INVENTION DISCLOSURE – MECHANICAL SUBJECT MATTER

VALVE TRAIN SYSTEM FOR CYLINDER DEACTIVATION IN SPARK IGNITION ENGINES

1. PREAMBLE

The disclosure pertains to a novel valve train system that is designed to control cylinder deactivation in Spark Ignition (SI) engines, wherein intake valve in cylinder is opened in all cycles for deactivating cylinder. The proposed valve train system controls cylinder deactivation with different strategies i.e., one-cylinder deactivation, two-cylinder deactivation and three-cylinder deactivation states, these modes depend on the driving torque in vehicle. The novel design is characterized by a simple structure, easy control and can fully meet strategies of cylinder deactivation control.

2. INTRODUCTION

CDA, which is also known as cylinder deactivation, is applied in SI engines by shutting off all valves and cutting off the fuel supply to deactivated cylinders for all cycles simultaneously as shown in Fig. 1. The aim is to reduce the stroke volume, instead of decreasing the mixture charge, by controlling the intake valve. Additionally, these deactivated cylinders act as an “air spring”, which performs compression and expansion cycles periodically. Hence, CDA also is considered an effective method to significantly reduce pumping losses at part load conditions.

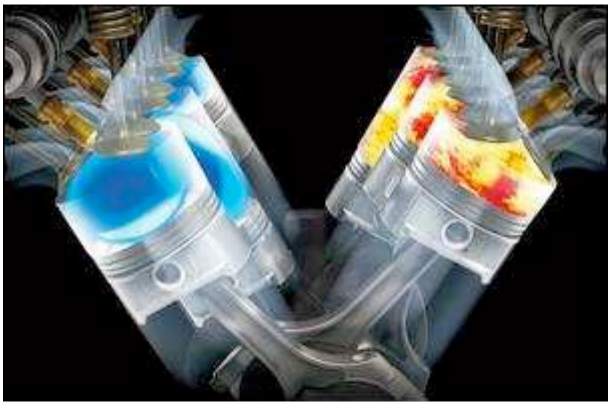

Figure 1. Cylinder deactivation for an exemplary 6 cylinder engine

The benefits of CDA in reducing fuel consumption and emission at low engine loads have been evident. The application of CDA of an inline 4-cylinder engine with 2 deactivated cylinders (50% CDA) can improve efficiency by about 20% and decrease HC-emission about

10-40% for low load conditions. Fuel consumption can also be improved over a wide range of operating conditions.

By using proposed two-cylinder deactivation mode, engine efficiency can be considerably improved at part load because each activating cylinder in the mode has to be operated at higher Indicated mean effective pressure (IMEP). This leads to a significant improvement for the pumping losses in this mode. The one-cylinder deactivation mode is selected for improving the engine efficiency at the medium load. At these loads, the use of one-cylinder deactivation mode satisfies the driving torque and it can use higher IMEP in each engine and therefore leads to improvement of engine efficiency of the vehicle. On the contrary, cylinder deactivation will not be used in engine at high engine loads because CDA cannot satisfy the output power and the improved engine efficiency is thermodynamically limited at full loads. Accordingly, these causes will lead to some disadvantages for the fuel consumption at that load.

3. PROPOSED VALVE TRAIN SYSTEM FOR CYLINDER DEACTIVATION

3.1 Cylinder Deactivation

Cylinder deactivation has some advantages for SI engines that have the large displacement volume. However, in the recent year, this method is applied in SI engines, which have small cylinder volume, for improving fuel consumption during part loads. An engine with the cylinder deactivation technology keeps the intake or exhaust valves closed through all cycles, at the same time, the ignition and fuel delivered to the cylinder deactivations are cut - off by blocking the injector and ignition signals. By closing valves in the cylinder, the cylinder can be used as an “air spring”. This air spring performs a periodical compression and expansion cycle, which eliminates pumping losses of the engine

The cylinder deactivation brings some benefits for engine efficiency by decreasing the pumping loses at part loads. Throttle valve is nearly closed and pumping losses are high in 2 cylinders active mode at part load. Whereas, throttle valve is more opened to get the same power and pumping losses are lower in one-cylinder active and one-cylinder de-active mode. This results in improving the engine efficiency and fuel consumption for cylinder deactivation.

