

Emission Performance Improvements with Turbulent Metal Substrates on 2 & 3 Wheelers

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ABSTRACT

Two and Three Wheeler industry in the Asian region is growing at a rapid pace, as commuting by these vehicles is more affordable and efficient, specially in the developing nations. However, tightening of emission legislations, aimed at creating a cleaner and healthier environment, has led to increasingly demanding efforts required in making more efficient engines / vehicles and also focus on effective after-treatment systems. Catalytic converters, being the most preferred option for after-treatment solutions, play an important role in achieving the desired end results.

Over the past several years, monolithic catalytic converters with laminar flow profile were being used by automotive industry. These catalytic converters though create some turbulence at the inlet, make the majority of the rest of the flow laminar, thereby reducing the mass transfer of the exhaust gas components to the effective catalytic sites.

Turbulent flow technology has been successfully developed more recently with metal substrates to get the required turbulent flow characteristics in the substrate channels. The advantages of this technology include better conversion efficiencies, lesser volume of the catalysts – and hence less packaging space requirements, lower system costs etc.

The present paper deals with the work done on two models of two wheelers and one model of three wheeler using Turbulent Structure metal substrates. On one two wheeler, it was possible to optimize the overall system cost by switching over to Turbulent Structure from the earlier Laminar Structure, thereby totally eliminating a start up catalyst used in the earlier design. Benefits on performance using Turbulent Flow technology also demonstrated on the other two wheeler and a three wheeler.

All the emission evaluation results with Turbulent Flow technology are presented in this paper, along with benefits on the cost and performance.

INTRODUCTION

Mass transfer for regular catalyst shows a laminar flow after intrusion in the catalytic converter after a short time. The major development in the catalyst substrate technology with this laminar flow pattern has been concentrated on increasing the cell density from 400 to 900 cpsi or even 1200 cpsi since a long time. The mass transfer rate can be improved only marginally, as shown in Figure 1, by increasing the cell density. A greater improvement in mass transfer can be obtained only if a turbulent flow pattern can be achieved (1).

If the design change in the substrates allows the change from laminar to turbulent one, more unconverted gases from the core of the channel come closer to the catalyst surfaces and more reaction takes place.

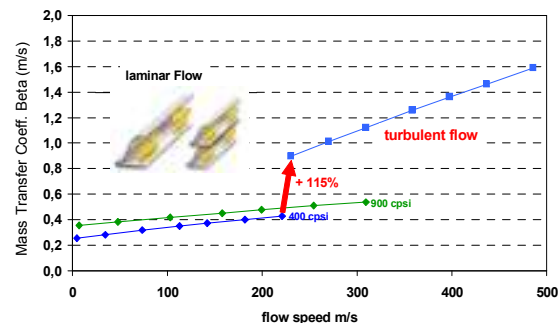


Fig 1: Mass Transfer Coefficient (beta), as a function of flow rate for laminar / turbulent flow

Various metal substrates have been developed over the years to make the exhaust gas flow through the substrate “Turbulent” using Transverse Structure (TS), Longitudinal Structure (LS) and Perforated Structure (PE) technologies. However, the present work is limited to TS Structures only.

TRANSVERSE STRUCTURE (TS)

To create turbulence, micro-corrugations are made on the foil transverse to the exhaust gas flow, as shown in Figure 2. As a result, the laminar flow gets converted into turbulent flow at the corrugations, thereby increasing the mass transfer from the

channel to the outer wall, which is catalytically coated with precious metals.

