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Work Description for Rhea Shah

Immatriculation Nr. 21489325

Erweiterung eines Trajektorienrechners zur Simulation von treibstoff-optimierten 4D-Flugzeugtrajektorien für Hyperschallflugzeuge

Extension of a trajectory calculator to simulate fuel-optimized 4D-trajectories for hypersonic airliner

Bachelor thesis

Introduction

According to a study of the International Civil Aviation Organization (ICAO) from 1985 to 2005, passenger and freight air traffic show both an annual growth rate of more than 6 %. Since global air traffic contributes with a share of approx. 5% of the total anthropogenic radiative forcing (RF) to the global climate change, the fraction of air traffic is significant and will thus most probably further increase in the future. The impact of air traffic on the global climate is not only determined by the quantity of pollutant substances emitted, but also decisively by the locus (longitude, latitude and flight altitude) and time of the emissions. Technological advances, such as the reduction of take-off weight, the improvement of engine technology and the increase in aerodynamic performance, including operational measures and new aircraft design concepts, are thus an aspired goal in aviation. Against this background, the feasibility and accessibility of STRATOFLY-MR3, a Mach 8 waverider fueled with liquid hydrogen to perform high-speed passenger stratospheric flights, is addressed in this bachelor thesis in terms of the H2020 STRATOFLY Project, funded by the European Commission under the Horizon 2020 framework.

Work Description

Trajectory calculators can simulate flight movements and estimate e.g. the associated flight time or fuel consumption based on flight performance models. For STRATOFLY, the institute of air transportation systems uses the so-called Trajectory Calculation Module (TCM), which calculates 4D-trajectories based on aerodynamic and engine property databases of STRATOFLY-MR3. Since pollutant gaseous emissions like CO_2, H_2O or SO_2 are approximately proportional to the aircraft's fuel flow, flight route optimizations regarding minimal fuel consumption must be performed as preliminary step before enhanced methodologies for aircraft emissions distribution analysis or 4D inventory generations shall be applied.
The goal of this bachelor thesis is therefore on minimizing the fuel flow of each flight segment, especially within the hypersonic cruise phase as well as in the vertical climb profile. For the latter, the aircraft is forced to dive on a constant energy level within the transonic region (while reaching Mach 1) to obtain an optimum climb path. A fuel-optimal flight level is

identified by an exhaustive search algorithm. While changing the vertical profile definition based on global variables like the hypersonic cruise flight level and simulate a set of different trajectories, an optimum for minimum fuel consumption of the aircraft can be found. This also incorporates a flight controller for keeping an optimal lift coefficient during the hypersonic cruise phase. For the sake of comparability, a flight route between Brussels and Sydney is chosen for the TCM simulations since detailed reference data of LAPCAT II-MR2.4, the design base of STRATOFLY-MR3, is available for this route.

Work packages

- Extended literature research (hypersonic/supersonic airliners; “Concorde”)
  → Focus: Vertical flight profile, flight envelope, key performance data
- Literature research: STRATOFLY MR-2.4/MR-3; overall design /mission/preliminary work, understanding of submodules (importance of engines, …)
- Reference trajectory BRU-SYD → Identify important aircraft states and their interrelations
- Obtain vertical flight phase table from reference trajectory for TCM simulations by reverse engineering (FPTV0)
- Create physically achievable flight phase table FPTV1 based on FPTV0
- Optimize trajectory with regard to minimal fuel consumption over whole flight envelope
  → Energy-controller for zoom dive
- → C_l-controller for optimal lift coefficient during cruise
- Compare TCM simulation results to simulations results of reference trajectory
- Detailed documentation of the results
- Optional: publish results in a scientific paper

The thesis should, if possible, not contain confidential content so that a potential publication after submission is not hindered.

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Betreuender MA