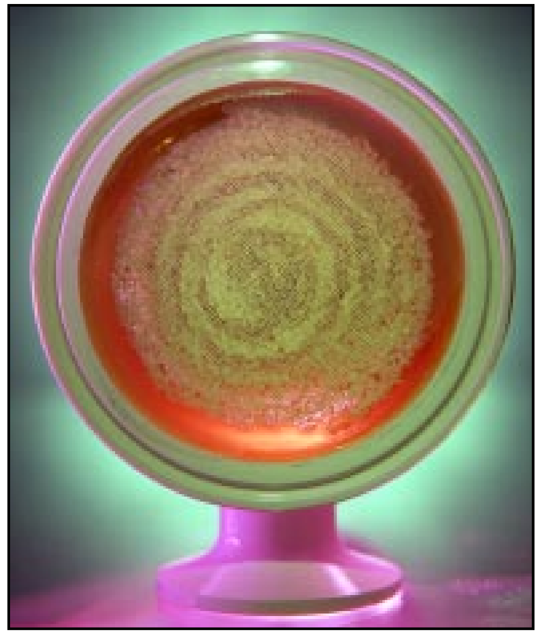
Modifying intake air to reduce unwanted emissions in diesel engines

OAAT ACCOMPLISHMENTS

Air Separation Membrane

Challenge

Compression-ignition direct-injection (CIDI) diesel engines offer high fuel economy, but present the challenge of reducing nitrogen oxides (NO_x) and particulate matter (PM) to meet emissions regulations. Exhaust gas recirculation (EGR), the most cost-effective means of reducing NO_x emissions from conventional, spark-ignition engines, produces undesirable effects (increased smoke and PM, reduced engine durability, and increased cylinder-to-cylinder variations) when applied to CIDI diesel engines. An alternative method of reducing NO_x and PM in CIDI diesel engines without producing unwanted effects would help vehicles meet emissions regulations and lead to improved air quality.



Special membrane "chemical filter" (seen here from its end, showing hollow-tube bundles).

Technology Description

The intake air of a 1.9-L turbocharged direct-injection (TDI) diesel engine was diluted with nitrogen-enriched air (NEA) supplied by an in-line membrane that separates intake air into oxygen-enriched and nitrogen-enriched air streams. Adding NEA lowers the oxygen concentration of the intake air, thus decreasing NO_x formation during combustion. The NEA is free of the PM present in EGR, does not impair engine life or durability, and provides a predictable, homogenous combustion air mixture.

Separate studies have also explored injecting oxygen-enriched air at the late combustion cycle diffusion phase to simultaneously control NO_x and PM emissions.

Accomplishments

An experimental setup to test prototype NEA systems was completed. At higher turbo boost pressures (greater than 8 psi), the NEA system reduced NO_x emissions by 15-20% more than EGR. Compared to operation without EGR, the NEA system reduced NOx emissions by an additional 10-20% at partial loads and lower speeds, and by an additional 20-30% at higher loads and/or speeds. The NEA system does not compromise engine performance and, in fact, the NEA membrane acts as a heat sink to cool the intake charge and further retard NO_x formation caused by higher intake temperatures.

Modeling simulations have been run to estimate the ability of oxygen-enriched air to simultaneously reduce NO_x and PM emissions.

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Benefit

Simultaneously reducing NO_x and PM emissions will help high fuel economy diesel engines meet EPA Tier 2 standards.

Awards

1999 R&D 100 Award for oxygen-enrichment membrane technology.

Future Activities

Future work will focus on optimizing the NEA system. NEA membranes can be matched to obtain greater NO_x reductions in the targeted engine operating range. Parasitic pressure drops of 1-2 psig and flow losses of 10-12% can be compensated for by modulating the turbocharger waste gate.

A prototype membrane will be developed for the oxygen-enriched air system. Experimentation will provide a strategy for simultaneously reducing NO_x and PM by employing oxygen enrichment. The NEA and oxygen-enrichment systems will then be compared.

Partners in Success

- Argonne National Laboratory
- AutoResearch Laboratories, Inc.
- Caterpillar, Inc.
- Compact Membrane Systems, Inc.
- University of Wisconsin-Madison