Lecture23:Advanced Catalysts for HC Control

The Lecture Contains:

- Catalytic Converters for Cold Start HC Emission Control
- Electrically Heated Catalysts
- Close-Coupled Catalysts
- Hydrocarbon Adsorber /Trap Systems

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ADVANCED CATALYTIC EXHAUST AFTERTREATMERNT

Catalytic Converters for Cold Start HC Emission Control

Figure 5.19 shows HC emissions on US EPA cycle beginning from the instant when the engine is started from cold. Also, the LEV and ULEV HC limits are shown on this figure.

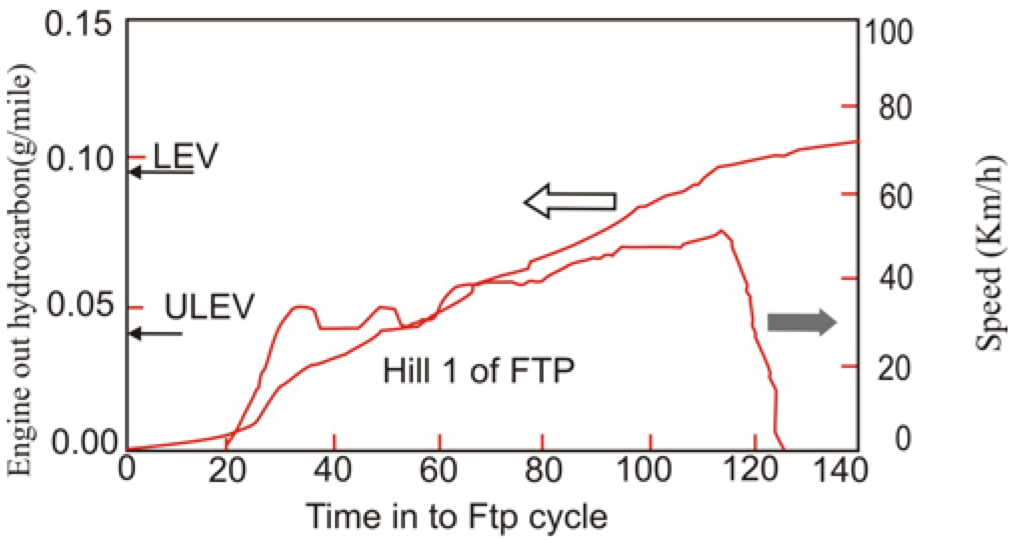

Figure 5.19	HC emissions during cold start in US FTP cycle. LEV and ULEV emission limits are alsoshown.

From this figure it is observed that;

- About 60 to 80% of total US FTP cycle HC emissions are produced during the first 2 minutes of vehicle operation after cold start.
- To meet LEV standards catalyst should become functional within 80 seconds
- For ULEV limts the catalyst should become functional within 50 seconds
  - Electrically heated catalysts (EHC)
  - Close-coupled catalysts
  - Hydrocarbon traps

Electrically Heated Catalysts

The converters can be electrically heated before the engine started. In the metallic monoliths, metal honeycomb itself has been used as a heating element. Use of thin steel foils reduces thermal capacity of the catalyst. However, electrical heating still requires considerable energy to be drawn from the battery particularly in cold climates. Under cold ambient conditions the batteries are subjected to very high power drain. This becomes more difficult proposition as at the low ambient temperatures the battery activity is low and a high amount of energy is also required to crank and start the engine.

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Close-Coupled Catalysts

A rapid catalyst light off is achieved by installing the converter very close to the engine to minimize heat losses from the exhaust gases as shown on Fig. 5.20. The catalysts installed so close are called 'close-coupled' catalysts. These catalysts have the following features;

- The close-coupled catalysts are designed mainly for oxidation of HC.
- In the close-coupled catalysts, CeO_2 is removed from the substrate washcoat as. CeO_2has excellent properties for oxidation of CO.
- The closed coupled catalysts have a small volume to improve light-off characteristics.
- These are designed to oxidize only part of HC and little CO so that generation of very high temperatures in the catalyst bed is prevented.
- HC oxidation in thee close-coupled catalyst raises the exhaust gas temperature so that the main under floor catalyst becomes operational rapidly within a short time. The under-floor catalyst mounted downstream converts the remaining HC and, also the CO and NO_x .

