Computational Fluid Dynamics Software

General Inviscid Fluid Flow – Extremely Fast Solution
Incompressible and Compressible Steady and Unsteady Fluid Flow
Fluid Structure Interaction - Acoustics - Acoustics in Flowing Media
Aeroelasticity – Boundary Element Method - Ease of Use

LINFLOW In Brief

LINFLOW® Computational Fluid Dynamics (CFD) software helps engineers simulate complex fluid flow problems without having to generate large, complicated models of the fluid domain. LINFLOW can be utilized for:

- General non-viscous, irrotational flow.
- Aeroelastic Harmonic Response.
- Transients solved in frequency domain.
- Fluid - structure interaction.
- Acoustics (also in Flowing media).
- Aeroelastic stability analysis.

LINFLOW is very easy to use. Thanks to its unparalleled computational efficiency, LINFLOW is ideal for studying the effects of design changes and for design optimization.

LINFLOW Applications

General Applications:

- Flow field influence on acoustic pressure fields.
- Flow field influence on structural dynamics (See Figure 1).
- Harmonic response of systems including fluid-structure coupling.
- Computation of hydrodynamic added mass.

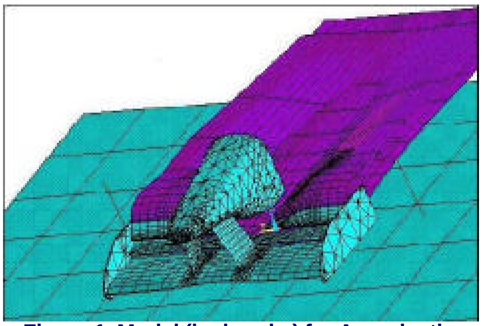

Figure 1. Model (incl. wake) for Aeroelastic Analysis of front wing system for a F1 car and it's influence on the system stability.

Automotive Applications:

- Noise in passenger compartment due to oscillations in car body.
- Steady and unsteady flows in engine block passages.
- Oscillating pressures in fuel lines.

Aerospace Applications:

- Steady and unsteady flows around geometrically exact 3-D wing and aircraft configurations.
- Aeroelastic flutter and other stability predictions.
- Optimization of propeller geometry.

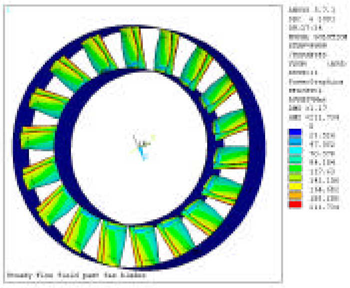

Figure 2. Aeroelastic Analysis of double bladed fan (image courtesy of Fläkt Woods AB).

LINFLOW Concepts

Numerical Approach:

LINFLOW is based on the Boundary Element Method (BEM). This means that the fluid domain itself is not modeled, only its boundaries. To analyze unsteady flow problems such as oscillating flow fields, a small-perturbation approximation of the potential equation is used. Wake elements are used in steady and unsteady simulations to model lift generating structures such as aircraft wings, propellers, and boat rudders.

An Engineering Tool:

LINFLOW was developed to provide non-specialist design engineers with a fast and reliable tool for solving everyday fluid and fluid-structure interaction problems. Heavy emphasis has been placed on ease of use. By utilizing BEM, modeling is much simpler than with software based on finite volumes or finite elements. Those require the fluid itself be modeled; LINFLOW never does.

Commercial Engineering Analysis Software Integration:

LINFLOW runs as a standalone package or as a module within ANSYS®, a general-purpose finite element analysis system for design verification and optimization. When LINFLOW is used in the ANSYS environment, pre-processing, solution, and post-processing can all be done in ANSYS.

LINFLOW includes a full set of ANSYS macros and other software needed for full and tight integration with ANSYS. Special LINFLOW commands for ANSYS are created with menu entries. These commands are used to set up input, run LINFLOW, and perform post-processing.

LINFLOW can also run with other software through its FEMAP interface or through its general interface program and GUI.

Fluid Dynamics Efficiency

In just a few minutes, LINFLOW calculates steady and unsteady flow results for non-separated flow fields around an entire aircraft. A Navier-Stokes analysis of this problem takes several days on the fastest workstations or on a super-computer.
Fig. 2 shows a model for unsteady fluid flow and aeroelastic analysis around a harmonically oscillating 3-dimensional ventilation fan. LINFLOW solves the flow part of this problem in seconds. For this study ANSYS modal analysis was used to calculate the mass and stiffness matrices needed in the aeroelastic analyses. LINFLOW results were read into the ANSYS database for post-processing (e.g. for animation of aeroelastic modes.) Required damping for neutral stability and aeroelastic modal frequencies were also plotted as a function of velocity.

LINFLOW Verification

Verification is a prime concern for users of engineering analysis software. LINFLOW is verified against a set of problems where analytical and/or experimental data are available. The excellent performance of LINFLOW solving unsteady fluid flow analyses is shown by the tight correlation in Fig. 3. The chart compares LINFLOW calculations (solid line) with NASA experimental test results (points) for the dynamic pressure amplitude on the flutter boundary of a finite span wing. Calculations were done for a speed of Mach 0.3 and compared with experiments at the 65% of span location. Experimental data is from the NASA Benchmark Aeroelastic Model Program, specifically the NACA0012 wing profile.

