The MSc track in Aerodynamics and Wind Energy combines fundamental and applied research disciplines of aerospace and wind-power systems, focusing on the development of new analysis techniques and their application in design. It is aimed at those who wish to acquire experience with both experimental and numerical methods as well as design procedures and optimisation techniques.

At TU Delft we offer you a leading academic programme in aerospace engineering and technology in Europe. Our internationally-oriented programme prepares you to respond effectively and rapidly to the needs in the aerospace sector with solutions that are innovative, technically feasible and commercially viable. At our state-of-the-art test and laboratory facilities you acquire the engineering skills needed in advanced industrial applications.

During your specialisation phase – the MSc track – you will develop into an independently-thinking, professionally oriented, innovative engineer and researcher.

### MSc Track structure

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Core courses</strong></td>
<td>Gain a broad view on a field of expertise</td>
<td>≥18</td>
</tr>
<tr>
<td><strong>Profile courses</strong></td>
<td>Focus on a particular subfield</td>
<td>≥13</td>
</tr>
<tr>
<td><strong>Elective courses</strong></td>
<td>Specialise in a particular area of expertise or add multidisciplinary elements, repair educational deficiencies or address a personal interest *</td>
<td>+/-16</td>
</tr>
<tr>
<td><strong>Literature study</strong></td>
<td>Prepare for the thesis subject</td>
<td>12</td>
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<tr>
<td><strong>Research methodologies</strong></td>
<td>Prepare for the thesis subject</td>
<td>2</td>
</tr>
<tr>
<td><strong>Internship</strong></td>
<td>Acquire professional skills during a three-month internship at a Dutch or international company or institute *</td>
<td>18</td>
</tr>
<tr>
<td><strong>MSc thesis</strong></td>
<td>An in-depth research project or design assignment in your subject of choice</td>
<td>42</td>
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*Optionally abroad

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**Aerodynamics and Wind Energy**

The MSc track in Aerodynamics and Wind Energy combines fundamental and applied research disciplines of aerospace and wind-power systems, focusing on the development of new analysis techniques and their application in design.
Profiles
Students can graduate within one of two thematic profiles, which determines the courses followed in the first year of the MSc.

Aerodynamics profile:
The aerodynamics profile covers the fundamentals of mathematics, flow physics, and flow analysis methods. Its courses include Partial Differential Equations, Gasdynamics, Aircraft Aerodynamics, Computational Fluid Dynamics, Experimental Simulations and Flow Measurement Techniques. After successful completion of the profile programme you will:
- Have an advanced knowledge of viscous and compressible flows, and of the influence of flow phenomena on external flow aerodynamics.
- Be familiar with the design of wind tunnel experiments, and have experience with modern measurement techniques including laser Doppler anemometry, infra-red thermography, and particle image velocimetry.
- Be familiar with modern computational methods for both incompressible and compressible flows, as well as advanced concepts in turbulence computation, mimetic methods, efficient time marching, uncertainty quantification and data assimilation.

Wind Energy profile:
The wind energy profile covers method and systems of energy extraction from wind. Both wind turbine and kite power systems. Profile courses: Kite Power and Propulsion, Wind Turbine Aerelasticity, Wind Turbine Design and Site Conditions for Wind Turbine Design. After successful completion of the MSc programme you:
- Will have thorough systems knowledge regarding these energy extraction devices.
- Will be able to apply advanced analysis and design techniques in at least one of the following areas: wind turbines, wind farms or kite power systems.
- Will have insight in related disciplines such as boundary layer meteorology, structural design and dynamics of structures, control and operations.

Academic staff
- Professor Stefan Hickel
  Head of Aerodynamics section
- Professor Fulvio Scarano
  Head of Aerodynamics, Wind Energy & Propulsion
- Professor Gerard van Bussel
  Head of Wind Energy section
- Dr Steven Hulshoff
  Aerodynamics profile coordinator
- Dr Wim Bierbooms
  Wind Energy profile coordinator

Job perspective
Graduates with a specialty in Aerodynamics are eminently qualified to work in the design of air and land transportation systems. Given their knowledge of flow physics and experience with experimental and computational techniques, there are also opportunities in the large number of industries where flows play an important role, such as offshore engineering, resource extraction, and process engineering, to name a few. Since the Aerodynamics specialty has a substantial fundamental component, its graduates are also well prepared for careers in fundamental or applied research.

For graduates with a specialty in Wind Energy, the recent rapid expansion in the number and size of wind turbines offers ample opportunities in the wide diversity of fields that make up the wind energy industry, including wind turbine manufacturing and engineering, wind farm development, consultancy, financial services, and research and academia.

