A Novel Technique to Design High Performance Low Noise Axial Fans;

An application to an engine cooling system

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The approach described here is concerned with developing and designing axial turbomachines, in particular, air moving fans. The aprroach is also capable of designing marine propellers and pumps.

It is well known that the aero-acoustic noise of axial fans mainly occurs due to turbulent flow and separation developing over the blades. Fans with improperly designed blade geometry often suffer from poor flow conditions leading to eddies that fluctuate with time and cause random dynamic forces acting on the blades. This produces broadband gust noise and, in most cases, trigger selectively organised structures over the blades causing tonal self-noise. Furthermore, the spectral characteristics of the noise may also change radially along the the blades. Swept blades, which creates an effective phase difference in the encounter of blade leading edge to inflowing air, has shown significant improvement on the aerodynamic and acoustic behavior of low-pressure fans. The procedure described here is concerned with designing axial turbomachines, in particular, air moving fans.

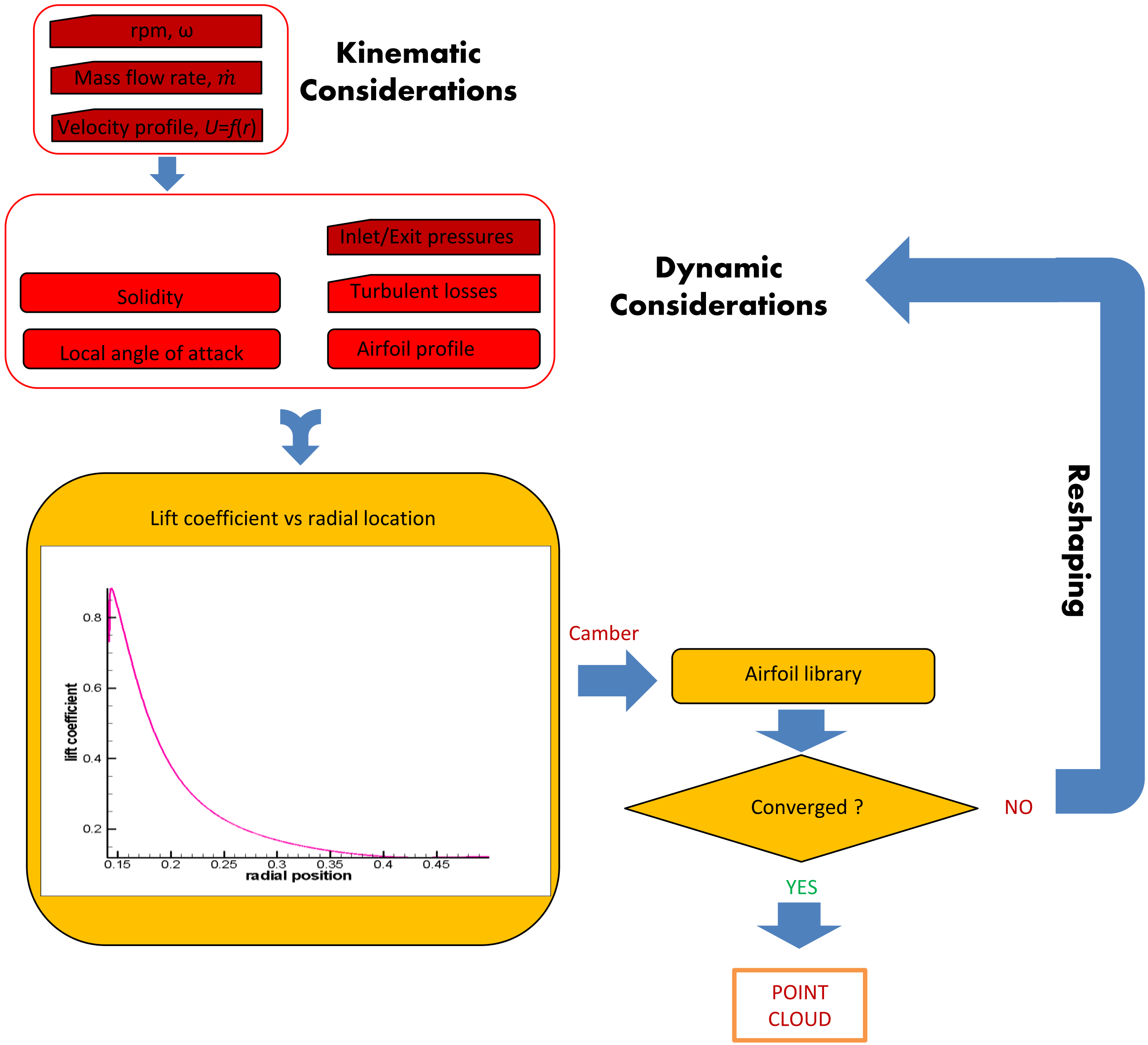
Using mass and momentum balances on a slice of flow passage surrounding a generic airfoil, lift and drag forces are possible to calculate. The forces are then used in an iterative procedure, in that the shape (camber, chordlength and thickness) and the local angle of attack of airfoil are continuously improved radially in order to satisfy pressure head and flow rate for a given rpm and geometry (hub and tip diameters). This approach requires a look-up table for the airfoil shapes versus lift coefficient. It is important to consider the losses associated with turbulence and cross-flow effects along the blade.

