

# Case study: Ceramic coatings for jet engine turbine blades



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- Funder: Rolls-Royce plc
- Sector: Aerospace
- Project Type: Research & development

Ceramic thermal barrier coatings (TBCs) are applied to jet turbine blades to protect them from the high temperature gases leaving the combustion chamber and to increase the efficiency of the engine. Professor John Nicholls of the Surface Science and Engineering Group, Cranfield University has been working with Rolls-Royce plc for about 17 years to improve the insulating performance of TBCs. As a result, the TBCs used in the current generation of aircraft turbofan jet engines achieve a temperature drop about 80 °C greater than at the start of the work, with an estimated fuel saving of about 1%.

This case study considered two engine types: Trent 700, used on about half the Airbus A330 aircraft currently in service, and Trent 500, used on all Airbus A340-500 and A360-600 aircraft. The greenhouse gas emissions considered were, in order of magnitude, carbon dioxide from combustion of the fuel, emissions during extraction and refining of the fuel, and emissions of other greenhouse gases during combustion. Emissions associated with transport of the fuel were found to be negligible compared with these, and all emissions not related to fuel consumption, for example manufacture of the coating, were also assumed to be insignificant or excluded from the assessment because they were unaffected by the change in the TBC.

The baseline fuel consumption during each flight phase (landing and take-off cycle and cruise) was estimated from publicly available data. Airline activity data for A330 and A340 models from European operators was taken to represent typical patterns of use, enabling annual emissions per aircraft to be calculated. Data on current operating aircraft and orders were then used to estimate the total current and projected future emissions. From these, the higher emissions that would have occurred in the past if the improved TBCs had not been used, and the corresponding future emissions, were estimated.

The best estimates of the current emissions (the retrospective brainprint) for individual aircraft were 1016, 1574 and 1646 t CO<sub>2</sub>e/year for A330, A340-500 and A340-600 respectively, giving 568 kt CO<sub>2</sub>e/year for the total fleet. Including all the aircraft on order, the prospective emissions reduction was 833 kt CO<sub>2</sub>e/year. Assuming a service life of 20 years, the total brainprint was approximately 17 Mt CO<sub>2</sub>e.

An uncertainty analysis was performed with assumed uncertainties for aircraft activity, fuel consumption and the efficiency change. The 95% confidence interval for the current annual emissions reduction was 429–721 kt CO<sub>2</sub>e/year excluding the efficiency change uncertainty, and 258–1105 if it was included. The relative changes in the other output measures were similar. Assuming that older engines do not and will not benefit from the improvement, reduced the total brainprint to 14 Mt CO<sub>2</sub>e. The assessment did not include an adjustment for the effect of emissions at high altitude, which would increase all the outputs by a factor of 1.9.