Faculty Engineering Technology
Program Mechanical Engineering

UNIVERSITY OF TWENTE.

COLLOQUIUM

Group: **Engineering Fluid Dynamics**

As part of his MSc thesis assignment

K.H. Lammers

will give a presentation, entitled:

A Blade Element Method for Inclined Propellers Applied to NICETRIP Tilt-Rotor Propeller

Date: Monday December 21, 2015
Time: 14:00
Room: **Horst Building Room N,109**

Summary:
A tilt-rotor aircraft combines the benefits of a helicopter and an airplane. Such an aircraft can take off and land vertically like a helicopter but can also fly fast horizontally like an airplane. In airplane configuration the tilt-rotor aircraft produces less noise and is more efficient for forward flight than a helicopter. The NICETRIP wind-tunnel model is a scale model of a prototype tilt-rotor concept for commercial flight. As part of an European project this model was tested in the DNW-LLF. The tests covered the low speed range of the flight envelope, from the helicopter configuration through the conversion configurations to the aircraft configuration. Especially, during the conversion phase the shaft of the propeller is significantly inclined with respect to the flow. This makes the inflow velocity distribution and the geometry of the wake more complex than is assumed in present simple propeller calculation methods. This study focusses on deriving a blade element method for propellers with a high inclination angle.

During the NICETRIP wind tunnel tests pressure distributions for steady and unsteady flow conditions were measured on the wing surface behind the propeller. The frequency of the unsteady pressures matches the blade passage frequency of the propeller. Furthermore the magnitude of the oscillations of the unsteady pressures increases with increasing collective blade pitch angle when using cyclic pitch. This indicates that the unsteady wing pressures are influenced by the wake of the propeller upstream.

The wake of the rotor blade is mainly determined by the circulation distribution along the span of the blade. A flexible and fast method is sought to determine that circulation distribution. Such methods are available for propellers and rotors that are aligned with the flow, e.g. the blade element momentum theory (BEM) and Goldstein's vortex theory (GVT). By modifying the inflow velocity distribution these theories have been extended to inclined propellers. For BEM an additional extension is made by accounting for the deformation of the wake; this method is called BEM VTOL. The lift and drag coefficient of the blade sections, required for BEM, are determined utilizing XFOIL.

GVT, BEM and BEM VTOL are validated for flow aligned propellers and for inclined propellers for relatively small inclination angles (α_{prop}<20 deg). The validation for flow aligned propellers was performed using experimental data for a propeller with Clark-Y airfoil section. The validation for the inclined propellers was performed using available data for a Fokker 50 propeller. All three methods give results that are in general agreement with the experimental data, but the results from BEM and BEM VTOL are closer to the experimental data than those from GVT. After validating the three methods, they have been applied to the NICETRIP case. For the aircraft configuration and for the helicopter configuration the predictions are in agreement with the experimental data. For the transition configurations, i.e. for high inclination angles (20 deg< α_{prop} <80 deg), the results of the calculations show the same trend as the measurements, but the predicted values do not fully agree with the experimental data.

During the experiments with the NICETRIP model blade torsion and bending moments were measured. The torsion and bending moments have also been calculated using GVT, BEM and BEM VTOL. Comparison with the experimental results shows that the propeller blades cannot be assumed to be rigid. This together with up wash and blockage effects of the wing behind the propeller might be reasons for the predictions not fully matching the measurements.

Assessment committee:		**Chairman,**
Prof.dr.ir. C.H. Venner	(chairman)	
Prof.dr.ir. H.W.M. Hoeijmakers	(mentor)	
Ir. A.C. de Bruin	(mentor)	
Ir. A. van Garrel		
Dr.ir. G.G.M. Stoffels		d.d. _______________