Three way Catalyst with faster light-off substrates – A promising approach to reduce tailpipe emissions

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1. Abstract

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- The ever-tightening regulation norms across the world
- Decision in India to leapfrog from BS4 to BS6 – with further reduction in emission limits
- Introduction of RDE norms in BS6.2 demanded further reduction in emissions under real time operating conditions
- The challenge more prominent in the turbocharged engines
- Innovative approach is needed to attain quicker catalyst “light-off”
- Three fold approach to achieve faster light-off
- Introduction of high-porosity substrates
- Resulted in improved emissions with a lower PGM content

2. Introduction

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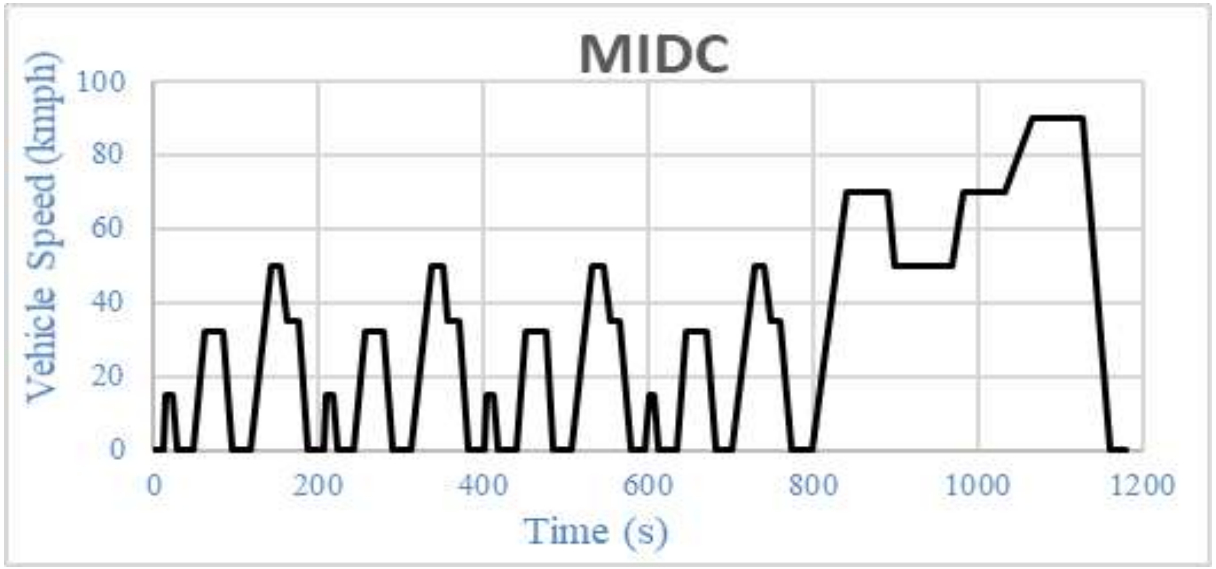
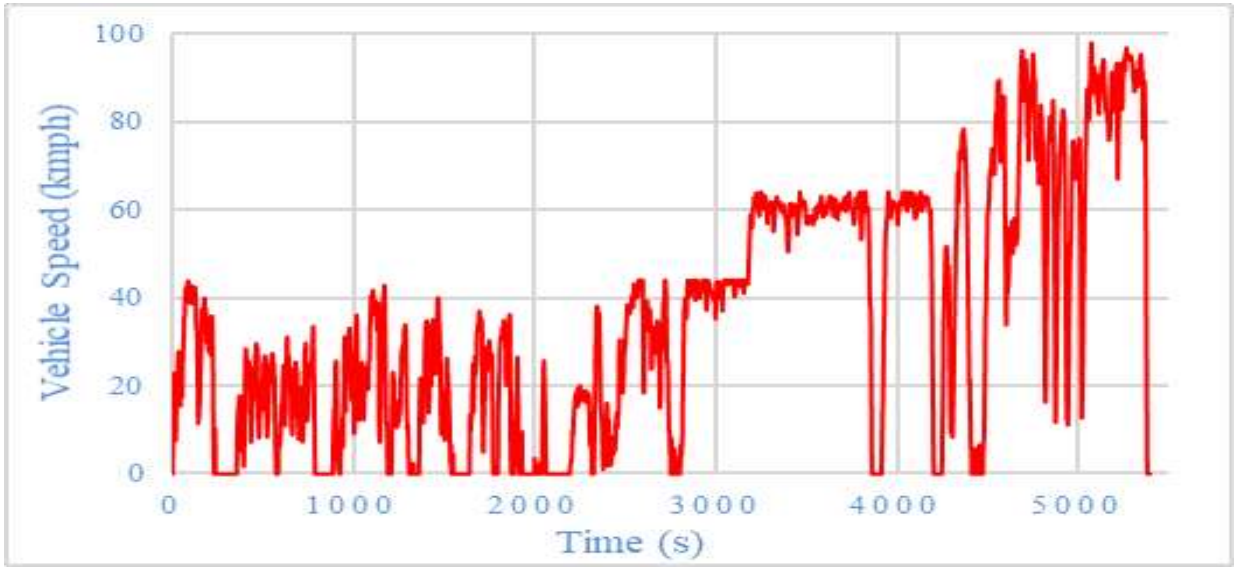
2.1 Emission test Driving Cycles for passenger cars – BS6 v/s BS6.2





