DEPARTMENT OF AUTOMOTIVE AND AERONAUTICAL ENGINEERING

Numerical and Analytical Takeoff Field Length Calculations for Jet Aircraft

Task for a Bachelor Thesis

Background

The Takeoff Field Length (TOFL) is the takeoff distance of an aircraft including some margin of safety. The TOFL is by definition the greater of the Balanced Field Length (BFL) and 115% of the all-engines-operative takeoff distance. The BFL is determined by the condition that the distance to continue a takeoff following a failure of an engine at a critical engine failure recognition speed (go case) is equal to the distance required to abort it (stop case). It represents the worst case scenario, since a failure at a lower speed requires less distance to abort, whilst a failure at a higher speed requires less distance to continue the takeoff. V1 during takeoff is the maximum speed at which the pilot is able to take the first action to stop the airplane (apply brakes) within the accelerate-stop distance and at the same time the minimum speed at which the takeoff can be continued to achieve the required height above the takeoff surface within the takeoff distance. V1 is called Critical Engine Failure Recognition Speed or Takeoff Decision Speed. The BFL is usually the distance that determines the TOFL for aircraft with two engines. With some precision, BFL and V1 can only be determined numerically with a calculation / simulation based on the integration of the differential equation describing the aircraft motion under BFL conditions. This has been done by a student at HAW Hamburg before, however, the software was written for a special purpose and cannot be used here. Simple analytical equations exist that could possibly be used to approximate a BFL calculation. Textbooks (Torenbeek, Raymer) for aircraft design claim to have such an equation. An SAE-Paper (https://doi.org/10.4271/2013-01-2324) claims to have an algorithmic approach. An approximate function derived in flight mechanics for the distance to lift-off could be used with a correction factor from aircraft statistics to determine the TOFL. This is reported by Loftin and Scholz.

Task

Set up a calculation / simulation based on the integration of the differential equation describing the aircraft motion under BFL conditions to output the BFL and V1. Compare with 115% of the all-engines-operative takeoff distance to arrive at the TOFL. Provide this software for general use. Check analytical functions that approximate BFL and TOFL and report about their accuracy. You may try to increase the accuracy. The following sub-tasks should be considered when working on this Bachelor Thesis.

- Present very briefly the fundamental principles from flight mechanics used in this thesis.
- Summarize the most relevant regulations regarding Takeoff Field Length (TOFL) and Balanced Field Length (BFL).
- Present all equations and concepts necessary to calculate the individual distance components from which the TOFL / BFL is finally determined.
- Perform a systematic review to find analytical equations for the approximation of the TOFL / BFL. Include also all three above mentioned approximations. Calculate the correction factor included in the approximation from Loftin.
- Set up a small aircraft statistic to check and improve the correction factor in Loftin's approximation.
- Set up a numerical software to calculate / simulate TOFL / BFL.
- Use the software to determine the TOFL / BFL for a jet aircraft with two engines and a jet aircraft with four engines. Comment on your findings from these numerical simulations.
- Compare the results from the numerical simulation with the analytical approximations and comment on the usefulness of the approximations pure from literature and with own improvements added.

The report has to be written in English based on German or international standards on report writing.