

Development of High Porosity Cordierite Honeycomb Substrate for SCR Application to Realize High NO_x Conversion Efficiency and System Compactness

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ABSTRACT

Today the Ammonia Selective Catalytic Reduction (SCR) system with good NO_x conversion is the emission technology of choice for diesel engines globally. High NO_x conversion SCR systems combined with optimized engine calibration not only address the stringent NO_x emission limits which have been introduced or are being considered for later this decade, but also reduce CO₂ emissions required by government regulations and the increase in fuel economy required by end-users. Reducing the packaging envelope of today's SCR systems, while retaining or improving NO_x conversion and pressure drop, is a key customer demand.

High SCR loadings ensure high NO_x conversion at very low temperatures. To meet this performance requirement, a High Porosity Substrate which minimizes the pressure drop impact, was introduced in SAE Paper 2012-01-1079 [1], [2], [3]. The High Porosity Substrate with an equivalent catalyst amount demonstrated a pressure drop reduction in SCR substrate against the baseline conventional substrate. Moreover, high porosity substrate with high catalyst amount shows a possibility to achieve high NO_x conversion and significant downsizing.

As previously proven [4], [5], [6], High Cell Density is an effective way to increase catalyst surface area and NO_x conversion at high temperatures due to the mass transfer effect. A High Porosity, High Cell Density Substrate has been developed which offers a notable improvement in NO_x conversion over a wide temperature range as well as SCR substrate volume reduction.

This paper will define the concept and SCR NO_x conversion performance of the new High Porosity with High Cell Density Substrate compared to conventional substrate. The evaluation also includes pressure drop, durability, and potential SCR downsizing.

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INTRODUCTION

NO_x regulations for diesel vehicles and trucks are becoming stricter in recent years. US10 were introduced in the USA and is followed by EURO-VI to be introduced in Europe. In these regulations, a new driving mode will be introduced and needed to meet over wide driving range. In addition, On-Highway Truck fuel economy requirements are to be introduced in the USA effective in 2017. Improvements in engine and exhaust gas

after-treatment technology are required to meet these government legislated criteria pollutant and greenhouse gases (GHG) requirements.

DOC+DPF+urea SCR system is commonly used to meet these regulations. In this system, high NO_x conversion efficiency is required over wide exhaust flow rate and temperature range by exhaust emission technology. Fig. 1 SCR catalyst performance

and catalyst amount are pathways considered to meet the performance requirements, which adversely increases pressure drop, and potentially, fuel consumption. These are key issues because the SCR portion of the emission system occupies about half the exhaust emission control system packaging envelope. A new SCR substrate features capacity of high catalyst amount and high NO_x conversion efficiency, while minimizing pressure drop increase.

As a urea SCR catalyst, Cu-zeolite, which has high NO_x conversion efficiency at low temperature and low NO₂:NO ratio condition [7], has already been introduced in the U.S. to meet US10 and is being partially introduced in Europe to meet EURO-VI. In Japan, Cu-zeolite has restricted use. However, recently, adopting Cu-zeolite is being considered positively and regarded as a mainstream catalyst for the future urea SCR.

This paper reports on the concept and provides an overview of the high porosity substrate technology as shown in Figure 1 which helps to keep large hydraulic diameter (minimizing pressure drop increase) by penetrating the catalyst within substrate pores.

