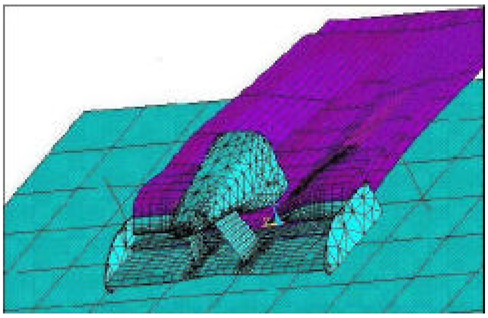
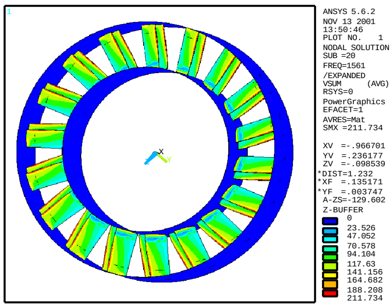


Linflow

Computational Fluid Dynamics Software

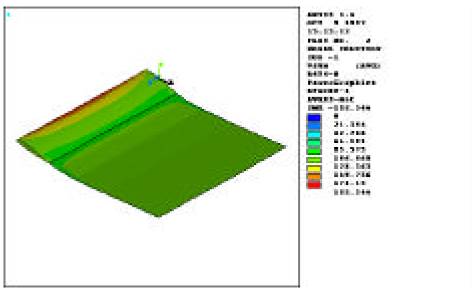
# LINFLOW APPLICATIONS



LINFLOW is a program for the simulation of Fluid Flow and Fluid-Structure Interaction problems. LINFLOW is characterized by ease of use and extreme computational efficiency. For the simulation of fluid-structure interaction problems, LINFLOW needs the modal information from a FE-based structural solver (Eigenfrequencies, eigenvectors, and modal load vector). LINFLOW is based on the Boundary Element Method. A unique implementation based on rigorous mathematics makes LINFLOW avoid the singularities found in the integral form of the equation system. Some examples of LINFLOW applications are shown below.

## COMPRESSIBLE AND INCOMPRESSIBLE FLUID FLOW

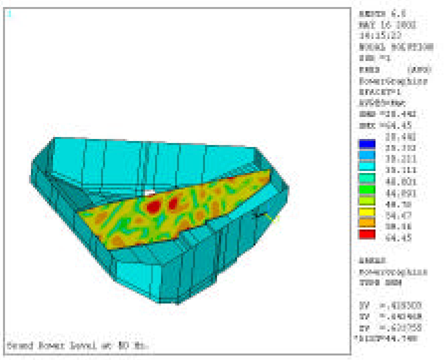
LINFLOW can solve Compressible and Incompressible Fluid Flow problems when the flow can be considered irrotational and inviscid. A thin-boundary layer solver based on the Navier-Stokes equations is used as a boundary layer thickness predictor for Boundary Layer Correction. Even when the flow is viscous, LINFLOW may give the user considerable insight in the problem.



The picture at the left shows the velocity contours over a finite wing. Included in the plot are the wing (left part) and the LINFLOW wake elements.
The wake elements in LINFLOW are needed for lift generating structures to satisfy the Kutta condition at the trailing edge of the structure (wing)

## ACOUSTICS

LINFLOW can solve acoustics problems, thereby accounting for acoustic damping if needed. The acoustic capabilities include the effects of the stiffness of interacting structures (e.g. buildings) if desired. Given one or more acoustic sources <u>outside</u> a building, LINFLOW will calculate the sound pressure levels <u>inside</u> the building.
There are virtually no limitations on the frequency range simulated.

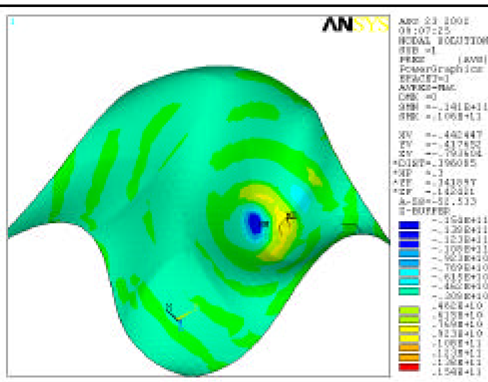


The picture shows the acoustic pressure levels in the middle plane of a concert hall.
For visualization purposes, the roof and parts of the walls have been removed. The effects of the audience and damping at the walls were represented by acoustic impedances.
The pressure levels can be determined in any point in the hall, various displays are possible.

## ACOUSTICS IN FLOWING MEDIA

If the medium is flowing, the fluid's speed and its direction may significantly influence the acoustics. LINFLOW is one of the few programs (if not the only) that can account for acoustics in flowing media.
This capability is significant, possible applications are:

- Underwater acoustics, ship moving
- Noise from an automobile exhaust pipe as a function of vehicle speed
- Acoustic pressure levels inside a building as a function of wind



Shown are the acoustic pressure levels in a landscape. The simulations performed showed that the pressure levels at a certain point are strongly dependent on wind speed and direction.
The simulations were also presented as animations which proved very useful in interpreting the results.