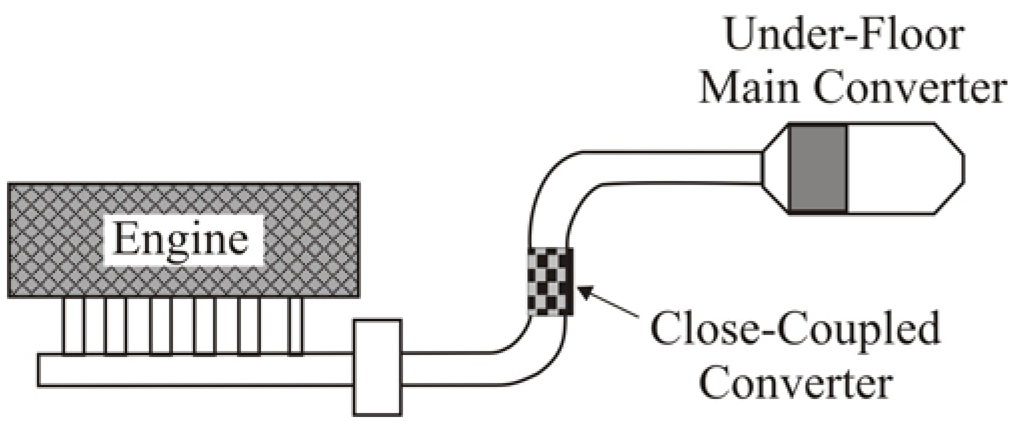

Figure 5.20	Schematic of exhaust system fitted with closed coupled catalyst

The main 3-way catalyst is installed sufficiently down stream of the exhaust manifold under the floor of the vehicles. These are also termed as 'underfloor catalytic converters'. The converters should not be exposed to excessively high temperatures during full engine load conditions and steep accelerations when the initial exhaust gas temperature at the inlet of the converter itself are quite high. During accelerations the unburned HC and CO concentrations are higher than the cruising conditions and their oxidation in the converter to achieve typically more than 90% conversion releases high amounts of energy that raises the gas temperatures substantially. However during engine cold start and warm-up conditions, the underfloor catalyst does not function as the gas temperatures are low and it also cools down as it flows from the exhaust port to the converter. With implementation of ULEV and US Tier 2 standards, HC emission control under engine cold start and warm-up operation are also required.
To reduce HC and CO emissions under cold engine conditions mew types of converters have been developed. For the direct injection stratified charge (DISC) engines, NOxemissions under over all lean engine operation are to be controlled. As the 3-way catalysts do not control NOxunder lean engine operation, new types of catalysts to reduce NOX for lean mixture operation have been developed.

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Hydrocarbon Adsorber /Trap Systems

A closed coupled catalyst needs up to 40 seconds to become operational after cold start and hence, considerable portion of the engine out emissions escapes the closed –coupled catalyst. A more advanced system has been developed that adsorbs and stores HC on an adsorbent which are released once the catalyst downstream reaches the light off temperature. A typical HC adsorption-release cycle is shown on Fig 5.21.

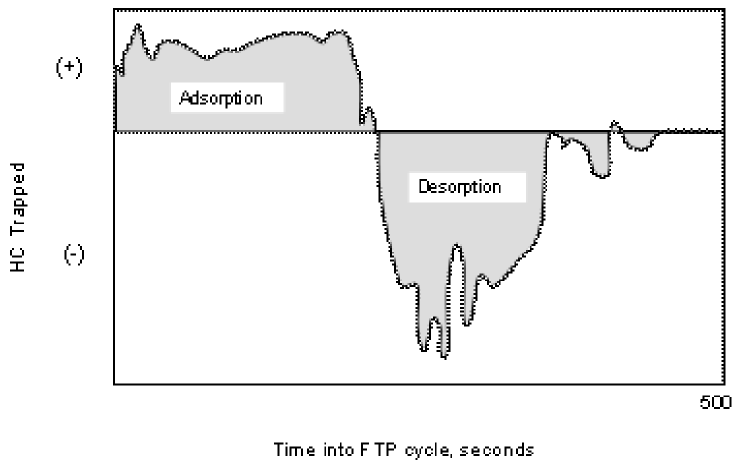

Figure 5.21	HC adsorption and release cycle for a HC trap

Typical layouts of the hydrocarbon adsorber/trap and main catalysts are shown in Fig 5.22 .

