COMSOL CONFERENCE ROTTERDAM 2013

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Optimal Heat Sink Fin and Cold Lid Heights for Liquid Immersed Servers

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Outline:

- Data center power consumption
- Data center cooling methods
- Natural Convection in cavity
- Model description
- Result and discussion
- Conclusion

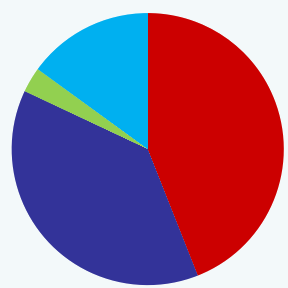
What is a data centre

Data centre electricity consumption in west Europe

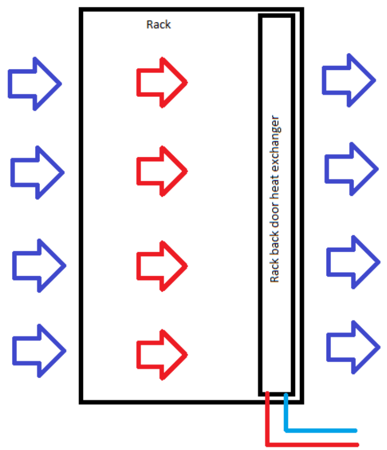
Year	Power consumption
2000	18.3 TWh
2005	41.3 TWh
2010	72.5 TWh
2015 (Projected)	128 TWh

22×10^6 Household electricity consumption per year

Electricity consumption of the data centre

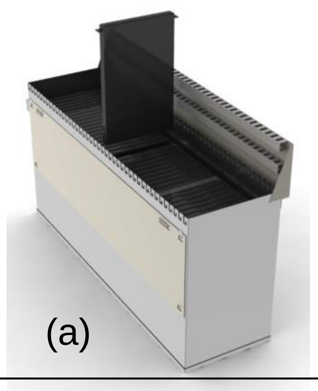


(1)

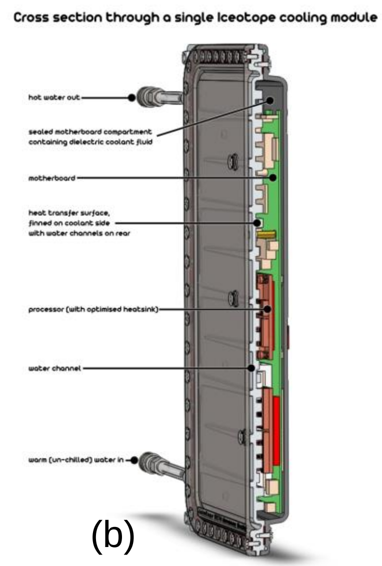


(2)

- Cooling methods
  - Air
  - Liquid
    - (1) Rack Back Door Heat Exchanger
    - (2) On Chip Heat Exchange
    - (3) Immersed cooling
      - (a) Green Revolution cooling
      - (b) Iceotope