For more information, please contact:
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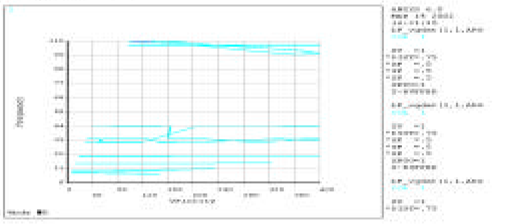
Picture of Fan: Courtesy Fläkt Woods AB
Picture of Aircraft Tail: Courtesy of PIAGGIO AERO INDUSTRIES SRL

# AEROELASTIC STABILITY OF AIRCRAFTS

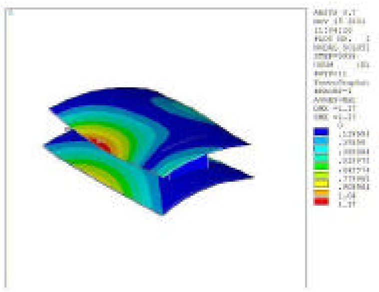
LINFLOW incorporates a fluid-structure interaction stability analysis module for aeroelastic stability studies such as flutter of an aircraft wing. Unsteady flows are solved in the frequency domain, this implies that LINFLOW is not constrained by any requirement to damp out initial transients. LINFLOW performs aeroelastic stability analysis based on the V-g and P-k methods. Multiple calculations are performed for unsteady fluid flows to ensure that each point in the V-g diagrams (damping and frequency plotted as function of velocity) is properly converged. V-g diagrams are generated within minutes. These capabilities are not found in any other fluid-flow analysis software.



Shown are the steady flow pressure contours and the aeroelastic eigenfrequency diagram for the tail of a small passenger aircraft.
For the actual project, the complete tail assembly and a part of the fuselage were included to correctly account for the flexibility of the tail attachment.
Two types of empennage Configurations, a T-Tail and a V-Tail were studied. The advantage of LINFLOW is that the true geometry of the structure and the angle of attack.

# AEROELASTIC STABILITY AND FATIGUE OF FANS

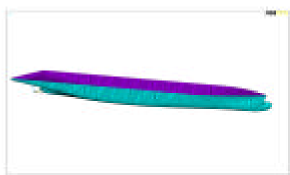
Aeroelastic stability investigations were originally developed for the aircraft industry. However, the physical phenomena requiring aeroelastic stability investigations are many. At the top left of the front of this sheet is the model used for a Formula 1 racing car shown. By utilizing LINFLOW, lift and drag of the spoilers was computed and conclusions regarding the handling of the car could be drawn.



In the example shown at top right at Page 1 of this sheet and at left, an axial fan was simulated to find to optimum geometry with respect to vibrations in order to avoid fatigue problems. The simulations were confirmed by subsequent measurements, the measurements were in excellent agreement with the simulations.

# COMPUTATION OF HYDRODYNAMIC ADDED MASS

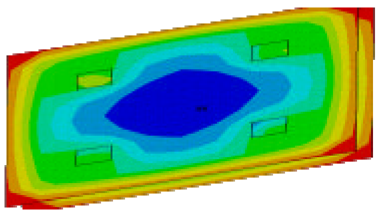
With LINFLOW, it is easy to accurately determine the hydrodynamic added mass for submerged structures. Virtually any 2- or 3-D geometry - simple or complex - can be accounted for. A free surface can be accounted for by elements (with damping).



Shown is the hull model of a ship structure. This model was used to determine the Hydrodynamic Added Mass for the ship.. Notice that the free (water) surface was not included in this case.

# SQUEEZED FILM EFFECTS IN MEMS

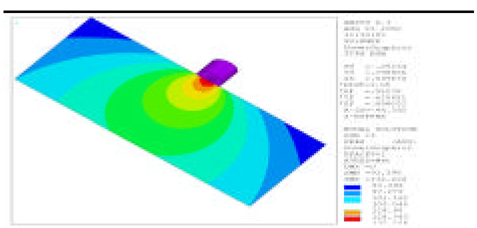
LINFLOW has a module for simulating squeezed-film pressure increase and damping due to viscosity in narrow gaps. This is particularly important for the MEMS industry which needs to account for squeezed-film effects in combination with fluid structure interaction.



Shown is the pressure distribution caused by squeezed film damping of two 80×80 $\mu m^2$ plates (one with four openings) oscillating towards each other. The pressure fields outside the openings are accounted for.

# UNDERWATER SENSORS

Fluid-structure interaction plays a very important role in the design of underwater (acoustic) sensors. LINFLOW efficiently solves this class of problems.
LINFLOW will also take the effect of the sensor moving relative to the water into account (e.g. ship moving).



This example shows a model of a submerged piston oscillating at a few kHz. In the figure, ISO-decibel contours are displayed on a surface through the fluid domain (this is a post-processing feature in LINFLOW).