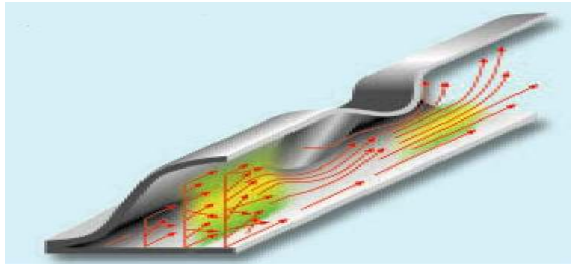


Fig 2 : Transverse Structure - Schematic

As reported earlier (2), some results obtained on a passenger car application using TS technology substrate are shown in Figure 3. All the substrates were coated with 40 g/cft, Pt5/Rh1 and tested on a 2.0 l passenger car on FTP cycle. The results of different TS substrates and a reference standard structured substrate of dia 118 x 174 mm, 400 cpsi, 1.9 l volume, were compared.

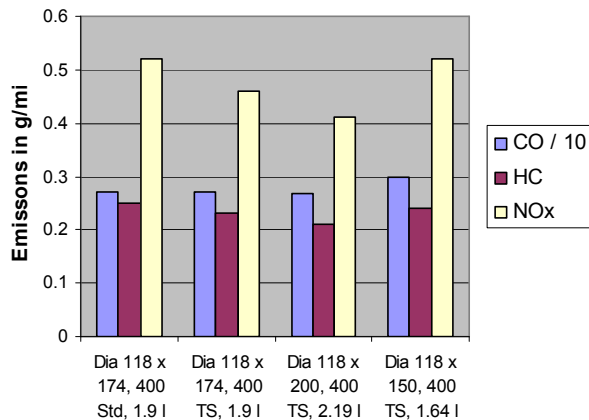


Fig 3 : Performance of TS structure on 2.0 l Passenger Car on FTP

As evident from Figure 3, the TS design with the same substrate volume, improved the HC conversion by about 8% and NO_x conversion by about 11%. Further increase in the substrate volume, reduced the HC and NO_x again. Even with a reduction in the volume of about 14 % compared to the standard foil, the TS structure had not negatively influenced the performance. The reduction in the surface area was compensated by the improved mass transfer causing increase in turbulence within the substrate.

The reduction in catalyst volume with change in the foil structure from standard to TS would also give advantage in terms of packaging and cost benefits, as the absolute amount of precious metals used per catalyst would be lower.

EVALUATION OF TS SUBSTRATES ON TWO WHEELER

The TS technology was also tried on a small 50 cc single cylinder 4 stroke vehicle earlier (3) . This vehicle was tested on ECE R47 cycle with dia 33 x 60 mm, 100 cpsi and dia 33 x 50.8 mm, 100 cpsi substrates with Standard and TS structures and with the same precious metal loading of 25 g/cft, Pt5/Rh1. The results are shown in Figure 4.

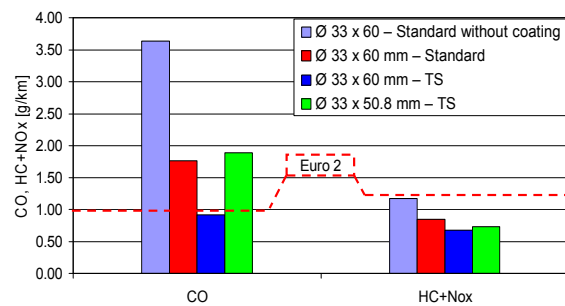


Fig 4 : Performance of TS substrates on 50 cc single cylinder 4 stroke Two Wheeler on ECE R47 Cycle

TS structure with dia 33 x 60 mm showed a 48% improvement in CO emissions and 21% in HC+ NO_x emissions when compared to the standard structure. Even dia 33 x 50.8 mm substrate with TS structure and with 18% lower in volume, showed almost similar performance to that of dia 33 x 60 mm standard structured substrate. This led to a decrease in the absolute quantity of precious metal per catalyst ,thereby offering a cost saving potential.

CURRENT WORK

As indicated above, the TS technology has been in existence over the past few years and is being used on various 4 wheelers and 2 wheelers world-wide.