3.2 Cylinder Deactivation Control Mechanism

The invention has been performed in Hyundai engine G4EK with conventional valve train system as shown in Fig 2. Engine uses single over head camshaft (SOHC) system, which has 12 valves for 4 cylinders, to control intake and exhaust valve timings.

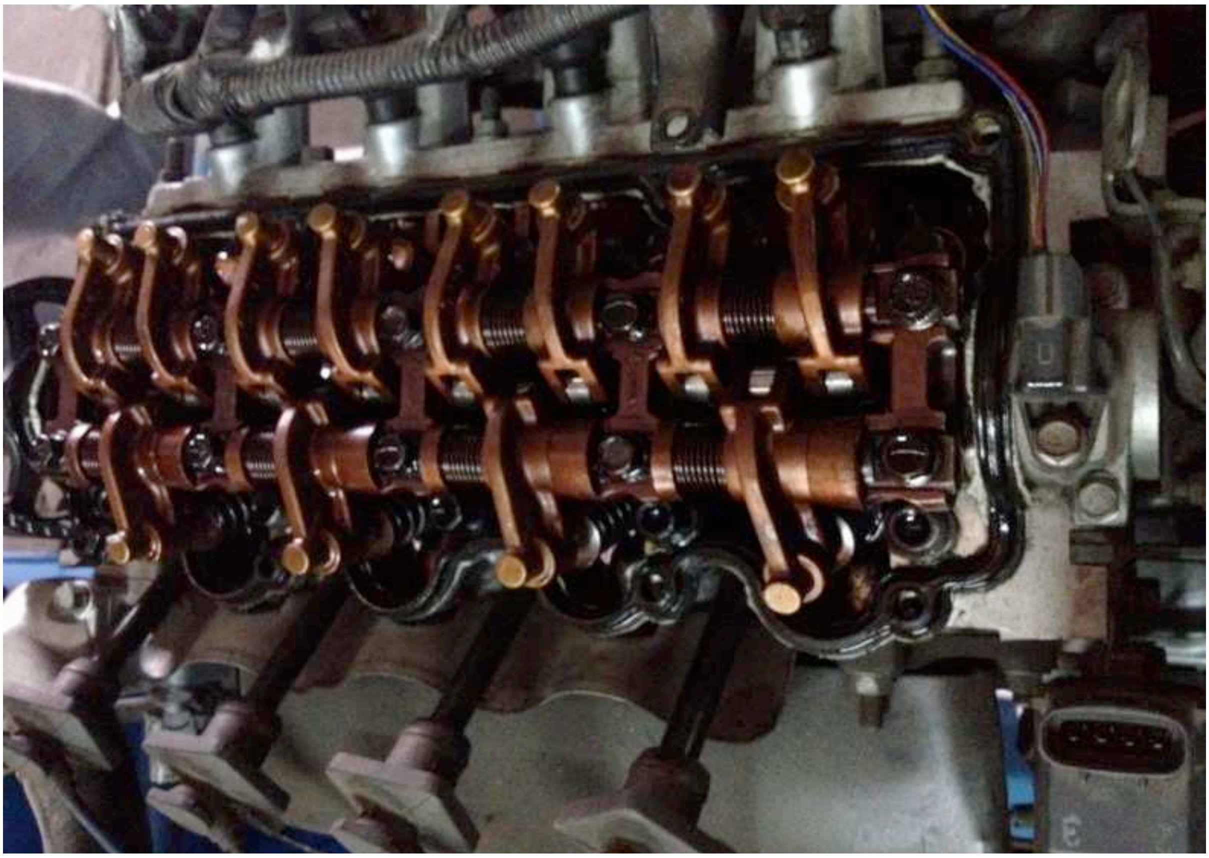

Figure 2. The conventional valve train system in Hyundai engine G4EK

The proposed design of valve train system has improved the conventional valve train by adding some parts to carry out the cylinder deactivation as shown in Fig 3. The secondary rocker arm and secondary camshaft actuates the intake valve at opening position for the cylinders which needs to cut off. This mechanism system, which differs from the existing cylinder deactivation control design, always keeps the intake valve in opening position when we need to de-active the cylinder along with cutting off the ignition and fuel to the cylinder deactivation. This results in reduced pumping losses due to the intake and compression cycles.

