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Title

Multi-Objective Multidisciplinary Design Optimization of Regional Truss-Braced Wing Jet Aircraft

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Abstract

As the air travels are estimated to grow by 3.5% annually, the environmental requirements are becoming more and more stringent to mitigate the environmental impacts resulting from increased aircraft emissions. As the tube-and-wing aircraft configuration has reached matured state over the decades, the new environmental targets set for 2030 and 2050 timeframe can be met by the development of novel configurations. These novel configurations not only should provide the capability to increase the performance and reduce the emission significantly, but also it should be economically viable. The very-high aspect ratio truss-braced wing aircraft is one of the most promising configurations which can reduce the fuel burn considerably, and on the other hand, it can incorporates the accumulated know-hows resulted from decades of tube-and-wing aircraft configuration development. Traditionally, the aircraft are designed and optimized for maximum profitability, which has defined the aircraft layout and mission. Considering the emission requirements in the optimization process, will result in different layout and mission profile, which should be taken into account in the design process. At the end, the final design would be a trade-off between cost and emission requirements.

To this aim, a design optimization methodology is implemented in a multidisciplinary aircraft design farmwork to optimize a regional very-high aspect ratio truss-braced wing aircraft layout considering both cost and emission requirements. This framework is capable of sizing the aircraft, weight analysis based on high-fidelity methods, engine analysis, performance analysis, cost analysis, and emission estimation. An aircraft emission analysis module based on existing methodologies is purposely developed for this design framework, which is capable of calculation of various types of emission based on the mission profile and aircraft performance. The calculated emissions are carbon dioxide (CO2), carbon monoxide (CO), nitrogen oxides (NOx), and Sulfate (SOx).

In order to optimize the aircraft layout, and considering computational costs, a surrogate-based optimization method is incorporated. In this approach a list of design cases is generated using Latin Hypercube Design of Experiment method, and the converged aircraft results are extracted. The results of these simulations are used to train a Neural Networks for each of objective functions. These networks are used in genetic algorithm to find the optimum solution and pareto front of the problem.

The results show that there is direct relation between the CO2 and cost objective, but on the other hand the optimum configuration for NOx and cost are different. The reason is found to be the mechanism by which these emissions are formed, and the altitude at which these emissions are created. The aircraft developed for NOx tends to fly slower and at lower altitudes which is different with the current mission profile of the current aircraft. At the end, the effect of engine bypass ratio, and mission profile (cruise altitude and cruise speed) are analyzed.