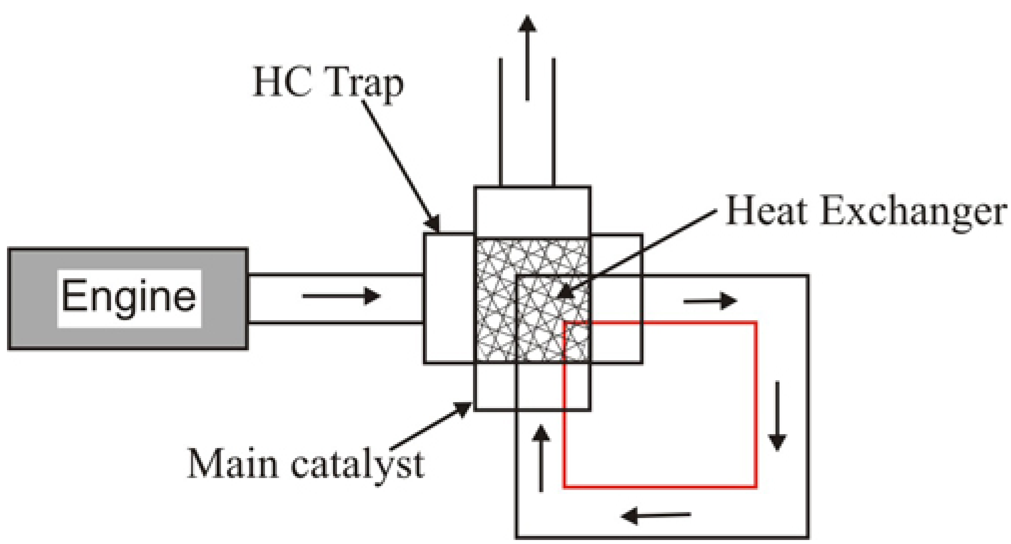

Figure 5.22	A schematic layout of exhaust system with hydrocarbon trap and main catalyst.

In another design, the hydrocarbon adsorber and the oxidation catalyst are integrated in one unit. This is followed downstream by the main catalytic converter for reduction of emissions under normal engine operation. In another advanced configuration of the integrated adsorber-catalyst system, double layered catalyst structure is coated on a cordierite substrate. The catalyst structure is shown schematically in Fig 5.23. The HC adsorbent is coated as the bottom layer close to the substrate and the normal 3-way catalyst as the upper layer. Under low temperatures the HC are adsorbed and released and get oxidized as the catalyst gets heated. However, under normal operation the adsorber being at higher temperature it does not absorb HC and all the emissions are converted in the main 3-way catalyst system.

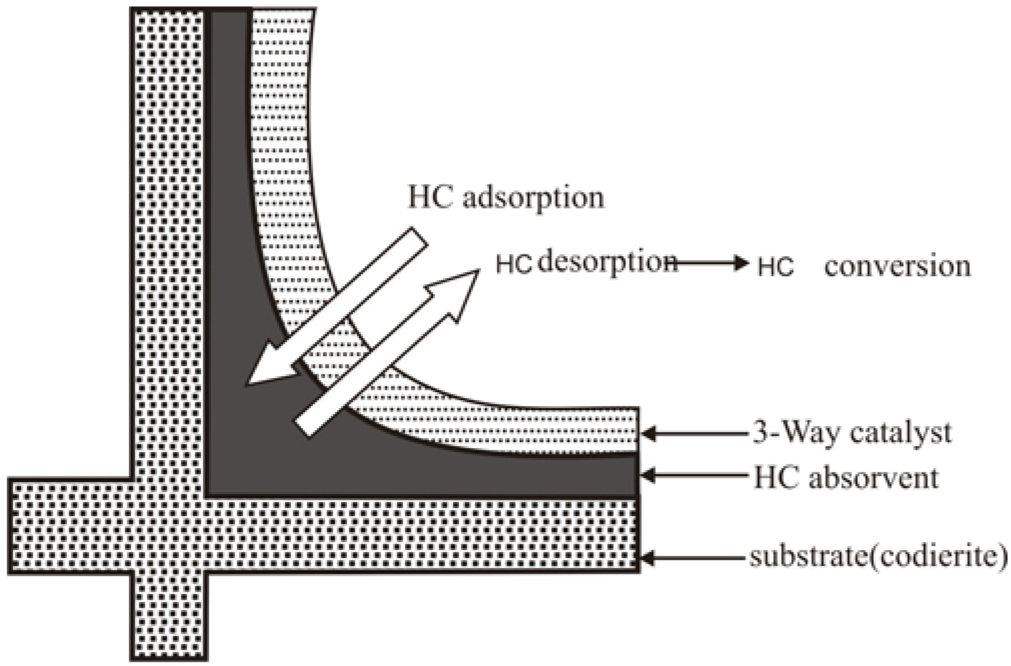

Figure 5.23	A two layer configuration of HC adsorbent and 3-way catalyst loaded on the same ceramic substrate.