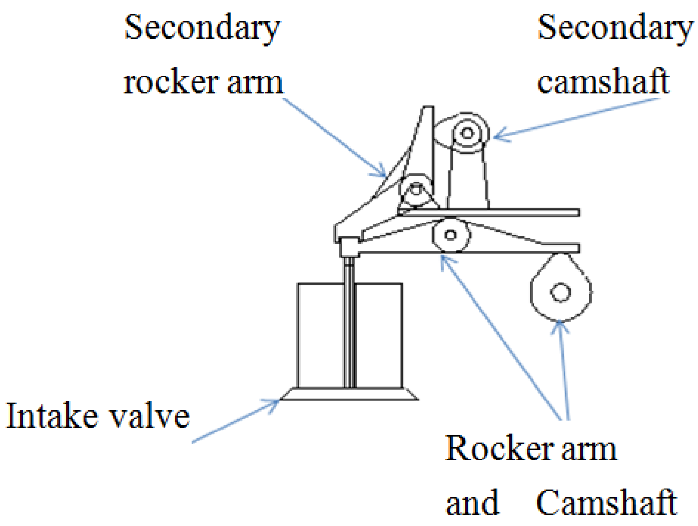

Figure 3. Intake valve control mechanism for cylinder deactivation

The mechanism can control to cut off one, two or three cylinders that depend on the driving torque at various operating loads. The camshaft includes two parts: camshaft with two cam lobes for deactivating cylinder #1 and #2, and camshaft with one cam lobe for controlling cylinder # 3. Both camshafts are engaged and disengaged which is controlled by motor B. Motor B can control the splined joint that slips for engaging or disengaging the camshafts. Motor A rotates the camshaft to press the intake valve at opening position. Therefore, the cylinder deactivation mechanism can cut off one-cylinder, two-cylinder or three-cylinder modes by combining motor A and motor B.

When electrical motor A rotates, it drives the secondary camshaft, cam lobe actuates the secondary rocker arm that presses the intake valve at open position. The maximum distance opening intake valve is about 0.2-0.5 mm. When the intake valve is opened, the cylinder will be deactivated. The cylinder deactivation must be accorded with the driving torque that depends on engine load. Therefore, maximum cylinder numbers can be cut off in engine about 3 cylinders. The valve train mechanism for deactivating is outlined in Fig 4.

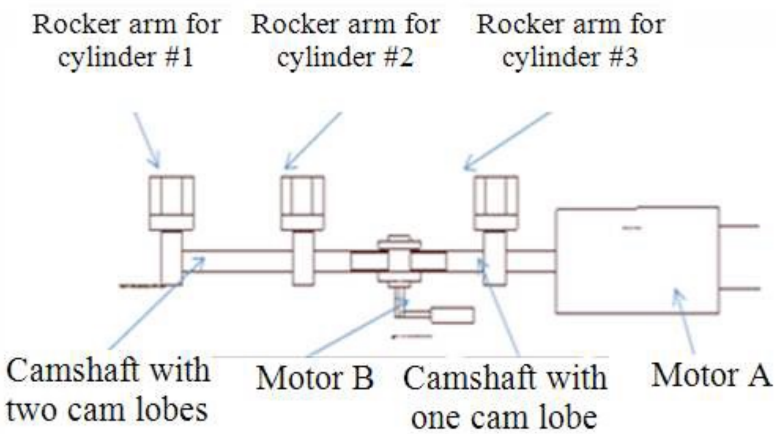

Figure 4. The outline of cylinder deactivation mechanism

The splined joint and fork, which control slip joint, can connect and disconnect 2 parts of camshaft as shown in Fig 5. The fork is controlled by the motor B (see in Fig 6).

