Lecture 29

3rd Semester M Tech. Mechanical Systems Design

Mechanical Engineering Department

Subject: Advanced Engine Design

I/C Prof M Marouf Wani

Lecture 29 – Technology used for Emissions reduction from internal combustion engines.

Topic – Three-way Catalysts – For Reducing NO and Oxidizing CO and HC – Using Rh and Pt Catalysts - 25-11-2020

Three-way Catalyst

If an **engine** is operated at all times with an **air-fuel ratio** at or **close to stoichiometric**, then both **NO reduction and CO and HC oxidation** can be done in a **single catalyst bed**.

The catalyst effectively brings the exhaust gas composition to a near-equilibrium state at these exhaust conditions;
i.e., a composition of CO_2, H_2O, and N_2.

Enough reducing gases will be present to reduce NO and enough O_2 to oxidize the CO and the hydrocarbons.

Such a catalyst is called a **three-way catalyst** since it **removes all these pollutants simultaneously**.

Figure on the following next page shows the conversion efficiency for NO, CO, and HC as a function of the air-fuel ratio.

There is a **narrow range of air-fuel ratios** near stoichiometric in which **high conversion efficiencies** for all **three pollutants** are **achieved**.

The **width of this window** is narrow, about **0.1 air-fuel ratios** (7*10-3 in equivalence ratio units) for catalyst with high mileage use, and depends on catalyst formulation and engine operating conditions.

This **window** is sufficiently **narrow** to be **beyond** the control **capabilities** of an ordinary **carburetor**, though it **can** sometimes **be achieved with**

1. **sophisticated carburetors** and
2. **fuel injection systems**.

Thus closed-loop control of equivalence ratio has been introduced.

An **oxygen sensor** in the **exhaust** is used to **indicate** whether the **engine** is **operating rich or lean side of stoichiometric**, and provide a **signal** for adjusting the **fuel system** to **achieve** the **desired air-fuel mixture**. --- see section 7.4 John B Heywood

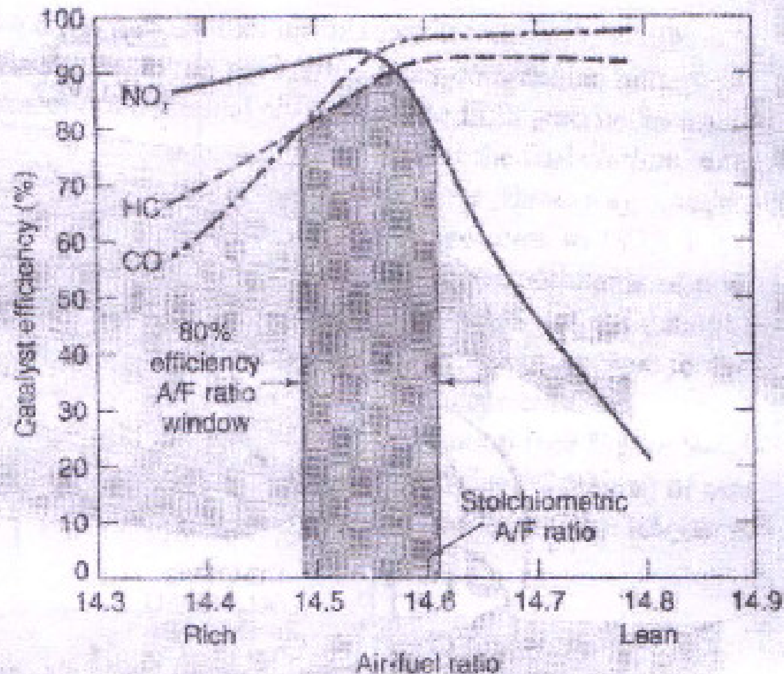

Figure 9-49 Conversion efficiency of a three-way catalyst as a function of the air–fuel ratio (Kummer, 1981).

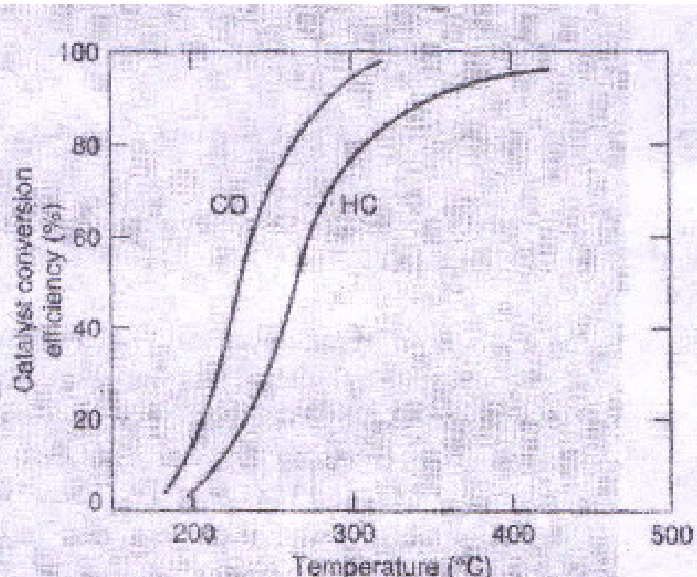

Figure 9-50 Conversion efficiencies for typical oxidizing catalysts (Mondt, 1989).

Holding the equivalence ratio precisely on the chosen near-stoichiometric value is not a **practical** expectation of such a **feedback system**, and the **equivalence ratio oscillates** around the set point in an approximately **periodic manner as the fuel flow is varied**.

Experimental data show that there is a considerable **widening of** the **air-fuel ratio window** where all **three pollutants** are **effectively removed**, with **cyclic variation** of the fuel flow. The maximum conversion in the middle of the window is reduced, however, from its value when there are no fluctuations.

The effect of **fluctuations** depends on the frequency; frequency of about 0.5 to 1 hertz are most effective and the **usable window** (at lower conversion efficiencies) can be **broadened to** about **1 air-fuel ratio**.

Rhodium is the principal ingredient used in commercial catalysts to remove NO.

It is **very active** for **NO reduction**, is much **less inhibited by CO** and **sulfur compounds**, and **produces less NH_3** than Pt.

To **remove NO** under **slightly lean-of-stoichiometric** conditions, the **catalyst must react** the **CO, H_2, or HC with NO** rather than with O_2, as the exhaust **gas passes** through the **catalyst bed.**

Rhodium shows some NO reduction activity slightly lean of stoichiometric.

On the rich side, the three way catalyst window is determined by hydrocarbon and CO removal.

Platinum is most commonly used for HC and CO oxidation; it has good activity under stoichiometric and slightly lean conditions.

When sufficient rhodium is present, the participation of Pt in NO removal is minimal.

In the rich regime the three-way catalyst consumes all the oxygen that is present in the exhaust, and as a consequence removes an equivalent amount of CO, H_2, and hydrocarbons.

Dated: 25-11-2020

Prof M Marouf Wani

I/C Advanced Engine Design
Mechanical engineering Department
National Institute of Technology
Srinagar, J&K
India – PIN 190006

Text Books:

[1] Internal Combustion Engine Fundamentals
By John B Heywood
Published By: McGraw-Hill Book Company

[2] Internal Combustion Engines
Applied Thermo-sciences
By Colin R. Ferguson
Allan T. Kirkpatrick
Published By: John Wiley & Sons, UK