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NOx Emissions of the 50 Most Used Engines for Passenger Aircraft

Nitrogen oxide (NOx) emissions (consisting of NO and NO2) from aircraft combustion engines contribute to <u>local</u> air pollution near airports and to <u>global</u> warming at cruise altitude.

Aircraft <u>local</u> emissions contribute to higher levels of fine particles (FP, PM2.5, with a diameter of 2.5 µm down to 0.1 µm or less) and to higher levels of ozone (O3), with well-documented health impacts including an increased risk of respiratory and cardiac diseases.

PURPOSE

This study investigates NOx emissions from the 50 most used commercial jet aircraft engines. The primary aim is to derive regression models to estimate NOx emissions based on engine parameters.

METHODOLOGY

The analysis begins by determining the 50 most used engine families in passenger aviation, based on the World Airliner Census 2020 and aircraft delivery data from the major commercial aircraft manufacturers. NOx emissions were obtained using the ICAO Engine Emissions Databank (EEDB). Emissions were analyzed for different flight phases from the ICAO Landing and Take-Off (LTO) Cycle (taxi, take-off, climb, and approach) and for cruise. For the cruise phase NOx emissions were calculated a) with the Boeing Fuel Flow Method 2 (BFFM2) based on LTO NOx and cruise fuel flow and b) with a method developed by the German Aerospace Center (DLR). Non-linear regression analysis was applied to estimate NOx emissions based on one or two selected engine parameters. Separate models were developed for the full dataset and for 13 specific combustor technology subgroups.

FINDINGS

NOx emissions from aircraft contribute to local air pollution near airports and to global warming at cruise altitude. Legal limits for NOx emissions are defined for the total LTO emissions per thrust as a function of Overall Pressure Ratio (OPR), with stricter standards introduced since 2004. The 50 selected engine families represent around 95 % of the global commercial jet fleet. NOx emissions from the BFFM2 and the DLR method agree well (R^2 = 0.99). The most predictive engine parameters are OPR, thrust and fuel flow, while Bypass Ratio (BPR) has limited influence. Engine design is a trade-off. Low fuel burn requires higher OPR, which increases NOx emissions. Some combustors can reduce NOx but may lead to more soot emissions, causing denser contrails with more global warming potential.