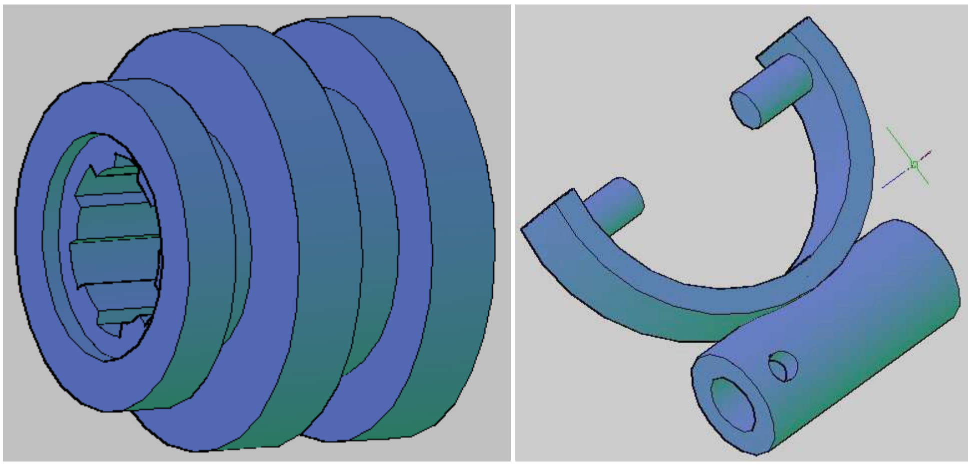

Figure 5. The splined joint and controlled fork

We have proposed a mechanism that controls cylinder deactivation with different strategies: one-cylinder deactivation, two-cylinder deactivation and three-cylinder deactivation states, these modes depend on the driving torque in vehicle. However, there-cylinder deactivation mode is only executed for very low loads that can't meet for the driving torque when vehicle run on the street. Therefore, in study we have proposed and manufactured a cylinder deactivation control mechanism that can cut off one or two-cylinder deactivation as shown in Fig 6. This design has mechanism, structure and control that are similar to the above mechanism as show in Fig 7.

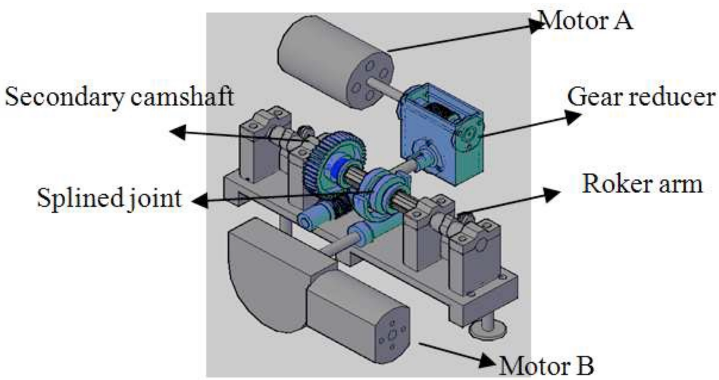

Figure 6. The cylinder deactivation control mechanism diagram

The mechanism for controlling cylinder deactivation is applied on Hyundai Accent engine with 4 cylinders. By adding the mechanism for deactivating cylinder and keeping the conventional valve train system for controlling valve timing.

Figure 7. The mechanism for controlling cylinder deactivation

The purpose of the proposed valve train system is to provide a mechanism that can cut off the cylinders. Depending on engine loads, mechanism controls one-cylinder or two-cylinder deactivation modes. One-cylinder deactivation mode is performed for medium engine load. Two-cylinder deactivation mode is used for low engine load. This improves fuel consumption in SI engines. To demonstrate this mechanism, a model is shown in Fig 6. Motor A rotates the secondary camshaft to press the intake valve at opening position. Motor B controls the splined joint for deactivating one-cylinder or two-cylinder deactivation modes. The mechanism for controlling cylinder deactivation is installed in Hyundai engine as shown in Fig 8.

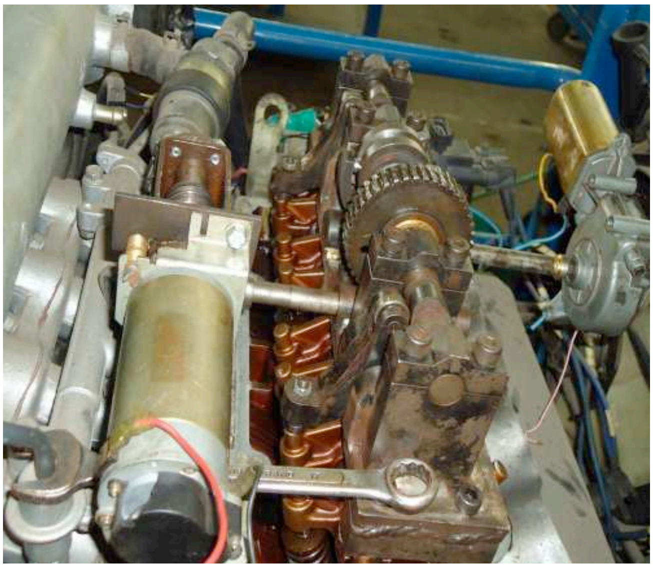

Figure 8. Mechanism installed in Hyundai engine

The novel valve train system can control and cut off cylinder easily which is not affected to the controlling of valve timing in engine.