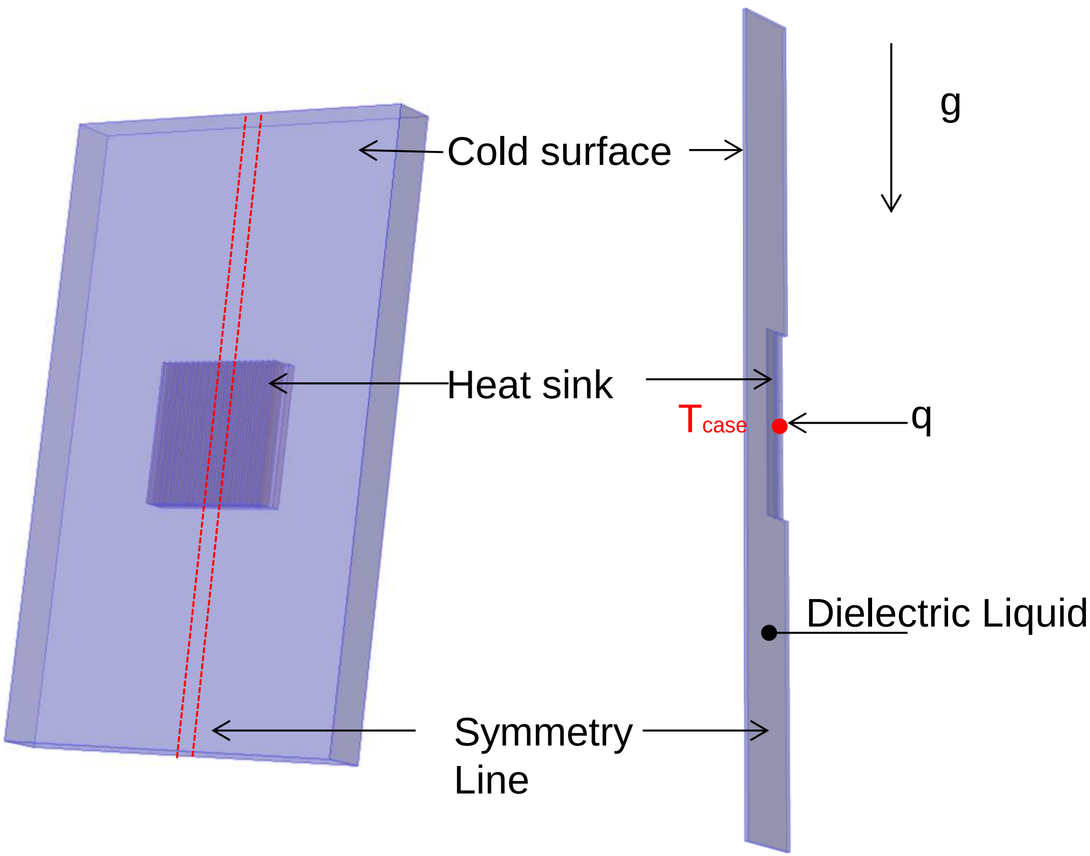


(a)



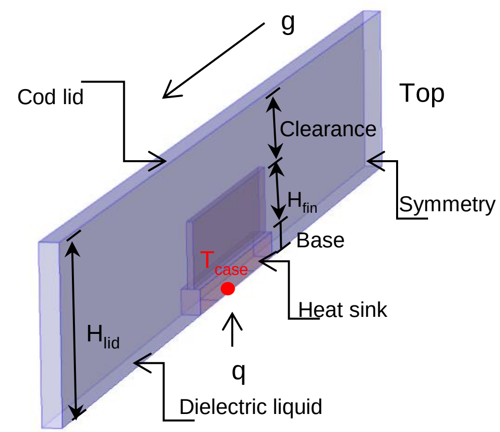
(b)

Model description of this study:



