Catalysts and Fuel Mixing for Diesel Reformer in a Fuel Cell Auxiliary Power Unit

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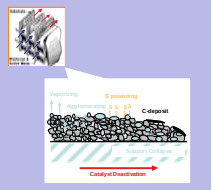
Need for Diesel Reforming

Military Applications
The military has a policy of "one fuel forward." Equipment must be able to run on the fuel available where military operations are taking place. If operations involve fuel cells, they must be able to run on diesel fuel.

Idling of Diesel Trucks
Regulations due out within the next few years will prohibit trucks from idling at night. The auxiliary power units that will heat and cool the truck cabs may be based on fuel cells, and diesel is the onboard fuel.

NOx Reduction
Upcoming emissions regulations will require that diesel trucks significantly reduce emissions of nitrogen oxides (NOx). The abatement technology uses catalytic reduction or regenerative absorber in the presence of reducing gases such as hydrogen. The hydrogen can either be injected into the engine intake manifold or directly into the post combustion treatment. In either case, some method of generating hydrogen is needed, and again, diesel is the onboard fuel and therefore the most logical source for the hydrogen.

The Challenges



Diesel is a hydrocarbon-based fuel that can be reformed through a series complex chemical reactions to extract the hydrogen from it, known as catalytic reforming. The catalyst must sustain intense reaction temperature and resist "poisoning" by sulfur, which is present in diesel fuel. The catalyst must also be low-cost for commercialization.

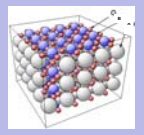
Proper mixing and dispersion of diesel with air and steam poses another set of challenges.

Argonne's Approach

Argonne has developed a catalytic autothermal reforming process that could be used as a compact and potentially cost-effective technology for diesel reforming. But because diesel fuel is more difficult to process (high sulfur content and large aromatic molecules), new catalyst materials and catalytic reactor design are needed.

Operating at higher temperatures lessens sulfur poisoning and coke formation but leads to rapid catalyst deactivation. Argonne is exploring the feasibility of diesel-fuel reforming by optimizing fuel/exhaust-gas mixing dynamics. Several engineering issues, such as how to avoid pre-ignition and coke formation will be examined.

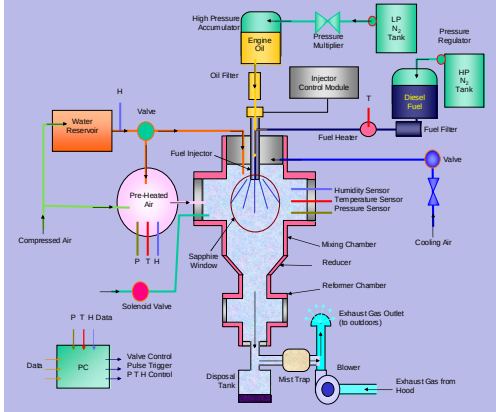
Argonne's Catalyst



The catalyst is based on a redox mechanism (oxidation-reduction, a chemical reaction in which an atom or ion transfers electrons between another atom or ion). Redox takes place inside an oxide crystal lattice such as a perovskite (right). The catalyst is an "autothermal reforming catalyst" which promotes the reaction between diesel and air and steam with maximum utilization of thermal energy in the fuel, and forms a hydrogen-rich gas mixture known as reformate.

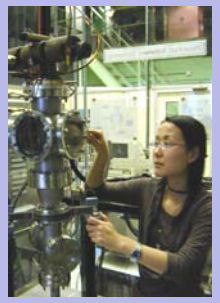
The reformate contains high levels of hydrogen and carbon monoxide (both are the fuel for the SOFC) balanced with carbon dioxide and nitrogen from air. For on-board reforming, the steam in the input mixture can be supplied through partial recirculation of the fuel cell exhaust, which has high water content from the electrochemical reaction of hydrogen and oxygen during the generation of electricity. In actual use, the catalyst will be supported over an engineered substrate such as a high-temperature ceramic known as "monolith".

The catalytic monolith will be built into a reactor known as a reformer, which will also include a fuel injection and mixing device. A new fuel mixing method is being investigated by Argonne at the Fuel Mixing Test Facility.



Argonne's Fuel Mixing Test Facility

Argonne has built a Fuel/Steam/Air Mixing Facility where engineers can vary fuel type, fuel-air-steam ratios, flow rates, temperature, and mixing methods to achieve optimal mixing and reduce coke formation.



Results to Date

Catalyst Development
Argonne's proprietary perovskite-based diesel reforming catalyst has shown high hydrogen yield, reforming efficiency and sulfur-poisoning resistance. The new catalyst also reduced the material cost by nearly a factor of ten over the existing rhodium-based materials.

Mixing Facility
The facility has been constructed, control software has been installed, and a fuel-injection system (provided by International Truck and Engine Company) has been evaluated. The next step is to test the system to determine optimal injection and mixing conditions.

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