The algorithm described above (also see next slide) is developed and programmed in a code called PAD® by Ozdemir. The output of the code are a point cloud describing surfaces of the blade and an ASCII file tabulating some other critical data, as for example, the number of blades, twist, etc. The code itself determines the solidity and allows to define the axial velocity profile on the pressure side of the rotor so that a blade design with diminishing axial velocities near the hub and at the tip is possible. This, in turn, suppresses tip vortices developing in shear layers at both ends of the blade and eliminates the tip noise. The spin-off of low velocities at the hub and tip of the balde is a radially-inward flow downstream of the rotor, which increases the energy efficiency and reduces noise of the blowing process into tail ducting.

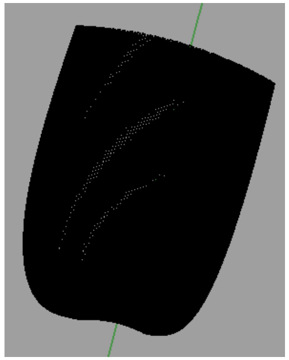
The code also has implementation of a phase shift option to generate forward or backward swept blades.

The code was successfully tested in other applications, such as, designing of marine propellers or pumps.

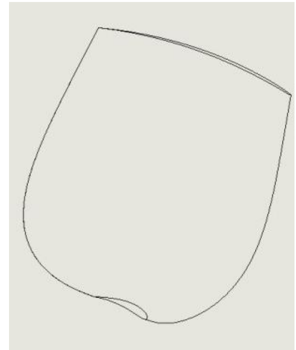
Flow chart of PAD



An example procedure



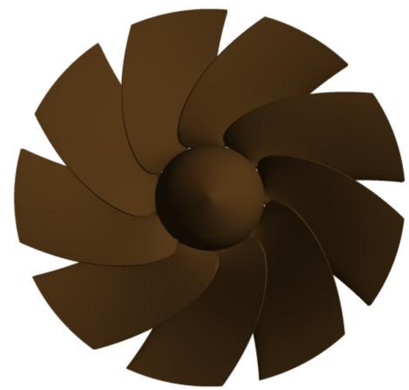
Point Cloud



to

Solid Blades

Rotor with forward swept blades



First Prototype

Diesel Engine Cooling Fan Specifications

- rpm	= 1900
- Flow rate	= 6 m^3/s
- Pressure	= 1.4 kPa
- Hub diameter	= 0.1 m
- Tip diameter	= 0.5 m
- Number of blades	= 9
- Solidity	= 82%
- Max. phase shift	= 28 degrees