It was decided to explore the benefits of this technology on Indian two and three wheeler applications in terms of performance and cost. The following vehicles were selected for this development work :

- Two Wheeler 2 Stroke 70 cc – BS II
- Two Wheeler 4 stroke 150 cc – Euro III
- Three Wheeler 2 stroke 200 cc – BS II

The engine / vehicle specifications are given in Table 1.

Vehicle Type	Two Wheeler	Two Wheeler	Three Wheeler
Applicable Emission Norms	BS II	Euro III	BS II
Engine Capacity	69.9 cc	149.6 cc	199.3
Cycle	2 Stroke	4 Stroke	2 Stroke
Power	2.36kW @ 5000 rpm	9.95 kW @ 8000 rpm	6.25kW @ 4000 rpm
Torque	4.95Nm @ 3750 rpm	12.3 Nm @6000 rpm	18 Nm @ 3250 rpm
Cooling System	Air Cooled	Air Cooled	Air Cooled
Fuel System	Carburettor	Carburettor	Carburettor

Table 1: Specifications of Engines / Vehicles selected for the evaluation of Structured Foils

A. TWO WHEELER 2 STROKE 70 CC GASOLINE – BS II

This vehicle uses one close coupled Heat Tube and a metal monolithic substrate for meeting the current Bharat Stage II (BS II) emission legislations. A schematic of the layout of the current exhaust system is shown in the Figure 5 .

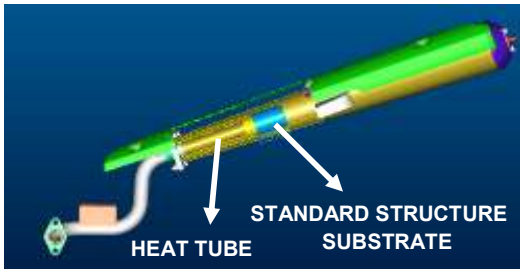


Fig 5 : Current Exhaust System Layout

The Heat Tube is of dia 25.6 mm x 100 mm. The metal substrate is a standard structured design of dia 40 x 50.8 mm, with 100 cpsi cell density

The temperature traces of the exhaust gas over the Indian Driving Cycle (IDC) for Bharat Stage II emission norms at the inlet of the Heat Tube and the Metal monolith substrate are shown in Figure 6.

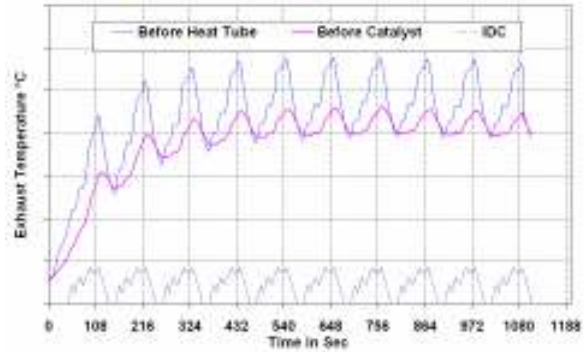


Fig 6 : Exhaust Temperature Traces over IDC

The temperature at the inlet of the heat tube is observed to be reaching about 200 deg C by the end of 1st warm up cycle of IDC and stabilizing between 200 and 280 deg C later on. The temperature at the inlet of the substrate is however stabilizing between 200 and 225 deg C , as it is slightly away from the location of the Heat Tube.

In order to evaluate the benefits of TS structure, the structure of metal substrate is modified to TS structure from Standard structure without change in any other dimensions or precious metal loading. However, in this case the Heat Tube is completely eliminated as shown in Figure 7. The substrate location is slightly shifted to an upstream position to take advantage of even higher temperatures compared to the values shown in Figure 6.

