Lecture 27

3rd Semester M Tech. Mechanical Systems Design

Mechanical Engineering Department

Subject: Advanced Engine Design

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Lecture 27 – Technology used for Emissions reduction from internal combustion engines.

Topic – Oxidation Catalysts – 23-11-2020

Oxidation Catalysts

The **function** of an **oxidation catalyst** is to **oxidize CO and hydrocarbons to CO_2 and water** in an **exhaust gas** stream **which** typically **contains**:

~ 12 percent CO_2 and H_2O

100 to 2000 ppm NO

~ 20 ppm SO_2

1 to 5 percent O_2

0.2 to 5 percent CO and

1000 to 6000 ppm C1 HC

Often with

small amounts of lead and phosphorus.

About **half the hydrocarbons** emitted by the **SI engine** are **unburned fuel** compounds.

The **saturated hydrocarbons** (which comprise some **20 to 30 percent**) are the **most difficult to oxidize.**
The ease of oxidation increases with increasing molecular weight.

Sufficient oxygen must be present **to oxidize the CO and HC.**

This may be **supplied by the engine itself** running **lean** of stoichiometric **or**

with a **pump** that introduces **air** into the exhaust ports just **downstream of the valve**.

Venture air addition into the exhaust port **using the pressure pulsations generated by the exhaust process** can be used to **add the required air**.

Because of their **high intrinsic activity**, **noble metals** are most suitable as the **catalyst material**.

They show

higher specific activity for **HC oxidation**, are

more **thermally resistant to loss** of **low-temperature activity**,

and are **much less deactivated by** the **sulfur in the fuel** than base metal oxides**.**

A mixture of platinum (Pt) and palladium (Pd) is most commonly used.

For the oxidation of CO, olefins, and methane, specific activity of Pd is higher than that of Pt.
For the oxidation of aromatic compounds, Pt and Pd have similar activity.

For oxidation of paraffin hydrocarbons (with molecular size greater than C_3), Pt is more active than Pd.

Pure noble metals sinter rapidly in the 500 to 900 C temperature range experienced by exhaust catalysts.

Since catalytic behavior is manifested exclusively by surface atoms, the noble metals are dispersed as finely as possible on an inert support such as γ-A_2O_3 which prevents particle to particle metal contact and suppresses sintering.

The particle size of the noble metal particles in a fresh catalyst is less than 50nm.

This can increase to ~ 100 nm when the catalyst is exposed to the high temperatures of the exhaust in vehicle operation.

Typical noble metal concentrations in a **commercial honeycomb catalyst** are between

1 and 2 g/dm^3 of honeycomb volume

with

Pt/Pd = 2 on a weight basis.

As a **rough rule of thumb**, the **ceramic honeycomb volume required** is about **half the engine displacement volume**.

This gives a space velocity through the convertor (volume flow rate of exhaust gas divided by the convertor volume) over the normal engine operating range of 5 to 30 per second.

Space Velocity = $\frac{Volume\ flow\ rate\ of\ exhaust\ gas}{Convertor\ Volume}$

Space Velocity = (5 to 30)/sec

The Conversion Efficiency

The **conversion efficiency of a catalyst** is the **ratio** of the **rate of mass removal in the catalyst of the particular constituent** of interest **to the mass flow rate of that constituent into the catalyst**:

e.g., for HC

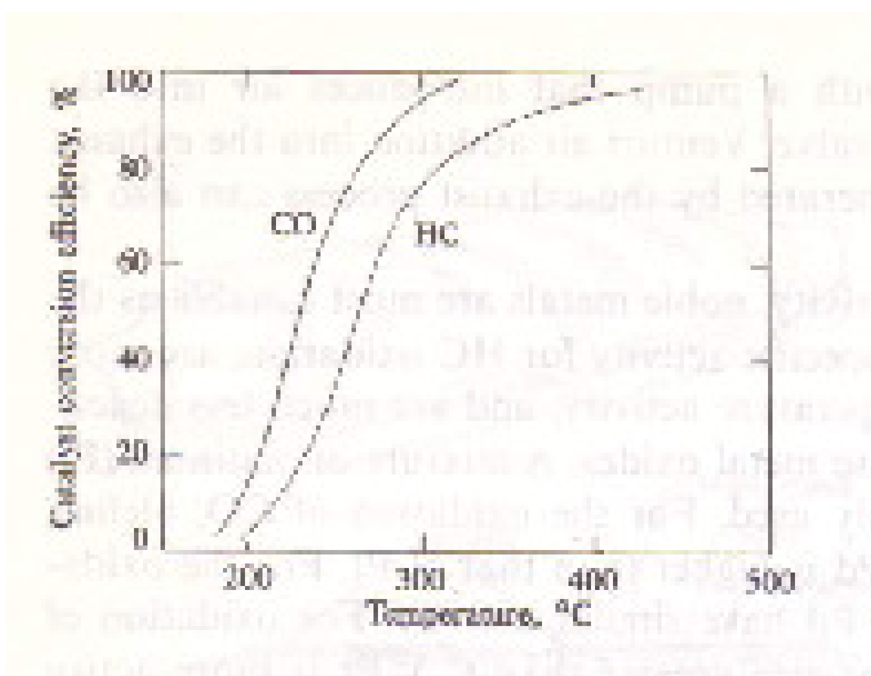
$$\eta_{cat} = \frac{\dot{m}_{HC,in} - \dot{m}_{HC,out}}{\dot{m}_{HC,in}}$$

Note:

in - more in magnitude
out - less in magnitude

$$\eta_{cat} = 1 - \frac{\dot{m}_{HC,out}}{\dot{m}_{HC,in}}$$

The **variation** of **conversion efficiency** of a typical oxidizing catalytic convertor **with temperature** is shown **below**.



At **high temperatures**, the steady state **conversion efficiencies** of a new oxidation catalyst are typically **98 to 99 percent for CO** and **95 percent or above for HC**.

However the **catalyst is ineffective until its temperature has risen above 250 to 300 C**.

The term **light-off temperature** is often used to describe the **temperature at which the catalyst becomes more than 50 percent effective**.

The above numbers apply to fresh noble metal oxidation catalysis; **as catalysts spend time** in service, their **effectiveness deteriorates**.

Catalysis involves the **adsorption of the reactants onto surface** sites of high activity, **followed** by **chemical reaction**, then **desorption of the products**.

Catalyst degradation involves both the deactivation of these sites by **catalyst poisons** and a reduction in the effective area of these sites through sintering.
Poisoning **affects** both the warm-up and steady state **performance of the catalyst**.

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Text Books:

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

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