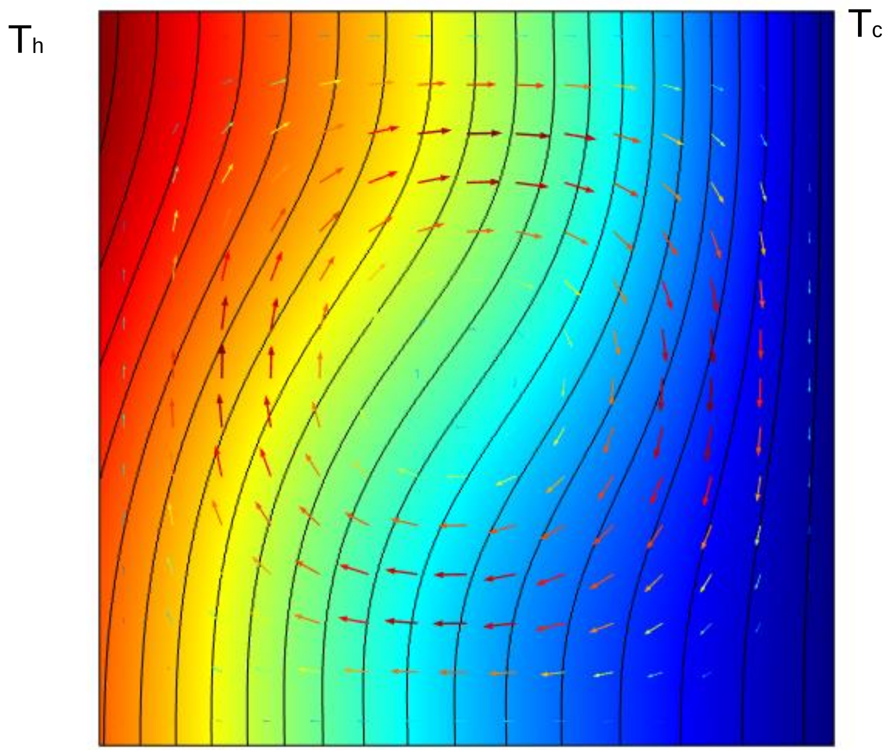
Full Server

Computional domain Slice of the sever



Another view of the Slice of the sever

Natural convection:



Assumption

The conjugate heat problem is a coupled heat conduction and heat convection with the following assumptions:

- The flow is steady state.
- The flow is turbulent based on the value of the Rayleigh number.

$$R_a = \frac{g\beta\Delta T L^4 q\rho^2 C_p}{k^2\mu} = 2.2x10^{11}$$

The Ra value of this case is greater than 10^7 so the flow is considered to be turbulent.

Fluid and material properties

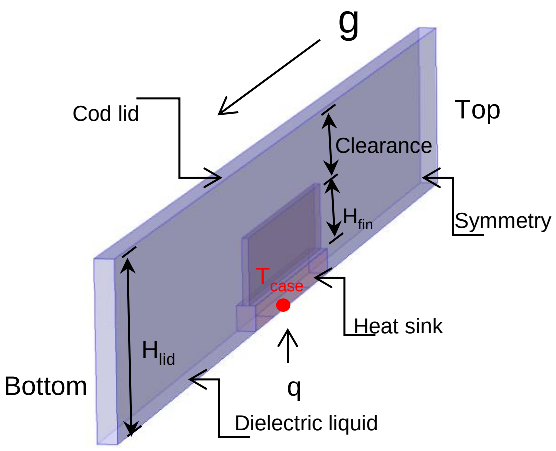
- The CPU is copper.
- Table presents thermal properties of the Novac liquid

Properties	Abbrev.	Novac
Specific heat capacity	C_p	1140 (J/kg.K)
Thermal expansion	β	1.151×10^{-3} (K^{-1})
Dynamic viscosity	μ	1.124782×10^{-3} (Pa.s)
Thermal conductivity	k	6.9×10^{-2} (W/m.K)
Density	ρ	1716.2-2.2T (kg/m^3)

Boundary condition:

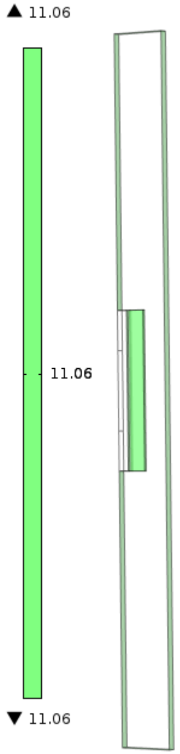
To solve the conjugate heat problem, the following boundary conditions are included:

- Top and Bottom surfaces of the server are insulated except for the CPU 45x4.5 mm^2 and the adjacent cold lid.
- The temperature of the cold side is constant which is 303.15 K.
- The heat flux is generated from the CPU surface and is q= 8888.88 W/m2.
- Symmetry conditions left and right to account for multiple fins.



