

論文 / 著書情報
Article / Book Information

題目(和文)	パッシブ後処理システムに向けた多層触媒粒子メンブレンフィルターの研究
Title(English)	A study of multi-layered membrane filters made of catalyst particles for a passive after-treatment system
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

(博士課程)
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論文要旨

THESIS SUMMARY

系・コース : Department of, Graduate major in	Mechanical Engineering	系 コース	申請学位 (専攻分野) : Academic Degree Requested	博士 Doctor of	(Engineering)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

This study was conducted to develop an exhaust after-treatment system in gasoline engines to eliminate current drawbacks and modernize the system for supporting HEV and PHEV. Currently, a well-known particulate filter issue is clogging caused by accumulated soot. The situation worsened upon introducing electric hybrid vehicles due to a lower temperature in the exhaust after-treatment system. At a low temperature, soot cannot be oxidized; as a result, active particulate filter regeneration is required, which causes higher fuel consumption. Therefore, an active soot oxidation catalyst made of potassium catalyst was coated at the membrane filter's top layer over the supporter, enhancing the direct contact between soot and catalyst. A support catalyst layer was fabricated using a Three-Way Catalyst (TWC) material to increase the membrane's versatility. As a result, a double-layer membrane composed of a K-cat/TWC was successfully fabricated on a conventional particulate filter, combining TWC and GPF functions into a single device. K-cat significantly lowered the soot oxidation temperature by near-diffusion effect. Soot that was adjacent to the catalyst could be rapidly oxidized at a low temperature, as it resulted in the first peak oxidation. This ensured a consistently clean filter with low-pressure drop. Additionally, the K cat/TWC membrane demonstrated at least 80% conversion of CO and NO while oxidizing soot within the temperature range of 420 ° C to 500 ° C. Integration of these functions simplifies the exhaust after-treatment system by reducing component complexity and allowing the particulate filter to be placed closer to the engine, leveraging higher temperatures for efficient soot oxidation. Thus, this novel filter is also suitable for hybrid electric vehicles with exhaust temperature decreased.

The numerical simulations were conducted in this study for several purposes. First, it was used to clarify the bridge formation phenomena, one of the significant characteristics of particle trapping on the granular filters, which is a cause of drastic pressure drop increase. The visualization combined with the qualitative data of pressure drop and filtration efficiency during particle trapping revealed that the bridge structure caused constricted area that shifted the flow velocity profile to the center, which yields the soot more likely to accumulate at the tips of dendrite structures around the center hall rather than piling at the edge. Furthermore, after the completion of bridge formation, filtration efficiency achieved 100% yields so that the coming particles accumulate only on the bridge structure, and the pressure drop increasing rate tended to decrease at this point. Nonetheless, the simulation results could find an excellent agreement with the experimental results in terms of quantitative and qualitative data, which proved the accuracy of the numerical simulation. The computer simulation could be utilized to study the effect of gas flow rate on membrane fabrication. It revealed that the lower flow velocity yields less TWC material in the membrane manufacturing process. The simulation results also demonstrated that increasing the membrane thickness improved soot filtration efficiency. The filtration efficiency reached almost 100%, with a 55µm membrane thickness. However, it also increased pressure drop. To optimize a balance between filtration efficiency and pressure drop, a 30µm membrane thickness was chosen, ensuring at least 94% filtration efficiency while avoiding excessive pressure drop.

Owing to excellent filtration efficiency from the outset, we no longer need the particulate filter as a function of soot capturing. The conventional GPF only plays a role as a granular substrate supporting the membrane filter. Therefore, The simulation of substrate optimization for supporting the membrane was conducted to deliver a suitable function as a supporter of the membrane. The results revealed that the thin granular substrates resulted in a lower pressure drop across various scenarios. Still, the durability of the support must also be taken into consideration. In the supporter's pore size aspect, a 12µm pore size granular supporter coated with a 30µm membrane

exhibited the lowest pressure drop. This approach resulted in a significant 33% reduction in pressure drop and a 39% reduction in material consumption compared to conventional GPF fabrication methods.

As the porous-particle membrane offers a significant advantage over a solid-particle membrane, thus the simulations on the porous-particle membrane were conducted with an aim to lower the pressure drop and enhance the catalytic activities. Velocity profile analysis revealed that the 350 nm PMMA particles contributed the most to flow through an interconnected pore network within the particles, leading to the highest reduction in pressure drop. On the other hand, the 60 nm PMMA particles, despite their larger specific surface area, primarily influenced molecular diffusion at the outer surface and had a minimal contribution to flow into the macropores. This was attributed to the small pore size of the 60 nm PMMA, which hindered the establishment of a connected pore network throughout the entire particle, resulting in limited flow and the highest pressure drop among the different PMMA cases. Consequently, based on these findings, PMMA particles with a size of 350 nm are recommended as they facilitate the fastest flow through an interconnected pore network, leading to the lowest pressure drop with a reduction of 21.9% compared to the solid-particle membrane while also enhancing catalytic activity.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).

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