

# **Turbulence Models for the Numerical Prediction of Transitional Flows with RANSE**

**LTJG Mert Gokdepe, TN**

<b>Prof. Stefano Brizzolara</b>
---------------------------------

Thesis Supervisor
-------------------

Research on turbulence modelling has extensively increased of importance over the years and it is now considered one of the most important aspects to get the accurate computation of high Reynolds number flows with Reynolds Averaged Navier-Stokes Equations (RANSE) solvers. In naval architecture turbulence models are necessary to solve typical hydrodynamic problems both in model scale, where  $Re=O(10^6)$ , and in full scale, typically  $Re=O(10^8)$ , since direct numerical simulations are not possible in these cases. This thesis aims to study the performance of different turbulence models for the prediction of the laminar-turbulent transitional flow in the boundary layer of streamlined bodies of interest in naval architecture: starting with a systematic study on a flat plate and arriving to transitional flow airfoils like the NACA 65-213. The RANSE solver is built on the libraries of OpenFOAM(Open Field Operation and Manipulation) which is a free, open source CFD program which enables a large group of users such as engineers, scientists, academics and commercial organizations to solve broad range of problems including complex fluid flows, solid dynamics and electromagnetics. Turbulence models considered range from one equation models such Spalart-Allmaras, two-equation models such as k-epsilon, k-omegaSST, three-equation model kkl-omega as RANS solvers, LES solvers and DES Solvers. The validation of OpenFoam based solver and the different turbulence models is made on the prediction of the friction and pressure drag components as well as lift predictions and in particular on the capability of the turbulent models to capture the transition between laminar and turbulent regime. Four different turbulence models are used in this scope: k-epsilon, k-omegaSST, Spalart-Allmaras and kkl-omega in conjunction with different wall functions. The kkl-omega t.m. is one of the newest transition models and it was developed to superior to the other models since it provides the transition region information. Its current implementation in OpenFOAM significantly underestimates the skin friction and the onset of the transition point. We propose a series of modifications we implemented on model equations and empirical parameters to improve the accuracy of predictions of the frictional drag component of transitional flows of interest in naval architecture.

**Master of Science in Mechanical Engineering**

**Naval Architecture and Marine Engineering**