Wind Effects on Atrium Fires

2d & 3d Generic Studies
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Two Dimensional Atrium

Bldg Size = 20 x 20 m, Inlets = 3 m, Exhausts = 2 m
Computational Details

- CFD Model: Fluent 6
- Kappa-Epsilon turbulence model
- First order accuracy
- Uniform flow inlet, \( U = 0, 0.5 \& 1.0 \) m/s
- Grid: Hexagonal 80,000 cells
- Time step = 0.1 sec
- Fire strength = 1,000,000 W/m\(^2\)/m
Up & Downwind Inlets: U=0 Streamlines

T=5s

T=10s

T=15s

T=25s
Up & Downwind Inlets: U=0
Velocity Magnitude Contours
Up & Downwind Inlets: U=0 Density Contours

T=5s

T=10s

T=15s

T=25s
Up & Downwind Inlets: U=0
Static Pressure Contours

T=5s

T=10s

T=15s

T=25s
Up & Downwind Inlets: U=0
Temperature Contours
Up & Downwind Inlets: U=0
Temperature Contours Animation
Up & Downwind Inlets: $U=0.5\text{m/s}$ Streamlines
Up & Downwind Inlets: $U=0.5\text{m/s}$

Velocity Magnitude Contours

Contours of Velocity Magnitude (m/s) (Time=3.4500e+01)  
FLUENT 6.1 (2d, segregated, ske, unsteady)  
Feb 14, 2004
Up & Downwind Inlets: U=0.5m/s Density Contours
Up & Downwind Inlets: $U=0.5\text{m/s}$
Static Pressure Contours
Up & Downwind Inlets: U=0.5
Temperature Contours
Up & Downwind Inlets: U=0.5
Temperature Contours Animation

Contours of Static Temperature (K) (Time=0.00000e+00)
Up & Downwind Inlets: U=1m/s Streamlines
Up & Downwind Inlets: U=1m/s
Velocity Magnitude Contours

Contours of Velocity Magnitude (m/s) (Time=5.32E+01)
Feb 14, 2004
FLUENT 6.1 (2d. segregated, skt. unsteady)
Up & Downwind Inlets: U=1m/s
Density Contours

Contours of Density (kg/m3) (Time=5.320De+01)  FLUENT 6.1 (2d segregated, ska, unsteady)
Feb 14, 2004
Up & Downwind Inlets: $U=1\text{m/s}$

Static Pressure Contours

Contours of Static Pressure (pascal) (Time=5.3200e+01)  
FLUENT 8.1 (2d, segregated, skw, unsteady)  
Feb 14, 2004
Up & Downwind Inlets: U=1 m/s
Temperature Contours

T=5s

T=10s

T=15s

T=25s
Up & Downwind Inlets: U=1.0
Temperature Contours Animation
Upwind Inlets: U=0 Streamlines
Upwind Inlets: U=0
Velocity Magnitude Contours

T=5s
T=10s
T=15s
T=20s
Upwind Inlets: U=0
Density Contours

T=5s

T=10s

T=15s

T=20s
Upwind Inlets: U=0
Static Pressure Contours

T=5s

T=10s

T=15s

T=20s
Upwind Inlets: $U=0$

Temperature Contours

- $T=5s$
- $T=10s$
- $T=15s$
- $T=20s$
Upwind Inlets: U=0
Temperature Contours Animation
Upwind Inlets: U=0.5m/s Streamlines

T=10s

T=20s

T=30s

T=50s
Upwind Inlets: $U=0.5\text{m/s}$

Velocity Magnitude Contours

- T=10s
- T=20s
- T=30s
- T=50s
Upwind Inlets: $U=0.5\text{m/s}$

Density Contours

$T=10\text{s}$

$T=20\text{s}$

$T=30\text{s}$

$T=50\text{s}$
Upwind Inlets: $U=0.5\text{m/s}$

Static Pressure Contours

- $T=10\text{s}$
- $T=20\text{s}$
- $T=30\text{s}$
- $T=50\text{s}$
Upwind Inlets: U=0.5m/s
Temperature Contours

T=5s

T=10s

T=15s

T=20s
Upwind Inlets: U=0.5 m/s
Temperature Contours Animation
Three Dimensional Atrium