Modified Indian driving cycle for passenger car (GVW < 3500 kg) applications

On Road Real Driving Emission test cycle

Till BS6 emission norms, for Type-I regulatory emission norms, MIDC (Modified Indian Driving Cycle) is only used

During Part I of the this cycle, the first 195 seconds contribute to major part of engine-out emissions in gasoline car applications.

In this initial cold phase, exhaust after treatment device (in this case, TWC) needs to reach its light off temperature as fast as possible to achieve maximum catalytic converter efficiency.

From BS6 Phase 2 onwards (1st April 2023), it is mandated that vehicle emissions meet RDE norms in addition to MIDC test cycle

RDE cycle trip always starts with urban driving mode followed by rural and motorway driving modes

Trip duration shall be between 90 and 120 min

2. Introduction – Challenges

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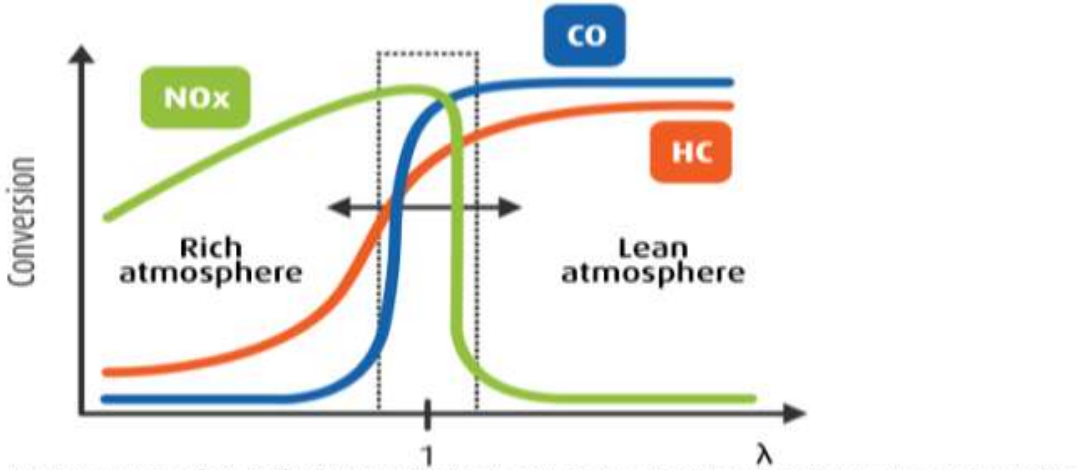
2.2 Working Principle of a Three Way Catalyst



Narrow range of air to fuel ratio with high conversion of all regulated gaseous components.

- ❑ **"Light-off" temperature. Lower the catalyst light off temperature, gas conversion will start happening soon**
- ❑ **The purpose is reduction in time taken for catalyst light-off**
- ❑ **TWC can maximize its gas conversion efficiency either by increasing the exhaust heat content or increasing the precious metal content (which increases the number of activation sites)**

- ➢ **Gasoline engines primarily operate close to stoichiometric with the air-fuel ratio fluctuating between less than or more than stoichiometric throughout the operating range.**
- ➢ **This characteristic of the gasoline engines can be used to simultaneously convert the gaseous emissions of NOx, CO and HC using a Three Way Catalyst (TWC).**
- ➢ **A catalyst provides microscopic activation sites that promote chemical interaction among the gas species present in the exhaust gas.**

2. Introduction

2.3 Three fold approach to achieve faster light-off

1. Catalytic converter design modification – Placing the TWC closer to the exhaust manifold

Existing BS6 TWC

BS6 Phase 2 TWC

- Distance of turbocharger outlet to top face of front catalyst substrate reduced
- This ensures that the gas reaching the catalyst is hotter (carrying higher heat content)
- Leading to higher gas conversion in the cold phase of emission test cycle

2. Improvement in EMS ECU Calibration strategy – Tuning of ECU parameters to achieve higher EGT

- Engine idle speed (rpm) set point was increased in BS6.2 EMS calibration by 10% for higher exhaust flow during every cold condition engine start operation
- Dependency of the catalyst light off active window calibration was changed from being time based (BS6) to exhaust temperature
- Engine Coolant Temperature based Variable Valve Timing (VVT) activation set point changed from 70°C (BS6) to 60°C (BS6.2).
- Also valve overlap was increased in BS6.2 for better scavenging effect.