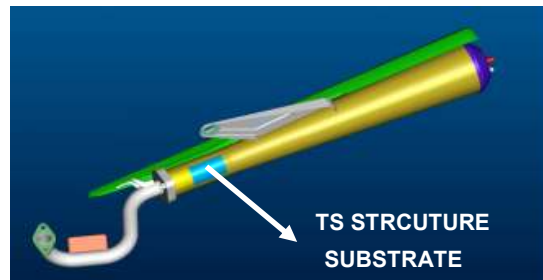


Fig 7 : New Exhaust System Layout

Comparative emission results with the current and the new exhaust systems are shown in Figure 8. As indicated, the stand alone TS structured metal substrate of the new system could meet the engineering targets comfortably for both CO and HC + NO_x components, with significantly lower system costs.

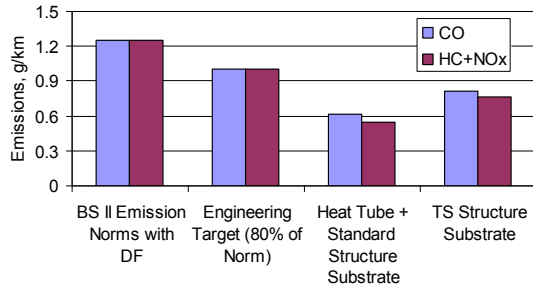


Fig 8 : Emission Results Two Wheeler 2 Stroke over IDC

A relative system cost comparison for both current and new exhaust systems is shown in Table 2.

	Current Exhaust System		New Exhaust System
	Heat Tube	Standard Metal Substrate	TS Metal Substrate
Substrate Specifications	Dia 25.6 x 100 mm length	Dia 40 x 50.8 mm length, 100 cpsi	Dia 40 x 50.8 mm length, 100 cpsi
PGM Specifications	2 g/sq m , Pt5/Rh1	40 g/cft, Pt18/Rh1	40 g/cft, Pt18/Rh1
Relative Cost of Precious Metal (Average Q2/2008 prices)	100%		68%
Total Relative Cost including Substrates & Coating	100%		68%

Table 2: Cost comparison of Current and New Exhaust System

As shown in the table, the new exhaust system could offer cost advantages of about 32%, when compared to the current exhaust system. This was possible due the introduction of efficient TS structure in the new system and there by completely eliminating the Heat Tube from the current system.

B. TWO WHEELER 4 STROKE 150 CC GASOLINE – EURO III

Another application was developed with TS Technology for Euro III emission legislations on a 150 cc 4 Stroke Two Wheeler.

On this vehicle, a metal substrate catalyst was placed within the exhaust muffler. The temperature trace at the inlet of the substrate over the Euro III cycle is shown in Figure 9. The exhaust temperature was observed to be much higher than 350 deg C during most part of the ECE R 40 test cycle.

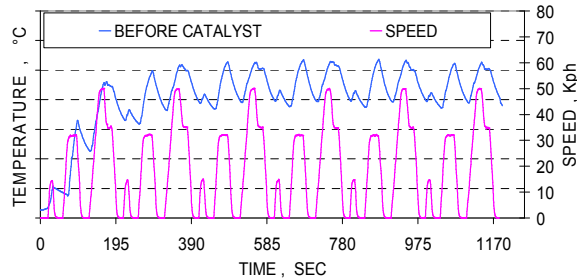


Fig 9 : Exhaust Gas Temperature Trace over Euro III (ECE R40) cycle

Two metal substrates, one with dia 40 x 74.5 mm, 300 cpsi Standard structure and the other with dia 40 x 74.5 mm, 200 cpsi TS structure were evaluated with the same amount of precious metal loading of 20 g/cft, Pt5/Rh1.

The results, as shown in the Figure 10, indicate that all the emission results of 200 cpsi TS substrate are much superior to 300 cpsi Standard substrate and are much lower than the engineering targets. CO , HC and NO_x results of 200 cpsi TS substrate were observed to be 17%, 20% and 23% lower respectively compared to the results with 300 cpsi Standard substrate. This Improved performance is also coupled with the benefit of lower back pressure of 200 cpsi TS structure compared to 300 cpsi Standard structure.