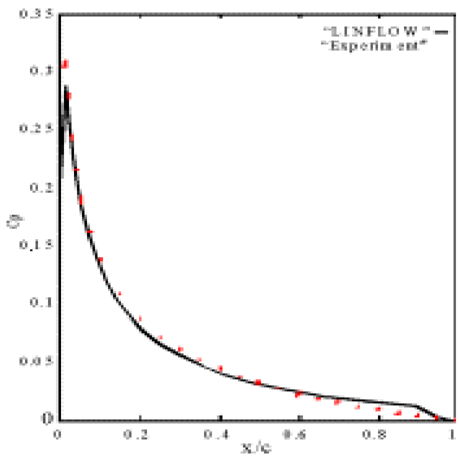

Figure 3. Comparison of analysis and experimental results of dynamic pressure amplitude on the flutter boundary for a finite span wing.

LINFLOW Execution Times

Determining the dynamic pressure amplitude over a harmonically oscillating finite 3-dimensional wing (as shown in Fig. 3) is generally a very difficult and computing intensive task.

Below are the running times for 2 simulations. All runs were done on an Intel Pentium II 300 MHz PC with 192 Mb memory.

It must be emphasized that 1,000 LINFLOW Elements correspond to many thousands of elements (or cells) in a conventional Navier-Stokes solver. Also, one should keep in mind that the aeroelastic stability analysis accounts for 10 eigenmodes, 1 steady state, and 1 aeroelastic analysis (12 runs).

Example:	Number of Elements:	CPU Time (Sec.):
3-D Aircraft Tail, Steady Flow:	917	50
3-D Aircraft Tail, Stability analysis:	1546	133

These examples demonstrate the extreme computational efficiency of LINFLOW.

LINFLOW Features

LINFLOW is based on unique and accurate solution algorithms for both steady and unsteady flow fields where viscous effects are negligible. LINFLOW runs in a fraction - typically 1/1000 or less - of the computer time consumed by Navier-Stokes solvers.

With many CFD programs, numerical damping becomes a (often overlooked) problem. This problem does not occur with LINFLOW.

In LINFLOW, the fluid domain itself is not meshed, only the surfaces limiting the fluid domain. This makes model generation (e.g. interfacing CAD systems) easy.

Fluid velocities and pressure loads on structural surfaces can be calculated for both steady and unsteady conditions.

LINFLOW incorporates an extremely efficient concept for solving fluid-structure interaction problems for small amplitude/harmonically vibrating fluids and structures.

LINFLOW has a fluid-structure interaction stability analysis module that can be utilized to perform aeroelastic stability studies such as flutter of an aircraft wing or a fan (Ref. Fig 2). 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.

LINFLOW Summary

Solution Features:

- Steady- and unsteady-flow algorithm.
- Thin-boundary layer solver based on Navier-Stokes equations for Boundary Layer Correction (i.e. boundary layer thickness predictor).
- External or internal flow.
- Aeroelastic stability analyses using V-g or P-k methods.
- Planar 3D surface elements.
- Full Harmonic Response Solver for Fluid-Structure Interaction analysis.
- ANSYS modal load vector may be used in LINFLOW response analysis.
- Squeezed-film pressure increase and damping due to viscosity in narrow gaps (MEMS.)
- Complex Acoustic Impedance, for energy absorption.
- Acoustic sources

Modeling:

- Surface type mesh for flow domain modeling.
- Wake elements for lift-generating surfaces.
- 3D geometry.
- 3- and 4-noded elements. (4-noded elements allow warping.)
- Inlet and outlet boundary conditions for internal and external boundaries.
- Integration with ANSYS
- General user environment to interface with external pre-/post-processors such as FEMAP.

Analysis:

- Incompressible and compressible flows (Mach numbers 0 to 0.7)
- Steady and unsteady flows.
- Allowing rotational motion of the structure (e.g. analysis of fan or propeller)
- Boundary conditions:
  - Rigid
  - Infinite
  - Symmetry

Acoustics:

- Sound pressure levels inside buildings and enclosures due to external sources (as a function of wind or flow speed).
- Complex Acoustic Impedance to account for damping.
- Sound distribution in open air as a function of wind speed.

Result Evaluation Capabilities:

- Field variable information:
  - Velocity potential.
  - Velocity.
  - Pressure at any location in the fluid domain.
- Field variables are available in the nodes on the structural V-g diagrams:
  - Required damping as a function of velocity (index) for a mode.
  - Frequency as a function of velocity for a mode.

Graphic Output

- All the imaging capabilities supported by ANSYS (contour, vector, path, plots, etc.) can be used to post-process LINFLOW models.
- Special commands in the LINFLOW-ANSYS interface include:
  - V-g diagram plotting
  - Time domain animation of LINFLOW results for unsteady flow analyses.

Graphical User Interfaces (GUI)

- LINFLOW has its own general interface with a GUI that will run besides any other program. This can be used to interface any FE-based structural analysis program.
- LINFLOW can be run as a fully integrated analysis module within ANSYS.
- LINFLOW utilizes special commands in the ANSYS user interface plus special commands to set up, run and post process LINFLOW models.
- Response diagram can be displayed in the ANSYS postprocessor.
- Interfaces for pre-/post-processing software packages other than ANSYS and FEMAP are under development.

Hardware Requirements

LINFLOW is available on most UNIX workstations and on PCs running Windows NT 4.0 or higher. 1024 Mb RAM or more is recommended.

New Features Implemented in Release 1.4

- PSD Module (e.g. for wind gust load)
- Semi-Automatic Wake Model Generation
- Improved p-k Stability Analysis

New Features Planned for Release 1.5

The following features are planned for LINFLOW 1.5 (without commitment):

- Further solver enhancements based on the New Solver Technology implemented in LINFLOW 1.3.
- Special version with Out of Core Solver and other technologies for very large problems
- Parallel Processing.
- General aeroelastic transient dynamics. (For aeronautics and MEMS.)

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