3. Introduction of low thermal mass TWC substrate

Substrate Details	BS6	BS6.2
Product Name	Celcor® 600/2	FLORA® 800/3
Composition / Phase	2 Al2O3. 2 MgO. 5 SiO2/ Cordierite	2 Al2O3. 2 MgO. 5 SiO2/ Cordierite
Number of cells (cpsi)	600	800
Wall Thickness (inch)	0.0025	0.0035
Cell Design	Square Symmetric	Square Symmetric
Porosity (%)	**35**	**55**
Geometric Surface Area (GSA) (cm2/cm3)	36.2	40.8
Matrix Bulk Density (g/L)	223	184

Higher porosity of the FLORA® helps in reducing the Matrix Bulk Density by 17.5 %

Thus higher surface area provides a clear “light-off” advantage to FLORA® over the standard substrate.

3. Results

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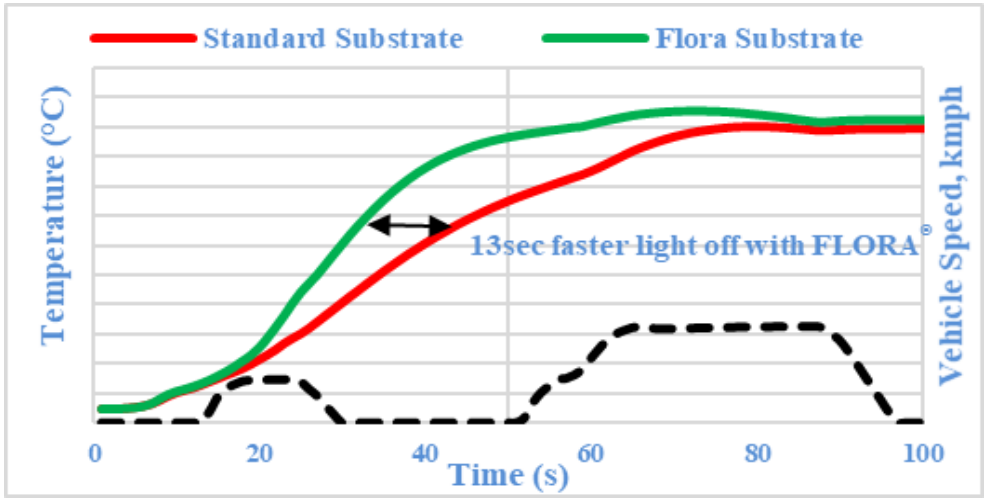
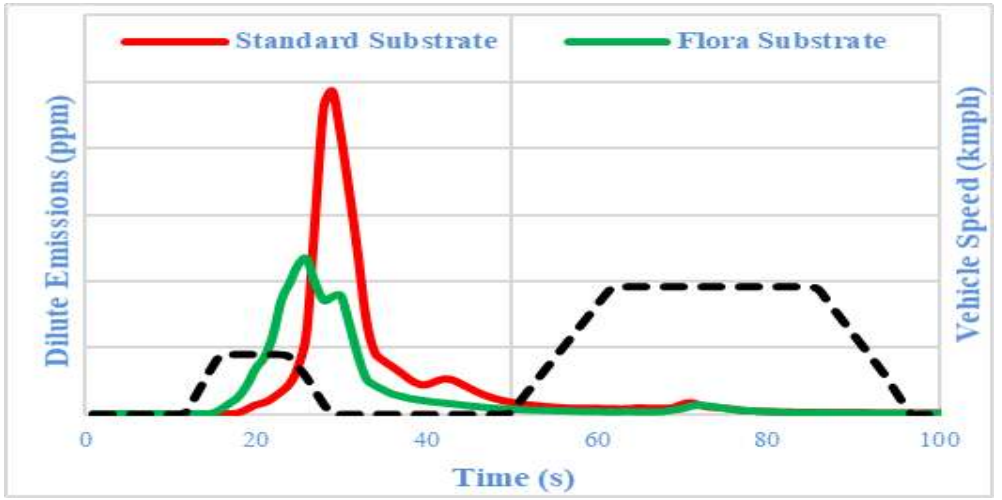
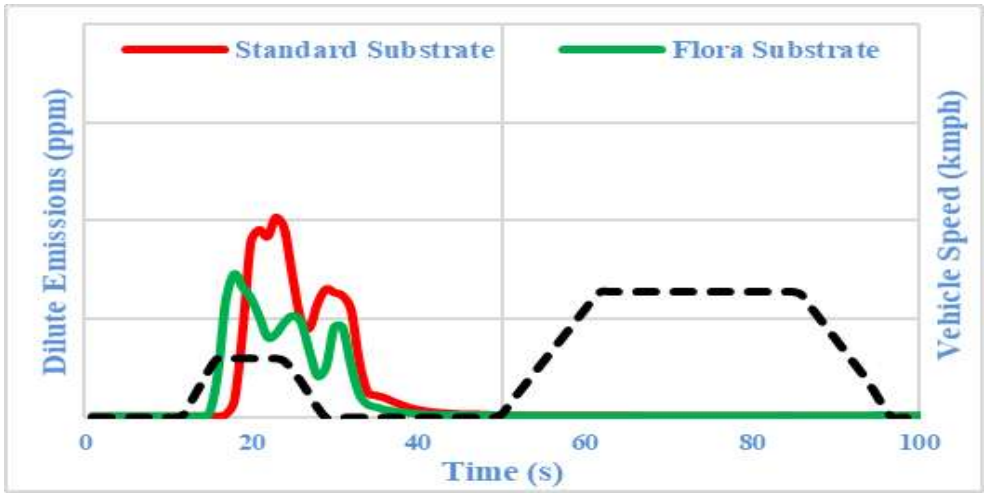
Exhaust Temperature profiles and Dilute emission traces with Flora and Standard substrate



