Mitteilung

Drehflügleraerodynamik:

Aerodynamic performance of two eVTOL concepts

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After the mobility company UBER published its white paper [1] on electrical vertical take-off and landing (eVTOL) concepts there is a 'gold rush' [2] in the VTOL community. While it is possible to lift loads vertically by using a purely electrical propulsion system, it is still questionable as to whether this is feasible for urban transport or not.

Recently, the aerodynamic possibilities of employing electric propulsion to vertical take-off and landing vehicles have been investigated by the DLR Institute of Aerodynamics and Flow Technology. While changing the propulsion concept not necessarily changes the aerodynamics per se, two potential advantages are identified that could improve the vertical lift concept in general using distributed electrical propulsion systems:

- Using many smaller propellers instead of one large rotor allows for the control of the vehicle alternating the RPM in contrast to a pitch control system known to conventional helicopter configurations. Besides the reduction of the mechanical complexity of such a system, this also enables the utilization of more efficient propellers [3].
- When using tilt-wing concepts, the wing itself can be made more efficient by immersing it in the slip-stream of many small propellers that cover the whole wing area instead of a single propeller. When correctly employed, a tip wing mounted propeller might reduce the required power by 8.5% or a row of propellers might increase the lift by 106% [4].

Therefore, from the many different configurations available, two concepts closely resembling existing vehicles are investigated. The first concept is related to the eHang 184 [5], a coax-quadrocopter featuring eight propellers in total. The second concept is loosely based on the A3 Vahana [6], a tilt-wing concept also comprising eight propellers on two wings. Both vehicles aim at a short-haul of one person in urban environments.

The aforementioned literature utilizes simplified aerodynamic models, with the highest being free-wake model coupled to a computational fluid-dynamics (CFD) code [4]. In this paper, pure CFD simulations are performed including laminar-turbulent transition prediction and the employment of a higher order filtering method. The latter is superior to capturing the wake interaction caused by the propellers to current state-of-the-art second order CFD solvers.

Both vehicles are investigated in hover and forward flight. While in hover, polars are generated, which show the effectiveness of RPM control, in forward flight the vehicles are trimmed for cruise condition. Both results are taken into account when the overall flight performance of the vehicles is estimated.

Figure 1a shows the vorticity field surrounding the coaxial rotor configuration in hover, while Figure 1b shows the vortices of the tilt-wing configuration in forward flight. In Figure 2, the Figure of Merit over thrust is plotted in hover for both vehicles. It is seen that the RPM controlled coaxial rotor is more efficient than the pitch-controlled duo-tilt wing configuration.

The final paper discusses the differences of coaxial and single rotor configuration for the quadcopter, while for the duo-tilt wing configuration the effect of either using four or eight propellers is discussed. The outcome is that for they are suited for their specific mission, yet factors other than aerodynamics will be an issue, such as safety regulations.

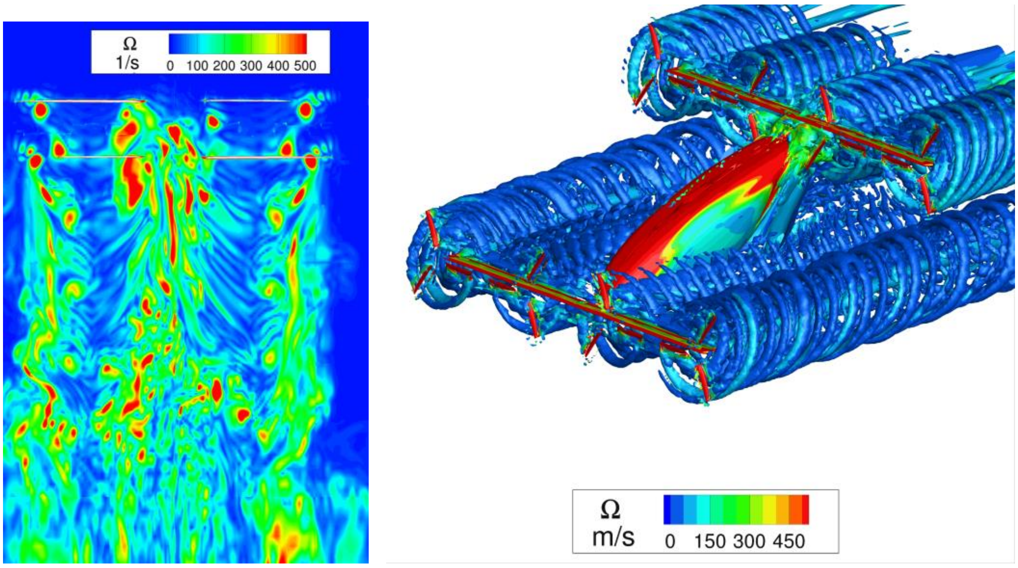

Figure 1: a) vorticity field of coaxial rotor in hover b) vortices of duo-tilt-wing configuration in forward flight

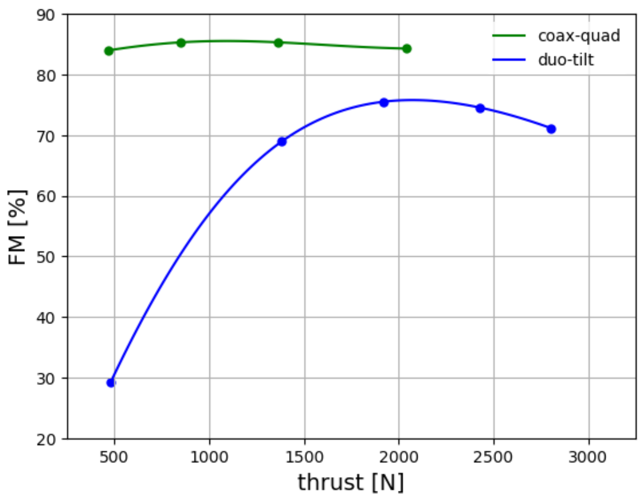

Figure 2: Figure of Merit over thrust polar for the rpm controlled coax-quad and the pitch-controlled duo-tilt wing configuration in hover

References
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