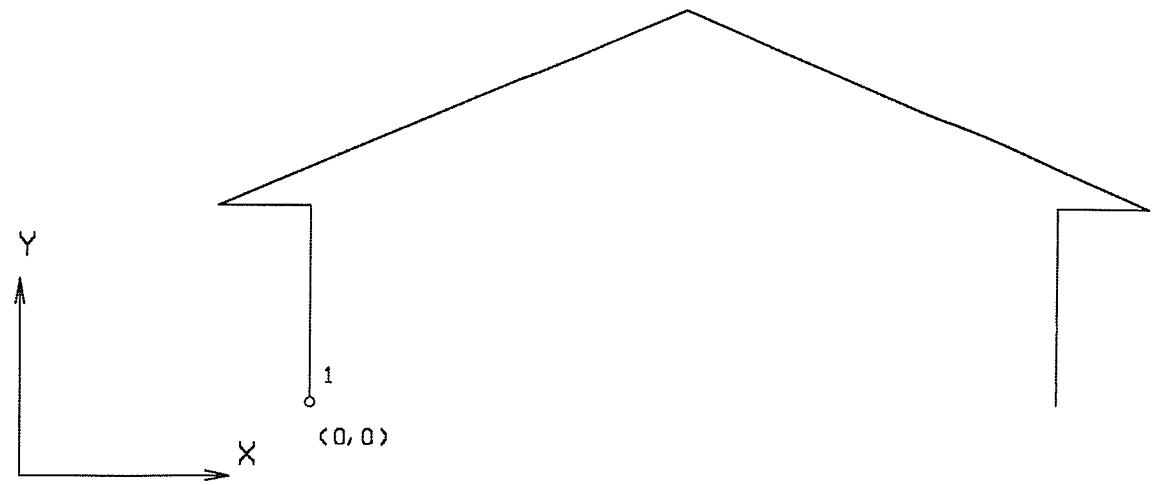
FIRM:DesignCalcs, Inc. | JOB NO. | SHEET NO: 1
MADE BY:KJH DATE:03-04-2013 | CHECKED BY: | DATE:
TITLE:WINDTUN2 Example Output

AERODYNAMIC MODELING - UNSTEADY VISCOUS FLOW:



Wind Velocity on left, right and top sides: VxMPH= 45.00 mph

Analysis Methology:

Design Reference: Article 10.5.1 from, "Essential Computational Fluid Dynamics" by Oleg Zikanov, (c) 2010

This program will calculate variable wind velocities and directions around a 2D object, using the Vorticity-Streamfunction formulation.

Streamfunction, χ, is defined by,

$u = \delta\chi / \delta y$ and $v = -\delta\chi / \delta x$

where

u = horizontal velocity (ft/sec)

v = vertical velocity (ft/sec)

From calculus, the total differential c) of the stream function is given by,

$d\chi = \delta\chi / \delta x \, dx + \delta\chi / \delta y \, dy = -v \, dx + u \, dy$

Along any stream line, is constant. It therefore follows that $d\chi = 0$ along any streamline. This program uses this principle to trace initial stream lines from the steady state solution computed previously.

AERODYNAMIC MODELING - UNSTEADY VISCOUS FLOW:

Analysis Methology (Cont'd):

Vorticity, w, is a vector field, which for 2D flow has a z-component term,

$$w = \delta v/\delta x - \delta u/\delta y$$

The initial values of w are computed by this program using u and v computed previously for the steady state solution.

Viscosity causes the vorticity to change with time. The transport equation for vorticity is used to compute the rate of change:

$$Dw/Dt = \delta w/\delta t + u\delta w/\delta x + v\delta w/\delta y = \nu(\delta^2 w/\delta x^2 + \delta^2 w/\delta y^2)$$

where,

ν =kinematic viscosity = 1.69 x 10^{-4} $ft^{2/sec}$ for air at 80 deg. F.

The relationship of streamfunction to vorticity is given by the following Poisson equation,

$$\delta^2 \chi/\delta x^2 + \delta^2 \chi/\delta y^2 = -w$$

The algorithm for solving the flow is as follows:

Step 1: Using the steady state solution for u and v at all nodes, the initial values for vorticity and stream function are computed.

Step 2: The vorticity at each interior point for the next time step is computed using a finite difference equation for the transport equation:

$$w_{i,j} = \text{Previous } w_{i,j} + \Delta t*\{-u*(w_{i+1,j} - w_{i-1,j})/(2*\Delta x) - v*(w_{i,j+1} - w_{i,j-1})/(2*\Delta x) + \nu[(w_{i+1,j} - 2*w_{i,j} + w_{i-1,j})/(\Delta x^2) + (w_{i,j+1} - 2*w_{i,j} + w_{i,j-1})/(\Delta y^2)]\}$$

Step 3: Streamfunction values, , are computed for the next time step using a finite difference equation for the Poisson equation:

$$\chi_{i,j} = [(w_{i,j} + (\chi_{i+1,j} + \chi_{i-1,j})/(\Delta x^2) + (\chi_{i,j+1} + \chi_{i,j-1})/(\Delta y^2)]/(2/Dx^2 + 2/Dy^2)$$

Step 4: Velocity components, u and v, are computed for the next time step:

$$u_{i,j} = (\chi_{i,j+1} - \chi_{i,j-1})/(2*\Delta y)$$
$$v_{i,j} = -(\chi_{i+1,j} - \chi_{i-1,j})/(2*\Delta x)$$

Step 5: Vorticity is updated at all boundary points, using the curre at χ interior points.