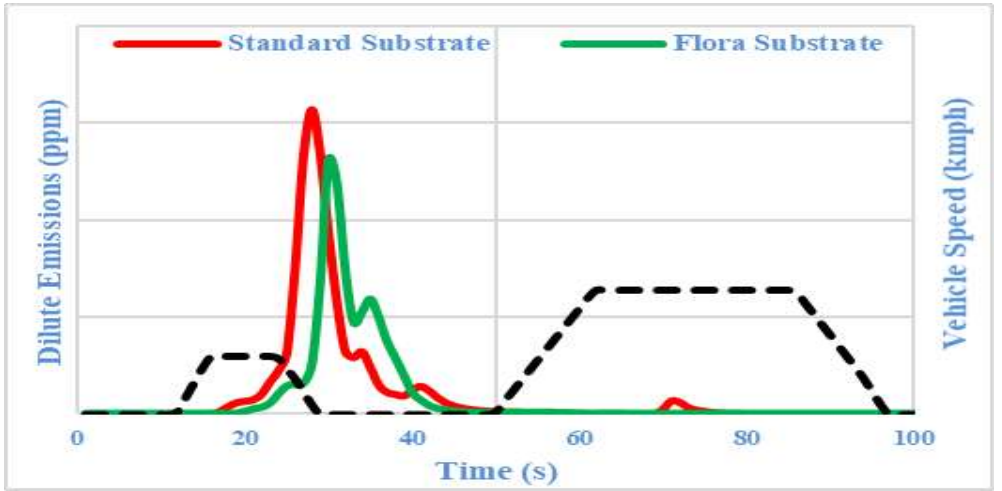
1. Exhaust Temperature profile in MIDC cycle cold phase



2. THC Pollutant profile in MIDC cycle – Cold Phase



3. CO Pollutant profile in MIDC cycle – Cold Phase



4. NOx Pollutant profile in MIDC cycle – Cold Phase

Pollutants	Overall (%) Reduction in BS6.2 compared to BS6
CO	17.8
THC	28.5
NOx	12.7

4. Conclusion & Future Scope

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- For the first time in India, a new emission control system comprising of a low thermal mass TWC Flora® substrate
- Improved the “light-off” performance and conversion efficiency of TWC - developed by Tata Motors to meet the BS6.2 emission norms
- The approach consisted of design change in the catalytic converter, an optimized calibration strategy and the use of a low thermal mass TWC substrate.
- The BS6.2 system allowed the TWC to “light-off” 13 seconds earlier than the BS6 system
- Sizeable reduction achieved in the gaseous cycle emissions.
- Further study is required to quantify the benefit of this system under RDE conditions.

THANK YOU !!!