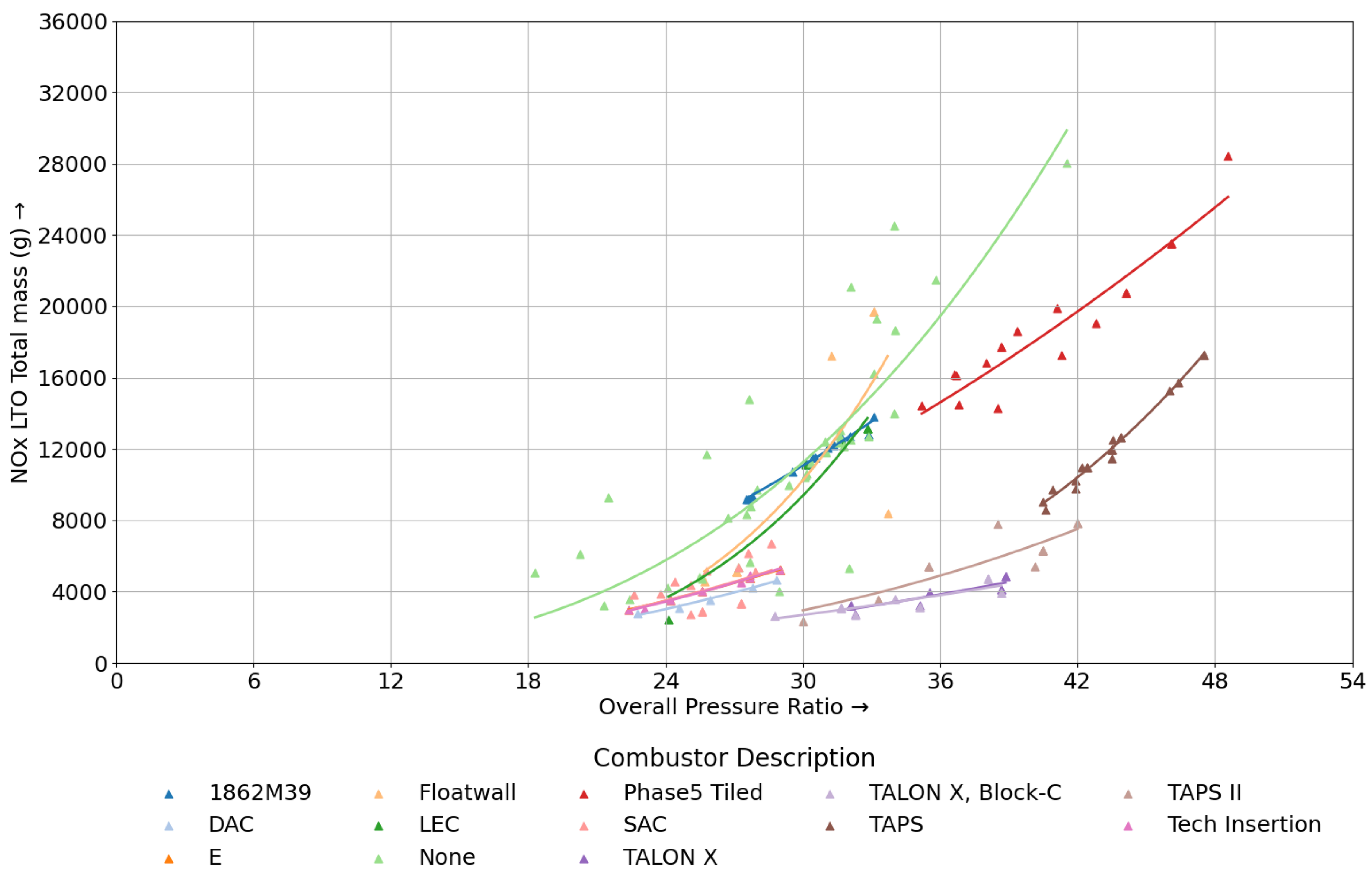

Figure 1: Differentiated representation of NOx mass over the LTO cycle as a function of OPR, categorized by combustor technology.

Combustor-specific regression significantly improves prediction accuracy. A model incorporating all combustor types yields a coefficient of determination of only R^2 = 0.398 and a Mean Absolute Percentage Error (MAPE) of 62.5 %. In contrast, combustor-specific models are much better. E. g. a model for the Twin Annular Premixing Swirler (TAPS) II achieves R^2 = 0.788 and a MAPE of 12.7 %. This underlines the necessity of considering combustor technology in NOx estimation (Figure 1). NOx mass over the LTO cycle can well be calculated from LTO fuel consumption (Figure 2).

RESEARCH LIMITATIONS

In this study, regression analysis was limited to a maximum number of two input parameters. However, more parameters seem not to lead to a substantially higher accuracy.

PRACTICAL IMPLICATIONS

The study provides equations for three NOx emission cases: total emissions during the LTO cycle, emission index at take-off, and emission index during cruise. For each of these three cases and for each of the 13 investigated combustor technologies, one equation is proposed based on one engine parameter and a second equation based on the best combination of two engine parameters. This leads overall to 78 equations.

SOCIAL IMPLICATIONS

Easy to use equations make NOx emission from passenger jet aircraft more accessible to a wider community of people to discuss the implications of aviation as a means of transport.

ORIGINALITY

No other study seems to be available that offers such a simple way to predict NOx emissions form jet engines for aircraft design or aircraft operation while accounting for different combustor technologies.

