The effect of oxide nanospheres on strength fracture in DPF porosity sinters

Paweł Fuc
Poznan University of Technology, Institute of Combustion Engines and Transport
ul. Piotrowo 3, 60-965 Poznań, Poland
E-mail: pawel.fuc@put.poznan.pl

At the end of 2004, a European automobile manufacturer equipped more than 1 million diesel engine passenger cars with pure SiC diesel particulate filters.

High porosity ceramics and ceramic-metal composites are now widely applied in a number of fields. The DPF may be manufactured from different materials i.e. cordierite, silicon carbide.

1. Introduction

Applying porous DPF in Diesel has been considered a promising concept in approaching a near-zero emission system. It takes full advantage of PM geometry and material characteristics to realize homogeneous combustion, therefore reduces significantly the emission of PM, under all operating conditions. In order to achieve the material properties, microstructure control philosophy has been kept as the principle to optimize the character of material to satisfy the necessary real diesel emission control. The DPF consists of narrow channels which are blocked on one side. The first segment of DPF consists of diesel catalyst filter DOC, which is made of silicon carbide sinters and porous Ti$_4$O$_7$ [1].

We investigated porous ceramic structure, under load condition – thermal shock, which can lead to fracture of ceramic material and damage the noble metal-catalyst-Pd-Ru$_3$, which is deposited on high porosity Ti$_4$O$_7$- SiC structure.

2. The Experiment

The Ti$_4$O$_7$ nanospheres are made by Flame Spray Pyrolysis-FSP process. The Ti$_4$O$_7$ sinters are obtained by PPS process at 970°C during 120 s.

3. Characterization

Reduction of titanium with hydrogen and water leads (during the FSP) to the formation of oxygen vacancies and Ti$^{3+}$ ions, located on titanium surface and electrons that occupy donor sites in the bulk of titanium. The number of these defects is controlled by the equilibrium and is therefore quenched by the presence of water vapor.

High porosity – 67% composite filter material SiC- SiO$_2$-Ti$_4$O$_7$ has been produced during solid-state reaction between hollow parts- Ti$_4$O$_7$ and surface of SiC- Si.

$$\text{SiC} \rightarrow \text{SiC+Si (atmosphere H}_2; T= 380^\circ\text{C}; t=5 \text{ h}}$$
$$\text{SiC+Si + Ti}_2\text{O}_3 \rightarrow \text{SiC+SiO}_2 + \text{Ti}_4\text{O}_7 (\text{atmosphere H}_2; T= 1230^\circ\text{C}; t=1 \text{ h})$$

The vacuum impregnation method has been applied to synthesize the Magnelli phase-titanium oxide powder on high porosity supporting materials-substrate SiC-Si.

The composite consisting of SiC-Ti$_4$O$_7$ and pure SiC support (as reference material) were tested under two boxes- hot box temperature and cold box temperature for 800 cycles.

A single basket product carrier moves between the hot and cold zones, subjecting the product to dramatic changes in temperature.
The samples to be tested are mounted inside an insulating enclosure open to the burner and air cooler side. The temperature at the front center, front edge and rear center of the probe was measured by three thermocouples.

4. Conclusion

The final oxide bonded formulation -\(\text{Ti}_4\text{O}_7\)-\(\text{SiC}\) has similar thermal expansion to pure \(\text{SiC}\) grits and a higher elasticity deformation under load conditions than the reference. The higher elasticity performance could lead to higher resistance to thermal shock. Oxide bonded \(\text{Ti}_4\text{O}_7\)-\(\text{SiC}\) formulation has: similar thermal expansion, elasticity adjusted to adsorb thermal stress of monolith and prevent cracks from developing between the elements during repeated severe regeneration cycles.

It was shown that there is a significant improvement (by 1.5 times) in the thermal shock resistance of the layered granular materials (at a lower value of porosity and higher strength) as compared to the materials having a granular structure. The results of our studies can be used for developing the materials for high-temperature installations.

In the catalyzed diesel particulate filter (CDPF), a catalyst is applied onto the filter media to promote chemical reactions between components of the gas phase and the soot (carbon) collected in the filter. It has been observed that catalytic combustion rate of combustible particulate matter on surfaces depends on the efficiency of the surface to make contact with particles.

1. Introduction

Applying porous DPF in Diesel has been considered a promising concept in approaching a near-zero emission system. It takes full advantage of PM geometry and material characteristics to realize homogeneous combustion, therefore reduces significantly the emission of PM, under all operating conditions. In order to achieve the material properties, microstructure control philosophy has been kept as the principle to optimize the character of material to satisfy the necessary real diesel emission control. Figure 1 shows SEM image of PM-high temperature.

The present commercial DPF-SiC with excellent filtration efficiency is composed of many elements mainly to avoid thermal shock failure during severe regeneration. The pore size and porosity of such a material are also too small to serve satisfactorily the necessary real diesel emission control.

