Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

DLR
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DLR Goettingen – In the Centre of Flow- and Structural Dynamics

Foreword

Flow and structural dynamics represent the focal point of research at the DLR site in Goettingen. Measurements on unsteady, separated and/or transonic flows and their interactions with moving structures are studied and used to validate predictions. The research results are rapidly made available for industrial applications and lead to advanced, cost effective and comfortable air transport systems which can be operated with minimal environmental impact through their reduced emissions. The system competence of the DLR in aircraft and helicopter development is lastingly enhanced by the technical and scientific capabilities of the partners at the Goettingen site.

This brochure presents an overview which documents the expertise, the potential and the attained synergy effects of the involved establishments in the area of flow- and structure coupling.

Society's challenge.

If the pressing challenges of our society are to be met, the future air transport and military aircraft systems must become more cost-effective, safer and ecological. They must be developed in multi-disciplinary design processes which make use of the latest advanced technologies. To achieve this, the prediction, analysis and target-oriented manipulation of the flow- and structural dynamics of the flight system are mandatory and essential. These core competences must underlie a continual transition and further development from research to industrial applications. Only in this manner can the European aeronautical industry gain and maintain a globally leading role, which indeed has been declared as the major goal by the Council of Aeronautical and Space Research (ACARE) in its strategic research agenda.

The DLR at its Goettingen site has accepted this challenge and offers solutions in flow- and structural dynamics.

Make use of synergy effects

The DLR site in Goettingen combines the core competence of the Institute of Aerodynamics and Flow Technology, the Institute of Aeroelasticity and the Foundation German-Dutch Wind Tunnels (DNW). The close cooperation between these establishments leads to valuable synergy effects.

Modern imaging test techniques are being developed and applied in the Institute of Flow Technology in order to gain new scientific insights in the field of flow- and structural dynamics. Techniques for flow simulation, such as the DLR Tau code, are being further developed and validated.

Experimental and numerical techniques are being developed in the Aeroelastic Experiments and Aeroelastic Simulation Departments of the Institute of Aeroelasticity. The aim here is to study, understand, predict and control the flow and the flow/structure interactions.

The Foundation German-Dutch Wind Tunnels (DNW) operates four of its ten wind tunnels at the Goettingen site. Through its close cooperation with the DLR in the areas of simulation and test techniques, the DNW is a vital partner for future research projects.

Focal points of research and development

The aim of research and development in flow and structural dynamics at the DLR Goettingen site is to further the development and improve the performance of future aircraft and helicopters. The work is concentrated in the areas of unsteady aerodynamics, structural dynamics and aeroelasticity. To achieve this, novel methods for the measurement of physical properties in unsteady aerodynamic and structural dynamic processes are being developed and applied to ground, wind tunnel and flight testing. For example, cutting edge optical field measurement techniques for the capturing of pressure, velocity, density, acoustic and temperature data in flows, as well as data of structural deformation and vibration of test models and their holders, are available: Pressure Sensitive Paints (PSP), Temperature Sensitive Paints (TSP), Particle Imaging Velocimetry (PIV), Background Schlieren Technique (BOS), acoustic microphone arrays, Infrared Technique (IRT), Image Pattern Correlation Technique (IPCT). Basic physical phenomena are studied with these techniques and modelled numerically, with the aim of obtaining and continually improving problem-oriented simulation tools and techniques. The innovative drive of the DLR at its Goettingen site is best exemplified by the multitude of applied for and granted patents and trade marks. The available knowledge and expertise in Goettingen in the areas of optical test techniques and aerodynamic and aeroelastic testing and simulation leads to:

- new technologies for the measurement and control of instabilities, aerodynamic loads and vibrations;

- validated simulation methods and processes for virtual design and testing for industrial applications;
- training and continuing education of highly qualified engineers and scientists in these areas.

DLR know-how in action

The areas of aeroelastic stability and vortex-dominated flows are current examples for the successful cooperation of experimental and numerical capabilities resident at the DLR Goettingen site.

The flutter limit of an aircraft shows a minimum at transonic speeds, known as the "transonic dip". Limit-cycle oscillations (LCO's) may occur in the vicinity of this minimum, replacing the classical flutter behaviour with exponentially growing oscillations which can damage the structure. Studies showed that the shock-wave dynamics and their interactions with flow separation can influence the shape of the transonic dip and the behaviour of the LCO's significantly. It was further shown that, and understood how, local flow phenomena in the vicinity of the wing, the engine nacelle and the pylon can aerodynamically excite structural vibrations. These findings led to a considerable improvement in the predictive capability for these technically relevant physical processes. Furthermore it was possible to derive development criteria, thus ensuring the safe operation of a transport aircraft already in the early stages of its development.

The flow around aircraft with delta wings is dominated by vortices in the flow field. Flight manoeuvres with such configurations lead to highly unsteady load distributions through breakdown of these vortices. Results from experimental flow studies on various moving models with movable flaps are made available in valuable, comprehensive data bases for use in the validation of numerical simulations of unsteady flight manoeuvres. These experimental data are based on various flow visualisations, unsteady force, moment and pressure measurements and on an optical position detection of the moving test model. The capabilities of the DLR simulation techniques in understanding flight manoeuvres of elastic delta configurations, right down to minute details, could be decidedly further developed and validated by available test data.

The angle of attack of a helicopter rotor blade in cruise flight is changed cyclically. This rapid change in the blade incidence leads to high aerodynamic loads, noise and vibrations. Detailed experiments led to the development of flow-control measures which could remove these detrimental effects while at the same time maintaining the aerodynamic performance.

The abovementioned examples in the area of flow- and structural dynamics were the result of a concerted effort and inter-working between the highly developed experimental and numerical analysis techniques, combining also the expertise of the cooperation partners. The results of this research enter into the development of future aircraft.