Step 6: Iterate solution (back to Step 2).

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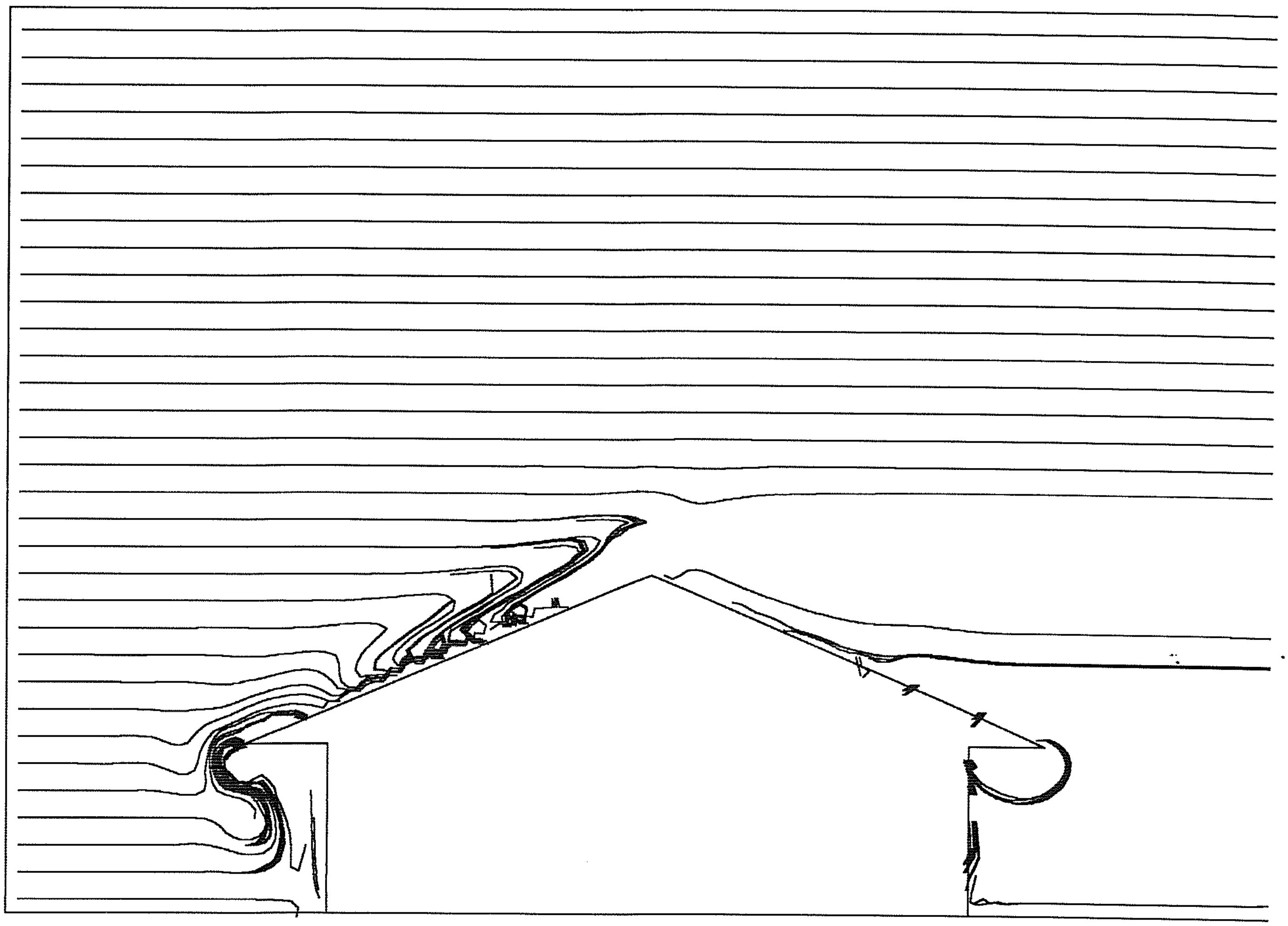
AERODYNAMIC MODELING - UNSTEADY VISCOUS FLOW:



Node spacing: DX= .533 ft, DX= .533 ft
Results shown after 100 interations:
Time step interval, ∆t = .000000200000 seconds
Elapsed time = .000020000000 seconds