Thermal and Laminar-Fluidic Workbench for a metric Portion of a Gun

Subject :
Part of a 120 mm gun has been represented as a perforated conic iron solid, surrounded by an annular screen. Inside the gun are limit conditions of isolation or thermal flux. The screen is described as a shell, receiving solar heat and exchanging with the outside atmosphere. It bears a defined number of holes on its top and bottom lines, maintaining semi-captive air between itself and the gun. The case has been modelized and solved in COMSOL 3.5a

This is to be seen as a **benchmark** to evaluate COMSOL. Indeed, NEXTER has no real use of COMSOL for this specific problem, since it has developped for a long time dedicated sophisticated codes to simulate in a transient way what's going on in a gun or nearby to it. Thus, this is a specific application whose results coud be compared to other, obtained by different ways.

Geometry has been created directly into COMSOL 3.5a by introducing cones and cylinders and performing boolean operations on them. At this stage of our study, two application modes have been activated : basic General Heat Transfer (htgh) and Weekly Compressible Navier-Stokes. The purpose was, in a second step, to activate other facilities such as Solid, Stress - Strain (smsld) and General Heat transfer (htgh2), in order to see what kind of differential thermal expansion could result, on solid parts, from fluid circulation and temperature fields in the semi-captive air zone. This one is expected to shelter some natural convection, of laminar type because of the small thickness available between the gun's surface and its surrounding screen.

Physical conditions in the air layer were :
Perfect Gas approximation,
rho = rho_htgh,
Fz = Grav*(rhoext-rho_htgh) creating buoyancy
Initial conditions : absolute pressure = patm,
this one beeing specified as a constant with patm = 101325 Pa.

Boundary conditions (concerning about 80 surfaces) :
For all openings, COMSOL's staff advised me to choose : open boundary, normal stress, f0 = patm. Practically, we account bottom line ports (∅ 4) to become inlets, although with an unknown mass flow, and top line ports (∅ 2) to become outlets.
In all places where it bears no hole, the outer border of the model, which is a truncated cone, is seen as a wall with an imposed temperature. On its lower half, this is the outside ambiant ; on its upper half, it is a modified brand of it, such as Text + Φ/h_{est}, where Φ accounts for the average normal incoming solar flux in simulated conditions (from 373 to 527 W/m^2 in our case) and h_{est} is the estimated heat transfer coefficient with the surrounding atmosphere (we chose $h_{est} \approx 30$ $W/(m^2.K)$). The purpose, indeed, was to study the influence of the sun on this device. But other approches could be imagined, such as imposing a huge thermal flow from the inside of the gun instead of adiabatic walls as we find presently, to study the influence of inner heat on peripheric thermal convection. With in both cases, a look on resulting thermal dilatations in the device.

Meshing has a great influence on calculation runs and convergence :
We initially tried to limit the number of meshes, with a coarse meshing of the metallic parts of the gun and an average of only two tetraedral layers filling the gap between the weapon and its surrounding screen. Except, of course, in and around the holes created by substracting small cylinders to the annular intersticial air layer (as it has been suggested talking about "boolean operations"), which benefited from a manually controled meshing. But this choice appeared unappropriate, leading to divergence after a 4 hour's run on a personal computer.
At that stage, contacted COMSOL support explained me that 4 layers of tetredron were a minimum to describe what could really take place in this layer, which lead me to remesh the whole model according to the same principles and to this additional constraint, leading to a total of about 650 000 meshes. Unfortunately, that was too much for the harware at my disposal.
Suddenly, a famous idea appaeared at a half-day training as COMSOL regularly proposes : why not split the model, in order to conserve only half of it ? Sure, unsymetric solar loads could no more be treated that way but so many cases were still possible ! That's precisely what I did, through another boolean operations and one more meshing, leading to an acceptable total of 340 000 tetradrons. So then, at last, a new calculation was lauched and reached its equilibrium.

Results :
This gave us interesting results about temperature fields and air flow immediately around the gun, showing a kind of closed cavity natural convection taking place in two different cells, covering respectively the upper and lower halves of the annular space. Unsurprisingly, since thickness is not constant, speads appears greater on the side where the air has more space to move. But we are surprised to see that no general natural convection seems to occur through the range of half-holes present at the bottom and to lines of our last model. True that our holes are especially thin, but is that a reason enough to explain these puzzling results, or is there in our program lines something which has not been set correctly, so that no incoming outside air seems to create any perturbation in the gentle quarter-cylindrical natural convection cells obtained ?

Apology :
This study has been realised on a period of 2 years, with a sparse succession of short term lending periods, such as for COMSOL's presentations or teachings, by someone (= myself) who had never touched COMSOL before but remains interested in it. Joined to the recent switch to COMSOL 4.0, which makes this model not easily eligible for a new run, this special context where unaccessibility is prevalent explains why some interesting questions here exposed have not yet been solved !

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