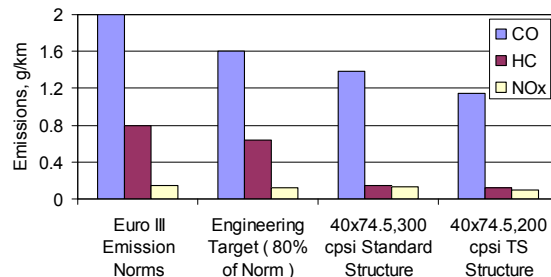


Fig 10 : Emission Results Two Wheeler 4 stroke 150 cc over Euro III test cycle

C. THREE WHEELER 2 STROKE 200 CC GASOLINE – BS II

The third vehicle selected for this evaluation was a Three Wheeler with 2 Stroke 200 cc engine for BS II legislations compliance.

On this application, two types of substrates of dia 60.5 x 74.5 mm, 100 cpsi were tried . One was with a Standard Structure and standard precious metal loading of 40 g/cft, Pt5/Rh1 and the second was with TS structure, but with 25% reduced precious

metal loading of 30g/cft, Pt5/Rh1. The comparative emission results are shown in Figure 11.

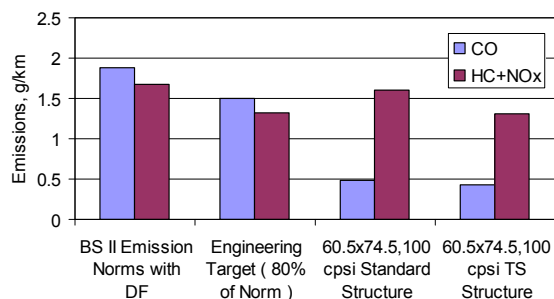


Fig 11 : Emission Results Three Wheeler over IDC

As shown in the figure, Standard Structure substrate results of HC + NO_x were higher than the engineering targets, though CO results were well within the limits. CO and HC + NO_x results of the TS technology substrate were found to be well within the engineering targets, even with a lower amount of precious metal loading. When compared to a Standard structure, results of CO and HC + NO_x of TS technology substrate were observed to be lower by 14% and 19% respectively.

A relative cost comparison of precious metal costs of the two substrates is shown in Table 3. As shown, a reduction of 25% on the precious metal costs could be achieved on this application by using a TS technology with lower amount of precious metal loading.

	Standard Metal Substrate	TS Metal Substrate
Substrate Specifications	Dia 60.5 x 74.5 mm length, 100 cpsi	Dia 60.5 x 74.5 mm length, 100 cpsi
PGM Specifications	40 g/cft, Pt5/Rh1	30 g/cft, Pt5/Rh1
Relative Cost of Precious Metal (Average Q2/2008 prices)	100%	75%

Table 3: Relative precious metal cost comparison of Standard and TS technology substrates

CONCLUSION

The benefits of Turbulent Structured metal monolith substrates could be well established on various two and three wheeler applications. The improvement in conversion efficiency of these TS technology substrates resulted in either performance improvement required for meeting the targeted

emission legislations or optimisation of the system design for cost benefits.

On 2 Wheeler 2 stroke 70 cc BS II application, a system cost benefit of 32% could be achieved by introduction of TS technology substrate and elimination of the Heat Tube used in the earlier design.

On the other 2 Wheeler 4 stroke 150 cc Euro III application, a 200 cpsi TS technology substrate was found to be performing better than a 300 cpsi standard substrate, there by even offering lower back pressure with improved performance

On a 3 Wheeler 2 stroke 200 cc BS II application, a benefit of 25% on the precious metal costs could be realized by adopting TS technology over the standard substrates.

With the benefits on performance and costs, this turbulent flow technology is being explored further on various other Two and Three wheeler applications. With the more stringent upcoming emission legislations like Bharat Stage III, the TS technology will further be investigated to avail all the comprehensive potential benefits.

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