name of the technology, and it allowed a V8 engine to run on six or four cylinders. Shortly after, Mitsubishi introduced a four-cylinder-to-two-cylinder variant [10,11]. Other than the fact that they add expense and complexity to the engine, there aren't many negatives to deactivation systems nowadays.

2. Materials and Methods

In order to achieve increased efficiency, only half of the cylinders receive fuel. The engine will not function at its best when it is exerting a lot of effort on it at a constant speed. When the pistons pull in and expel air, they must overcome air resistance, which is known as pumping loss. Pumping losses are larger when it is light on the throttle, due to pressure variations between the intake and exhaust manifolds.

Pistons move up and down in their cylinders to turn a central crankshaft. The crankshaft revolves, and the force generated turns the wheels. When a cylinder deactivates, the system shuts the intake and exhaust valves, allowing air to enter and spent gases to exit. It also turns off the fuel injection to the cylinder. Figure 1 shows the schematic of the cylinder deactivation technology for diesel engines [12]. As it is tied to the rotating crankshaft, the piston still goes up and down.

![Figure 1. Diesel engine cylinder deactivation technology](image)

There is no pumping loss when some cylinders are disabled because no air is moving in or out of them. Furthermore, because the engine adjusts for the missing cylinders, the intake-exhaust pressure difference is reduced [13]. This lowers pumping loss in active cylinders, allowing them to operate more efficiently. Even though they are assisting in the movement of the deactivated pistons, the engine is still more efficient when they are connected to the crankshaft. When more power is required the mechanism reactivates the inactive cylinders. It is practically impossible to notice the shift because it is usually so smooth. According to Natural Resources Canada, cylinder deactivation can reduce fuel usage and emissions by 4 to 10%.

In addition, certain automobile engines now have a start/stop capability. While this was once only seen on hybrids, it is now being seen on regular gasoline vehicles, as well as some light-duty diesel. It is being added by automakers in order to reduce fuel consumption and pollutants even more. The engine turns off when you come to a complete stop with your foot on the brake, such as when stopped at a red light. The lights, audio, and climate control in the vehicle continue to work, and specific conditions, such as ambient and engine temperature,
must be met. When you let go of the brake pedal, the engine automatically resumes.

![Figure 2. Cylinder deactivation](image)

The manner in which the vehicle restarts is determined by the vehicle. In a hybrid, the car's electric motor handles it, whereas traditional cars utilize a heavier-duty starter. Many cars feature a button that can be pressed to turn off the start/stop system, and if that is not possible, the car can be put to "Sport" mode. Variable displacement engines allow the displacement of the engine to change for better fuel economy, usually by deactivating cylinders [14]. The method is generally employed in multi-cylinder engines with a large number of cylinders. Despite the fact that the concept has been known for a long time, many automobile producers have approved this type of technology in 2005. Cylinder deactivation is helped to lessen an internal combustion engine's fuel consumption and emissions when it is operating at a low load.

In normal light-load driving, usually the driver utilizes about 30 percent of the engine power. The throttle valve is practically locked in these situations, and this engine has to toil hard to pull air. Pumping loss is the result of this inefficiency. At mild load, some high capacity engines must be throttled to the point where the cylinder’s pressure at top center is around half that of a tiny 4-cylinder engine. Fuel efficiency is reduced when cylinder pressure is low [15].

At low loads, cylinder deactivation reduces the number of cylinders taking air from the intake manifold, increasing the fluid (air) pressure. The amount of gasoline spent is greatly reduced by shutting down half of an engine's cylinders. In highway circumstances, fuel consumption can be decreased by 8 to 25% by lowering pumping losses, which increases pressure in each functioning cylinder, and reduces the amount of fuel pushed into the cylinders [16].

To deactivate a cylinder, the intake and exhaust valves are kept closed. It generates "air spring" in the combustion chamber by keeping the intake and exhaust valves closed [17]. To equalize the strain on the engine, the confined exhaust gases are compressed and decompressed, resulting in virtually no additional stress on the engine. The engine management system is also employed in the latest generation of cylinder deactivation systems to reduce fuel flow to the deactivated cylinders. Cylinder deactivation is typically used on engines with relatively large displacements that are inefficient under mild load. Up to 6 cylinders of a V12 engine can be disabled. Cooling imbalance and vibration are two problems that all variable displacement engines need to overcome [18,19].

3. Results and Discussion

The pumping losses are eliminated since the air spring performs a periodic compression and expansion cycle. Deactivation can begin at either of three points namely before or after the exhaust stroke and after the intake stroke. When a valve is deactivated before the operation of the exhaust stroke, hot gases are trapped within the cylinder. It retains the cylinder warm, and high temperatures have advantages in terms of thermal efficiency [20].

Because of the timing, the compression end pressure is higher. Deactivating the engine after the intake stroke results in temperatures and pressures close to ambient, which has the effect of reducing the compression end pressure. When deactivation occurs after the intake stroke, the compression end pressure is even lower. Because of blow-by effects and cylinder wall heat transfer, cylinder pressure and temperature will gradually level off.
Due to the low power requirements associated with internal combustion engines, internal combustion engines generally run under low engine load most of the time. The engine's efficiency depends on engine load and is greatest at high Brake Mean Effective Pressure (BMEP). To maintain the same total BMEP after deactivation, the active cylinders must run at a higher Indicated Mean Effective Pressure (IMEP). Cylinder deactivation can be beneficial in the combination of those two operating conditions. BMEP represents the performance of the entire engine, whereas IMEP represents the performance of each individual cylinder.

![Image](image1.png)

**Figure 3.** Oil flowing in latching mechanism

![Image](image2.png)

**Figure 4.** Rocker arm latch and unlatch mechanism

The rocker arm latch mechanism is unlatched with the oil pressure and cylinder deactivation is done in this method. When engine ECU signal off, then the oil supply flow is stopped from the engine oil supply unit and the rocker arm mechanism latch is locked again and then the cylinder is active in this condition. In unlatched condition there is no valve lift and it is at 0 degree.
When cylinder deactivation is used at low loads, the throttle valve can be opened even wider to maintain the identical output power. The pumping losses are reduced, and the pressure in the individual cylinder is increased. In most cases, fuel consumption may be reduced by roughly 20%. Cylinder deactivation is commonly employed on engines with large displacements that are inefficient at low loads. A V12 engine can have up to 6 cylinders deactivated.

4. Conclusion

The cylinder deactivation technology enhances the efficiency and fuel efficiency of the engine in various modes. It is most effective and appropriate to use the CDA mode to lower pumping loss since it closes both intake and exhaust valves. When deactivated cylinders are fixed, the hydraulic friction loss in the cylinders is increased. In the deactivated cylinder, the reductions in the BSFC are a result of improved indicated efficiency, reduced pumping losses, and reduced friction losses associated with valve trains. For a medium-speed high-power engine, exhaust gas recirculation used in conjunction with CDA closes all valves. It decreases the engine emission levels while reducing the BSFC without requiring significant engine modifications. Among the other engine modes, CDA has the lowest BSFC and overall fuel consumption. For the speed load points examined, steady-state BSFC increases in the range of 10% to 30% were observed without impacting engine emissions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.
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