2. Experiment

The TiO₂ nanoparticles are made by Flame Spray Pyrolysis-FSP process. The FSP process was performed with the use of an external mixing gas assisted atomizer supported by premixed hydrogen and oxygen flames. Liquid precursors such as Titanium IV isopropoxide in an alcohol solvent was used as precursor for TiO₂. A combustion of liquid precursor droplets is used to obtain high purity and relatively narrow size nanoparticles of TiO₂. Composite consisting of SiC-TiO₂ and pure SiC support (as reference material) were tested under two boxes- hot box temperature and cold box temperature during 800 cycles. Nanoparticles of TiO₂ were investigated by BET surface area analysis and measured by the Z-sizer. Composite consisting of SiC-TiO₂ was examined by SEM, TEM techniques.

The TiO₂ nanoparticles are made by Flame Spray Pyrolysis-FSP process. The FSP process was performed with the use of an external mixing gas assisted atomizer supported by premixed hydrogen and oxygen flames. Liquid precursors such as Titanium IV isopropoxide in an alcohol solvent was used as precursor for TiO₂. A combustion of liquid precursor droplets is used to obtain high purity and relatively narrow size nanoparticles of TiO₂. Composite consisting of SiC-TiO₂ and pure SiC support (as reference material) were tested under two boxes- hot box temperature and cold box temperature during 800 cycles. Nanoparticles of TiO₂ were investigated by BET surface area analysis and measured by the Z-sizer. Composite consisting of SiC-TiO₂ was examined by SEM, TEM techniques.

The porosity of TiO₂, the pore size- macropore in size of 1500 nm, exhibits an open-cell structure with interconnected macropores which provide the potential for the transport of the gases by the filter body. Figure 6 presents the image of porosity PdRu, sinter.

The final oxide bonded formulation -TiO₂-SiC has similar thermal expansion to pure SiC grits and a higher elasticity during regeneration process. Therefore, it is desirable for the DPF materials to have a high thermal resistance and a thermal stress capability.

The TiO₂ nanoparticles are made by Flame Spray Pyrolysis-FSP process. The FSP process was performed with the use of an external mixing gas assisted atomizer supported by premixed hydrogen and oxygen flames. Liquid precursors such as Titanium IV isopropoxide in an alcohol solvent was used as precursor for TiO₂. A combustion of liquid precursor droplets is used to obtain high purity and relatively narrow size nanoparticles of TiO₂. Composite consisting of SiC-TiO₂ and pure SiC support (as reference material) were tested under two boxes- hot box temperature and cold box temperature during 800 cycles. Nanoparticles of TiO₂ were investigated by BET surface area analysis and measured by the Z-sizer. Composite consisting of SiC-TiO₂ was examined by SEM, TEM techniques.

The porosity of TiO₂, the pore size- macropore in size of 1500 nm, exhibits an open-cell structure with interconnected macropores which provide the potential for the transport of the gases by the filter body. Figure 6 presents the image of porosity PdRu, sinter.

The final oxide bonded formulation -TiO₂-SiC has similar thermal expansion to pure SiC grits and a higher elasticity during regeneration process. Therefore, it is desirable for the DPF materials to have a high thermal resistance and a thermal stress capability.

The TiO₂ nanoparticles are made by Flame Spray Pyrolysis-FSP process. The FSP process was performed with the use of an external mixing gas assisted atomizer supported by premixed hydrogen and oxygen flames. Liquid precursors such as Titanium IV isopropoxide in an alcohol solvent was used as precursor for TiO₂. A combustion of liquid precursor droplets is used to obtain high purity and relatively narrow size nanoparticles of TiO₂. Composite consisting of SiC-TiO₂ and pure SiC support (as reference material) were tested under two boxes- hot box temperature and cold box temperature during 800 cycles. Nanoparticles of TiO₂ were investigated by BET surface area analysis and measured by the Z-sizer. Composite consisting of SiC-TiO₂ was examined by SEM, TEM techniques.

The porosity of TiO₂, the pore size- macropore in size of 1500 nm, exhibits an open-cell structure with interconnected macropores which provide the potential for the transport of the gases by the filter body. Figure 6 presents the image of porosity PdRu, sinter.

The final oxide bonded formulation -TiO₂-SiC has similar thermal expansion to pure SiC grits and a higher elasticity during regeneration process. Therefore, it is desirable for the DPF materials to have a high thermal resistance and a thermal stress capability.

The TiO₂ nanoparticles are made by Flame Spray Pyrolysis-FSP process. The FSP process was performed with the use of an external mixing gas assisted atomizer supported by premixed hydrogen and oxygen flames. Liquid precursors such as Titanium IV isopropoxide in an alcohol solvent was used as precursor for TiO₂. A combustion of liquid precursor droplets is used to obtain high purity and relatively narrow size nanoparticles of TiO₂. Composite consisting of SiC-TiO₂ and pure SiC support (as reference material) were tested under two boxes- hot box temperature and cold box temperature during 800 cycles. Nanoparticles of TiO₂ were investigated by BET surface area analysis and measured by the Z-sizer. Composite consisting of SiC-TiO₂ was examined by SEM, TEM techniques.

The porosity of TiO₂, the pore size- macropore in size of 1500 nm, exhibits an open-cell structure with interconnected macropores which provide the potential for the transport of the gases by the filter body. Figure 6 presents the image of porosity PdRu, sinter.

The final oxide bonded formulation -TiO₂-SiC has similar thermal expansion to pure SiC grits and a higher elasticity during regeneration process. Therefore, it is desirable for the DPF materials to have a high thermal resistance and a thermal stress capability.