Bldg Size = 20 x 20 m, Inlets = 1 x 3 m, Exhausts = 2 x 2 m
Three Dimensional Atrium
Computational Details 3-d

- Fluent 6
- Large eddy simulation (LES) turbulence model
- Second order accuracy
- Uniform flow inlet, U = 0 & 2.0 m/s
- Grid: Hexagonal 442,000 cells
- Time step = 0.1 sec
- Fire strength = 2,500,000 W (2.5 MW)
3-d Cube: LES, $U = 0 \text{ m/s}$

Velocity Magnitude 3-d

$T = 330\text{s}$
3-d Cube: LES, U = 0 m/s
Density Contours

T = 330s
3-d Cube: LES, $U = 0$ m/s
Static Pressure Contours

$T = 330$ s
3-d Cube: LES, U = 0 m/s
Temperature Contours

T = 330°C
T = 350°C
3-d Cube: LES, $U = 0$ m/s

Temperature Contours Animation
3-d Cube: LES, U = 2 m/s
Velocity Magnitude

Before fire starts

t = 330 s after fire starts
3-d Cube: LES, U = 2 m/s
Velocity Magnitude

Before fire starts
3-d Cube: LES, U = 2 m/s
Density Contours

T = 330s
3-d Cube: LES, U = 2 m/s
Static Pressure Contours
3-d Cube: LES, $U = 2 \text{ m/s}$
Temperature Contours

Contours of Static Temperature ($k$) (Time=3.4425e+02)  
FLUENT 6.1 (3d, segregated, LES, unsteady)  
Feb 22, 2004
3-d Cube: LES, U = 2 m/s
Temperature Contours Animated
3-d Cube – rke - Offset doors, U = 0 m/s

- Offset inlets can produce fire vortex behavior.
- Doors on 4 faces have been offset 4 m from center
3-d Cube – rke Offset doors, U = 0 m/s, t = 325 sec

**Temperatures**

**VelocityX, x = 90 m**

**VelocityZ, Z = 100 m**
3-d cube – rke - Offset doors, U = 0 m/s, t = 325 sec
3-d Cube – rke - Offset doors, U = 0 m/s, Iso Temp Surface = 400 > 375 > 350 F
3-d cube – rke - Offset doors, U = 2 m/s, t = 0 sec

- Z = 100 m
- Z = 103.5 m
- Y = 2 m
3-d cube – rke - Offset doors, U = 2 m/s, t = 325 sec
3-d cube – rke - Offset doors, U = 2 m/s, t = 325 sec

Iso-surface, $T = 325$ k

Iso-surface, $T = 350$ k

Iso-surface, $T = 375$ k

Iso-surface, $T = 400$ k
3-d Cube – rke - Offset doors, 
U = 2 m/s,  Iso Temp Surface = 400 > 375 > 350 F
3-d Cube – LES - Offset doors, U = 0 m/s, t = 325 sec
3-d Cube – LES - Offset doors, U = 0 m/s, t = 325 sec

Iso-surfaces T = 350 K

T = 350 K

T = 375 K

T = 400 K
3-d Cube – LES - Offset doors, U = 0 m/s, Iso Temp Surface = 400 > 375 > 350 F
3-d Cube – LES - Offset doors,
U = 2 m/s, t = 260 sec

Z = 100 m

T = 325 k, Y = 2 m

Vz, z = 100 m
3-d Cube – LES - Offset doors, U = 2 m/s, t = 260 sec
3-d Cube – LES - Offset doors, $U = 2 \text{ m/s}$, $t = 350 \text{ sec}$
3-d Cube – LES - Offset doors, U = 2 m/s, t = 350 sec

Iso-surface T = 325 K

T = 350 K

T = 375 K

T = 400 K
3-d Cube – LES - Offset doors, U = 2 m/s, Iso Temp Surface = 400 > 375 > 350 F
Conclusions

- Two dimensional simulation tends to exaggerate effects due to effective size of openings, but wind influence is demonstrated clearly.
- Three dimensional simulations are very dependent on placement of openings, but again wind influence is demonstrated clearly.
The End