Water injection on commercial aircraft to reduce airport NOx

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Abstract

The Boeing Company and Rolls-Royce Corporation have been working with NASA Glenn Research Center (GRC) to study the effects of injecting finely atomized water into aircraft turbine engines during takeoff. This method of water injection will dramatically reduce NOx emissions at the airport and will also reduce engine stress, most likely resulting in cost savings to aircraft operators.

In the effort to improve fuel efficiency, most new aircraft turbine engines have increased compressor pressure ratios. New combustors have been developed to help offset the exponentially higher NOx that goes with these increased pressure ratios. However, achieving real NOx emissions reductions at the airport has been a daunting task. Water injection is an old technology that is currently being investigated, with a new twist, as a possible NOx emissions solution.

Boeing and NASA-GRC investigated three types of engine water injection techniques; misting water before the Low Pressure Compressor (LPC), misting water before the High Pressure Compressor (HPC) and directly injecting atomized water into the combustor. For each of these system designs, airframe hardware was configured for a commercial aircraft and the airplane performance was then calculated. Additional thrust became available during water injection, but was not used in order to eliminate any potential safety issues should the system fail.

In collaboration with the US Air Force Research Laboratory/WPAFB, NASA Glenn supplied Boeing with water misting emissions test data. NASA Glenn also calculated and supplied engine performance impacts for all 3 water injection types.

Rolls-Royce Corporation designed a similar LPC water/methanol misting system for use in emergency situations to boost engine power. This allowed the engines to be down-sized and resulted in impressive engine performance and maintenance cost savings. The size of the injected water droplets needs to be small enough (e.g. 5-10 microns) to completely evaporate and avoid its being centrifuged onto, and cooling, the engine case.

If water atomization and evaporation into the LPC can be accurately controlled, these studies suggest this system would offer engine performance benefits over the other two designs. At a water misting rate of about 2.2%, NOx emissions could be reduced some 47%. On days above 59º, a fuel efficiency benefit of about 3.5% would be experienced. Reductions of more than 400º in turbine inlet temperature were also calculated, which would lead to increased hot section life. A slight noise reduction is anticipated with this system. A nominal airplane weight penalty of less than 400 lbs. (no water) was estimated for a mid-sized passenger airplane. Without including engine maintenance savings, the airplane system cost is estimated to be an additional $41 per takeoff, giving an attractive NOx emissions

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