3.3 Optimal CDA Strategies for Load Engine Ranges

The two-cylinder deactivation and one-cylinder deactivation modes have been investigated at low and medium engine loads. At high engine loads, the use of CDA causes some disadvantages for engine performance and fuel consumption. Correspondingly, the effects of CDA are not examined for high loads. Additionally, the use of more than two deactivated cylinders cannot satisfy driving torque at all of operation conditions in the engine. Therefore, this application will not be investigated in this approach, either.

The two-cylinder deactivation mode generates maximum torque at 5.2 bar Brake Mean Effective Pressure (BMEP), whereas the one-cylinder deactivation mode produces maximum torque at 8.6 bar BMEP. Therefore, the two-cylinder deactivation mode is examined only at low engine loads, while the one-cylinder deactivation mode is examined from low to medium load. Fig 9 shows the effects of CDA on Brake specific fuel consumption (BSFC) at full range of engine load. The simulation results conclude that the use of two-cylinder deactivation is the most optimal solution for low engine loads. Similarly, the one-cylinder deactivation mode is an optimal selection for medium loads. And finally, normal engine is best used for high engine loads.

By using two-cylinder deactivation mode, engine efficiency can be considerably improved at part load because each activating cylinder in the mode has to be operated at higher IMEP. This leads to a significant improvement for pumping losses in this mode. The one-cylinder deactivation mode is selected for improving engine efficiency at medium load. At these loads, the use of one-cylinder deactivation mode satisfies driving torque and it can use higher IMEP in each engine and therefore these lead to improvement in engine efficiency of the vehicle. On the contrary, cylinder deactivation cannot be used in the engine at high engine loads because CDA cannot satisfy the output power and improvement in engine efficiency is thermodynamically limited at full loads. Accordingly, these causes will lead to some disadvantages for the fuel consumption at that load.

As the results shown in Fig 9, an SI engine controls opening of valves so that it operates at the two-cylinder deactivation mode to reach the optimal fuel consumption at low engine load. The one-cylinder deactivation mode is controlled to result in some benefits about fuel economy at medium engine load. Finally, SI engines operate at normal engine mode to obtain fuel economy and satisfy the engine power at full engine load.

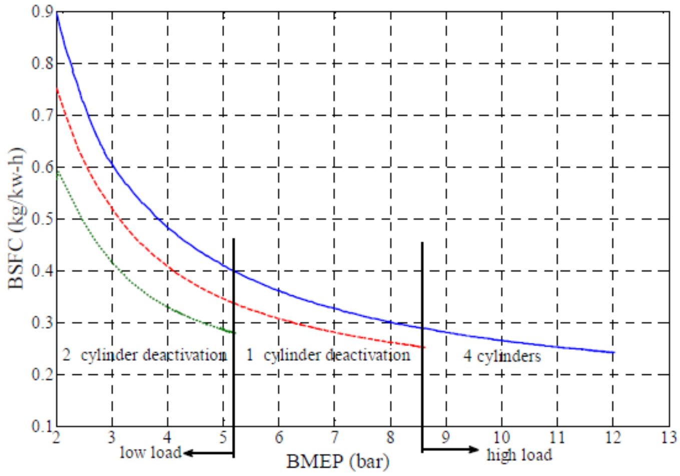

Figure 9. Effects of cylinder deactivation at entire load ranges

4. CONCLUSIONS

A new valve train system, which differs to the existing design, has been proposed to control cylinder deactivation in SI engines. The novel design is characterized by a simple structure, easy control and can fully meet strategies of cylinder deactivation control. The use of CDA results in several benefits in improving SI engine efficiency at low engine load. Improvements resulting from CDA will degrade as engine load increases. The two-cylinder deactivation mode considerably improves fuel consumption at low engine load. Meanwhile the one-cylinder deactivation is an optimal fuel economy mode at medium engine load.

***Note for the Participants in IPDC:**

The evaluation of the patent specification and claims would be based on how many additional embodiments are added to make the coverage broad in addition to what is provided in the disclosure. Exact replica of the structure and scheme of the disclosure in the draft would lead to lower marking. The participant is expected to read and understand the background of the subject matter himself/herself in order to formulate the various embodiments of the invention with proper claim set etc.