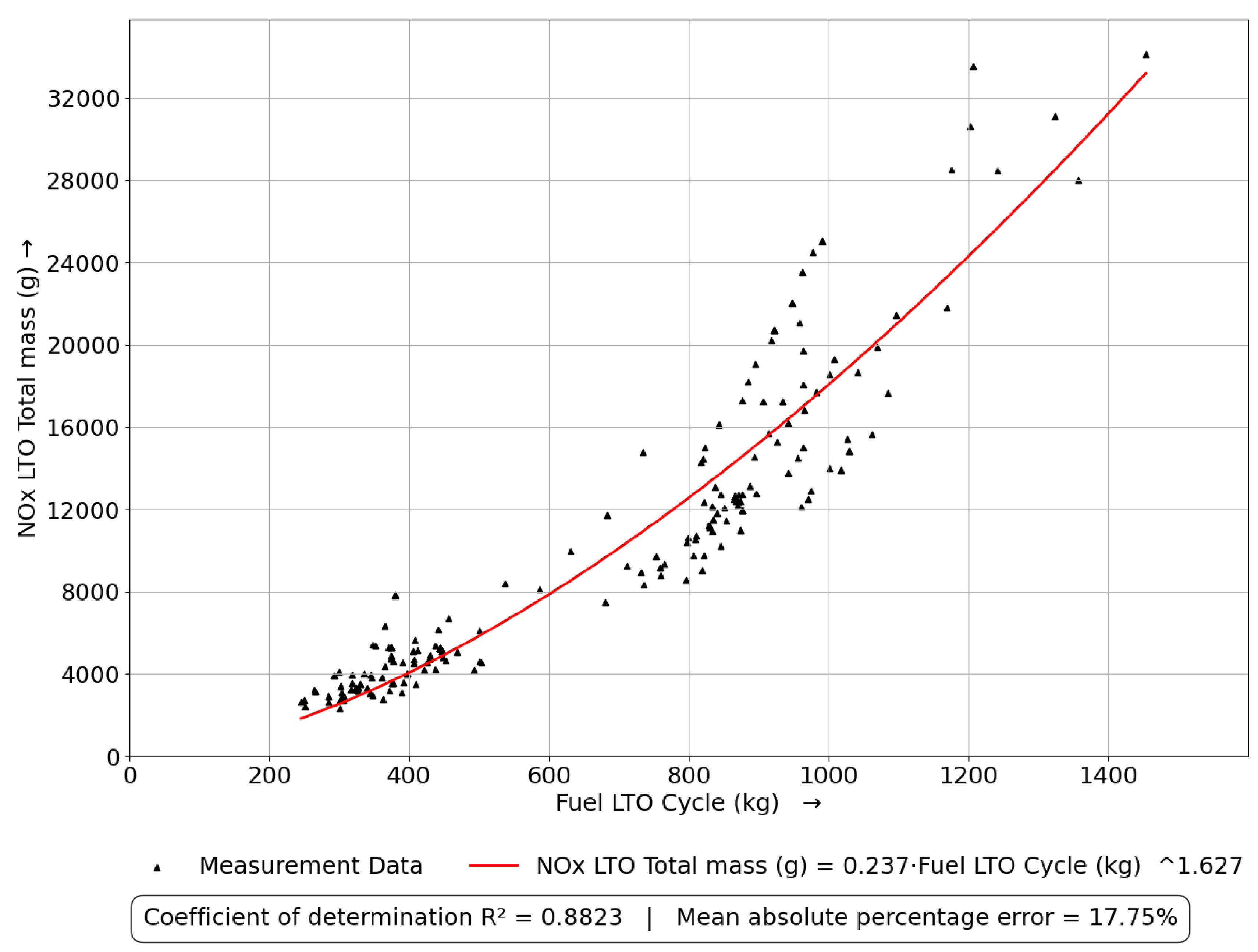

Figure 2: Total NOx mass over the LTO cycle in relation to fuel consumption per cycle for all 50 engine.

All details in the Master Project:
https://nbn-resolving.org/urn:nbn:de:gbv:18302-aero2025-06-13.01

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