Research in the Aerodynamics group
The Aerodynamics group is engaged in both fundamental and applied research related to the understanding and control of aerodynamic flows. The group’s strengths lie in the development of new experimental and computational techniques and the investigation of complex flow phenomena.

Concerning experimental techniques, the aerodynamics group is at the forefront of the development of particle image velocimetry (PIV) including its application to both unsteady and high-speed flows. This includes the development of methods to derive forces from PIV data, and which optimally combine experimental results with numerical flow simulations. The group is also very active in the development of new methods for numerical flow simulation. This includes methods which exactly preserve flow kinetic energy and helicity, optimal methods for the large-eddy simulation of turbulent flows and efficient techniques for fluid-structure simulations. In addition, methods for propagating input uncertainty are being advanced, along with Bayesian techniques for turbulence model selection and calibration. Finally, the aerodynamics group is engaged in the characterisation of several complex fluid phenomena for application to flow control. Examples include the effect of micro-ramps on shock-boundary layer interactions, sound production induced by trailing-edge turbulence interactions and the effects of low-frequency and nano-pulse plasma actuators on boundary-layer transition. MSc projects can be carried out in all these disciplines both in the Aerodynamics Lab as well as in collaboration with industry.
From 2005 to 2007 I followed the Aerodynamics Master programme, specialising in Computational Fluid Dynamics. After an internship in Chile working on wind tunnel lay-out designs, I returned to the Aerodynamics Laboratory in Delft to perform my Master thesis research on compressible two-fluid flow modeling. This was performed in collaboration with the Center of Mathematics and Computer Science (CWI) in Amsterdam. What attracted me most to the Aerodynamics Master was the combination of both applied and fundamental topics in its course programme, and the mixture of numerical and experimental expertise at the Aerodynamics Laboratory. In my opinion the Aerodynamics Laboratory is a unique location which has allowed me to deepen as well as broaden my knowledge Jasper Kreeft of fluid dynamics. After having worked for a year at the National Aerospace Laboratory in Amsterdam, I returned to the Aerodynamics Laboratory to start my PhD research on structure-preserving (mimetic) numerical techniques for, but not limited to, fluid dynamics.

Now, in my current role as fluid flow researcher at Shell R&D, I am involved in the computational modelling of multiphase flows in production facilities, turbulent reacting flows in reactors and fluid-structure interactions in offshore platforms. I find the knowledge of fluid dynamics, fluidstructure interactions and numerical analysis I obtained during my years at the Aerodynamics Laboratory is still of great value and used on a daily basis.

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### Research in the Wind Energy group

#### Rotor Aerodynamics

The group has a unique wind tunnel to test model rotors: the Open Jet Facility (OJF). Furthermore, the group uses the low speed low turbulence tunnel (LSLT) which is perfect for the design of airfoils for wind turbine application. We make extensive use of advanced experimental techniques such as laser sheet stereo PIV and CTA hot wire anemometry. We have our own rotor aerodynamic design and analysis tools and use commercial CFD packages. Not surprisingly, the research is often a combination of experiments and analysis.

#### Wind Turbine Design

Since offshore wind power is the most demanding application, the development of design methodologies is focusing on offshore wind power stations. Two design aspects prevail in this research: to keep the loads on the offshore wind turbines as low as possible, and to aim for a maximum availability of the wind power station with low maintenance requirements.

#### Kite Power

The design of a kite power system is highly connected to its dynamic behaviour. Important aspects are operational optimisation and economic feasibility. In 2012 the kite-power group demonstrated the fully automated operation of a kite power system. The current research addresses some limitations of that control system.
Other research areas are the development of a reliable kitepower system-state estimator and the development of a fast, adaptive controller for the ground-station. The Wind Energy research group collaborates with, among others, ECN, Ecofys, Vestas, Siemens and Makani Power.

**Student profile**

For the Aerodynamics and Wind Energy track a strong background in mathematics and fluid mechanics is required. A basic knowledge of numerical methods, computer programming, statistical methods and experimental methods is recommended. Make sure that you provide evidence of these skills in your application.

**Admission requirements**

- a Dutch BSc degree in Aerospace Engineering, Mechanical Engineering, Maritime Engineering, Electrical Engineering, Civil Engineering, Physics, Applied Physics, or Physics & Astronomy or
- A BSc degree in Military Systems & Technology of the Netherlands Defense Academy (NLDA) or
- a Dutch degree of a University of Applied Sciences in Aeronautics, Aviation, Mechanical Engineering, Maritime Engineering, Civil Engineering, Design & Innovation. These students have to complete a special bridging programme prior to enrolment on the MSc.

Details about admission are available on the TU Delft website:
www.tudelft.nl/admission

For further information

More information about the MSc profile “Aerodynamics” can be obtained at:
www.ir.tudelft.nl/awe

You can also contact the Aerodynamics profile coordinator:
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