Contracts and industrial cooperation on European scale.

The research work at the DLR in Goettingen is oriented towards a contribution to industrial applications via an exchange of tools and methods, knowledge and personnel in a national and European framework.

On the one hand, the aeronautics industry is supported directly through provision of a service in experimental and numerical simulation, including validation: as an example, the DLR is coordinating the Network of Excellence EWA (European Wind Tunnel Association), which is financed by the EU. The goal of this network is to provide the European aeronautics industry with considerably improved services in the European wind tunnels. The excellent cooperation with NASA, the US Army, the DNW, ONERA and various DLR institutes in the framework of the helicopter rotor project HART II made available for the improvement of numerical methods the arguably most comprehensive data bank on unsteady aerodynamics and blade deformations.

On the other hand, highly effective studies can be carried out directly on the end product, as exemplified by the successful ground vibration testing of the Airbus A380. This last and crucial test shortly before the A380's first flight was carried out together with ONERA.

Utilisation and operation possibilities

The research and development in flow- and structural dynamics at the DLR Goettingen site is of vital importance for the design and proof of safety of aircraft and turbo machines. The provision of services encompasses amongst others:

Wind tunnel experiments and computer simulations with forced moving and freely fluttering models

The offered service encompasses qualification tests and proficiency certification, with due compliance to the physically relevant similarity laws, and through the use of ultra-modern test (including optical) techniques. This enables experiments which are appropriate for the derivation and validation of modelling for industrial "virtual testing" methods. Support can cover the whole range from model design, construction and manufacturing down to the final scientific processing of the data. A qualification by analysis is possible even to this day through the available simulation methods and computer capabilities.

Ground vibration testing and aeroelastic certification

The identification of the structural dynamic properties serves as the basis for the aeroelastic certification of a new aircraft. The offered service encompasses the aeroelastic certification which is necessary to guarantee the safe operation of the aircraft. The appropriate developmental and airworthiness proof engineers of the DLR development service team are situated at the Goettingen site.

Structural dynamics qualification

The service offered includes the experimental proof that the structure in question does withstand the expected dynamic loads. This proof can be necessary in some applications to obtain the required approvals.

Complete solutions give competitive edge

Taken over the entirety of their technical service offer in the area of experimental and numerical unsteady aerodynamics and aeroelasticity, the partners have a market position which is unique in Europe and outstanding worldwide. This also applies over large areas to several of the measurement and test methods, to the simulation techniques and to the analysis and validation procedures.

The provided services by these partners are complete solutions and cannot be offered by any other research establishment. Long term continuity in development, with contact persons and in efficiency gives the DLR a clear competitive edge. In this way, contract work can be carried out reliably, effectively and efficiently. The close coupling of experiment and simulation, seldom seen worldwide in this form, gives the partners a strong position over their competitors in other research establishments.

Worldwide research cooperation

The goals of the DLR include its further strong competitive positioning in Europe and worldwide. The DLR at the Goettingen site contributes to this goal in flow- and structural dynamics of fixed and rotary wing aircraft with the following:

- Europeanization and consolidation of research resources
- Effective and efficient utilisation of facilities
- Qualitatively outstanding research results
- Avoidance of redundancies

With these guidelines, the cooperations with international research establishments in aeronautics and space research were rigorously further developed over recent years. The major partners include ONERA (France), NLR (Netherlands), ESA (Europe), NASA (USA) and JAXA (Japan).

Universities, colleges and institutes of technology – our partners

The DLR in Goettingen contributes to innovative applications and aeronautical products by operating large-scale facilities, doing research and development and rendering results from basic research for technical use. The central research partners here are the national universities and institutes of technology. The cooperation with them as partners is varied and intensive. It is seen in the various Special Research Areas (SFB's), in the groups of young workers, in the combined appointment of DLR institute's director and university professor and in the university lectureships of many DLR workers.

The goals of partnering with the national universities are:

- coupling of science and applied research
- meeting complex research and development challenges through use of scientific expertise and suitable large-scale facilities
- expediting technology transfer from science to application through the education of knowledge carriers
- education with a view to the whole system aircraft.

Local networking

The DLR at its Goettingen site is a member of Measurement Valley e.V., which is a regional institutionalised cooperation amongst local small- and medium-size companies working in the area of measurement techniques.

Promotion of the young

The DLR in Goettingen carries out an active program in promoting the interest of young people in science and technology:

- to engender their enthusiasm, pupils are shown and can participate in experiments in flow- and structural dynamics in the DLR_School_Lab.
- students in the subject area of information technology at the university of cooperative education in Mannheim are coached in measurement techniques and contribute to the further development of measurement systems and to the processing of measurement data.
- students, university graduated scientists and engineers and young and visiting scientists work actively on their further education in the research area flow- and structural dynamics.

Women in research

The DLR in Goettingen offers special programs to women. These include the opportunity for training and practical traineeships for female students in various European countries or special courses in the DLR_School_Lab, specially designed for young female students and pupils.

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The DLR in overview

DLR at a glance

DLR is Germany´s national research centre for aeronautics and space. Its extensive research and development work in Aeronautics, Space, Transportation and Energy is integrated into national and international cooperative ventures. As Germany´s space agency, DLR has been given responsibility for the forward planning and the implementation of the German space program by the German federal government as well as for the international representation of German interests. Furthermore, Germany's largest project-management agency is also part of DLR.

Approximately 5,100 people are employed in DLR´s 27 institutes and facilities at nine locations in Germany: Koeln-Porz (headquarters), Berlin-Adlershof, Bonn-Oberkassel, Braunschweig, Bremen, Goettingen, Lampoldshausen, Oberpfaffenhofen, and Stuttgart. DLR also operates offices in Brussels, Paris, and Washington, D.C.