Aerodynamics and Aeroacoustics of Co-rotating rotors

In the past two decades, small to mid-sized unmanned aerial vehicles have become increasingly popular due to their versatile nature. Their applications include various areas for civil (healthcare, mining, etc.), military (training, reconnaissance, etc.) and research purposes (oceanology, atmospheric studies, etc.). A relatively new concept of Urban Air Mobility (UAM) has emerged which proposes the idea of employing air taxis (both manned and unmanned) in an urban environment. Since such vehicles will be an all-electric aircraft, rotors/propellers are the best choice for propulsion systems due to their higher efficiency and simplistic design as compared to a turbofan or turbojet, especially when operating at lower Reynolds Number.

Future propulsion systems for such vehicles will demand more efficient propellers with lower noise signature due to their operation in the urban environment. In such context the design of propeller, therefore, assumes significant importance. Amongst various propeller concepts, is a Co-rotating rotor in which two propellers rotating in the same direction are stacked on top of each other. The objective of the thesis is to explore various advantages that co-rotating rotors have over conventional rotors. A study was done by Mahendra\textsuperscript{1} in which he compared performance of co-rotating and contra-rotating rotors, shown in Figure 1. It shows that by varying azimuthal spacing between the upper and lower rotor, the co-rotating rotor can perform better than contra-rotating rotor.

![Co-rotating rotor geometry](image1)

![Figure of Merit variation](image2)

Figure 1: Comparison of contra and co-rotating rotors

Source: Mahendra\textsuperscript{1}

During the next few months, the performance and acoustic characteristics of different configurations of co-rotating rotor will be studied by performing CFD simulations on commercial software package PowerFLOW. Various parameters will be varied such as azimuthal and axial spacing, differential radius and pitch angle between rotors, etc. The whole work is divided into 4 phases. First phase will consist of resolution study of a specific configuration. Second phase will consist of validation study in which PowerFLOW results will be compared to an experimental study. Third phase will focus on differential radius between rotors and the advantage it offers in performance and acoustic characteristics. Fourth phase will involve proposing a new design of rotor/blade/airfoil (either of upper or lower rotor) so as to further improve rotor characteristics. In each phase, the aim will be to explain the results obtained based on flow physics of rotors and suggest further improvements which can be performed in future studies. The results of the thesis will help to improve propeller designs, especially concerning their acoustic signature and will be a step forward towards bringing UAM into reality.

\textsuperscript{1}Mahendra Bhagwat. “Co-rotating and Counter-rotating Coaxial Rotor Performance”. In: (2018).