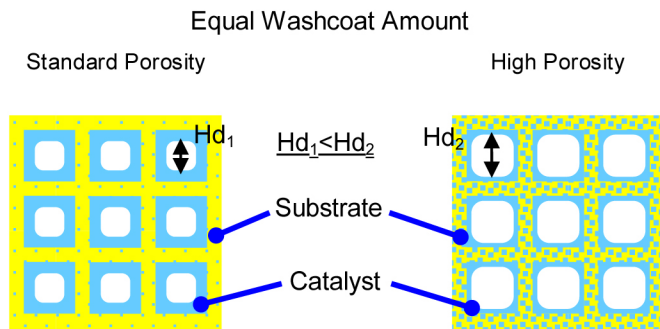


Fig. 1. Concept of High Porosity Substrate

PERFORMANCE OF SCR CATALYST

The surface area and the catalyst amount are the key factors to improve the NO_x conversion efficiency for SCR. The NO_x conversion efficiency at several temperatures amongst different cell structures and catalyst amounts is shown in Figure 2. The catalyst sample size for the NO_x conversion testing was $\Phi 1'' \times 1.5''$ L. Cu-zeolite was used as the catalyst. After the thermal treatment of 650deg.C for 100hours with water, testing was conducted at 100kh⁻¹ space velocity using a synthetic gas device. Table 1 shows the testing condition.

Table 1. Synthetic gas testing conditions

SV: 100kh⁻¹

Temperature: 200deg.C – 525deg.C

Gas composition

Gas	O ₂	NH ₃	NO ₂	NO	H ₂ O	CO ₂	N ₂
Concentration	10.0%	350ppm	0ppm	350ppm	4.6%	5.0%	balance

Table 2 shows the substrate characteristics. Samples were selected with different cell structures, porosities, and mean pore diameters. Cordierite ceramic honeycomb structure was

used in the test. Substrate with high porosity was selected to achieve the strength required for the canning process. Cell structures of 6/300 and 5/400, which have enough isostatic strength equal to that of the marketed product, were adopted for evaluation.

Table 2. Substrate Characteristics.

Cell Structure (mil/cpsi)	Porosity (%)	Mean pore diameter (μm)	Catalyst Amount
5/300	Std.	Small	Std.
6/300	High	Large	High
5/400	High	Large	High

Porosity, Std.: approx. 35%, High: ≥45%

Mean pore size, Small: approx.. 5μm, Large: ≥10μm

mil = 0.0254mm, cpsi: cells per square inch (=1/6.45cm²)

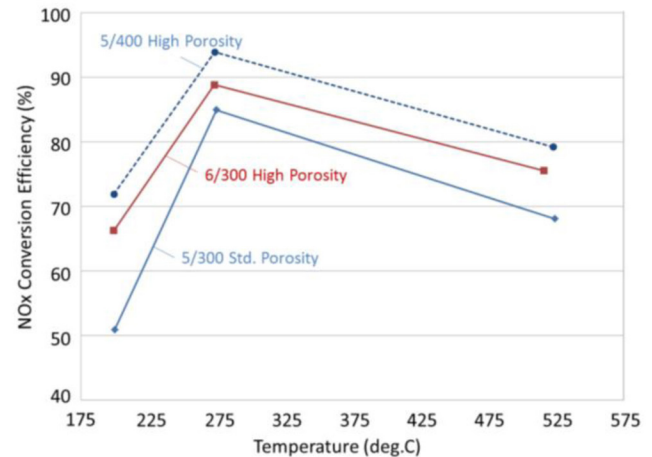


Fig. 2. NO_x conversion efficiency amongst different cell densities and catalyst amounts

As shown in the Figure 2, at low temperature of 200deg.C, NO_x conversion efficiency increases by about 15% when the cell structure and catalyst amount change from 5/300 with standard catalyst amount to 6/300HP with high catalyst amount. NO_x conversion efficiency increases by about 6% when the cell structure changes from 6/300 with high catalyst amount to 5/400HP with high catalyst amount.

At high temperature of 525deg.C, NO_x conversion efficiency increases by about 5% when the cell structure and catalyst amount change from 5/300 with standard catalyst amount to 6/300HP with high catalyst amount. NO_x conversion efficiency increases by about 6% when the cell structure changes from 6/300 with high catalyst amount to 5/400HP with high catalyst amount.

NO_x conversion efficiency can be improved by both enlarging the surface area and by increasing the catalyst amount. However, increasing cell density of honeycomb structure to