Mesh study:

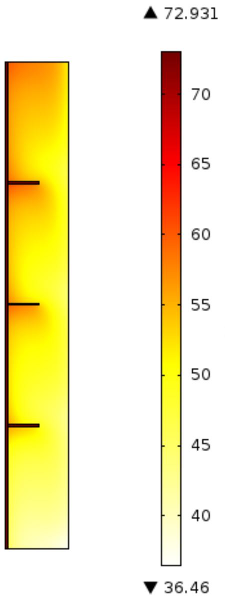
- The mesh study was performed for the case of H_{fin}= 10mm and H_{lid}=38mm. The mesh consisting of 37563, 77977, 14586, 238149 and 465968 elements were used for the model simulation. The best mesh is 238149 elements.
- The wall-lift-off for all walls is 11.06 as recommended.



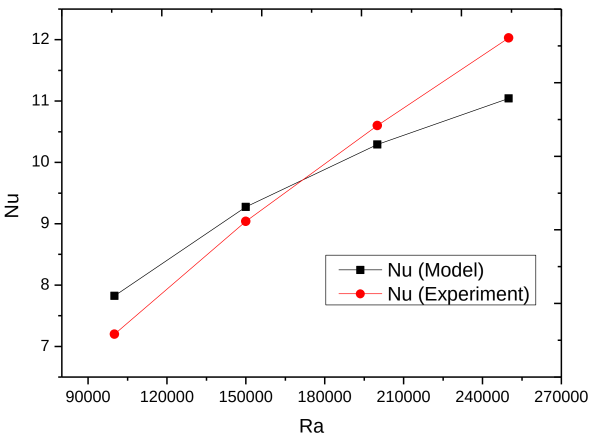
wall-lift-off

Model validation:

- The validation has been conducted to published experiment by Nada*. Figure shows the temperature surface for Ra=200000
- The average error is 5.4%. As shown comparison figure.



Temperature surface



Nusselt number for experiment and the model

*Nada, S., Natural convection heat transfer in horizontal and vertical closed narrow enclosures with heated rectangular finned base plate. International Journal of Heat and Mass Transfer, 2007. 50(3): p. 667-679.

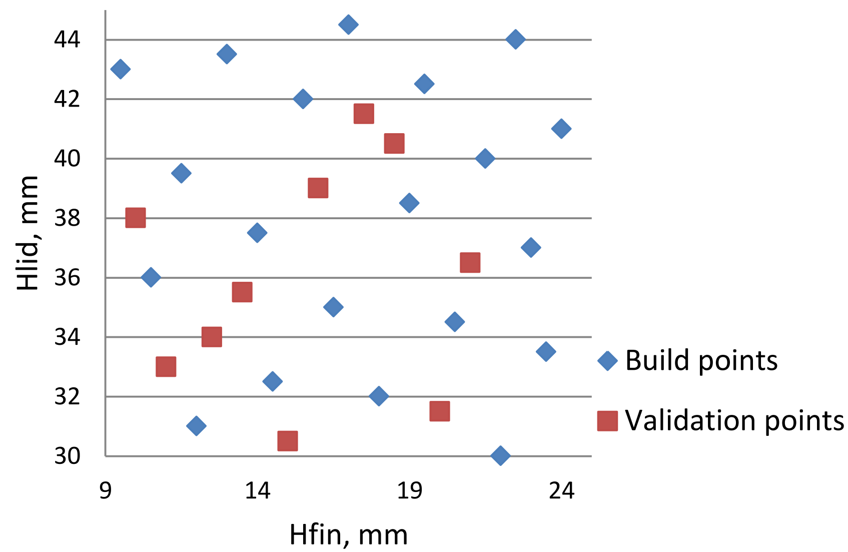
Result and discussion:

Design variables limits

Variables	Upper (mm)	Lower (mm)
Fin height	9.5	24
Cold lid Height	30	44.5

- The upper and lower limits of the two design variables is illustrated in the Table.

- An optimum Latin Hypercube Design of experiment (DoE) is performed to create 30 combination of two design variables. The distribution is shown in the figure.

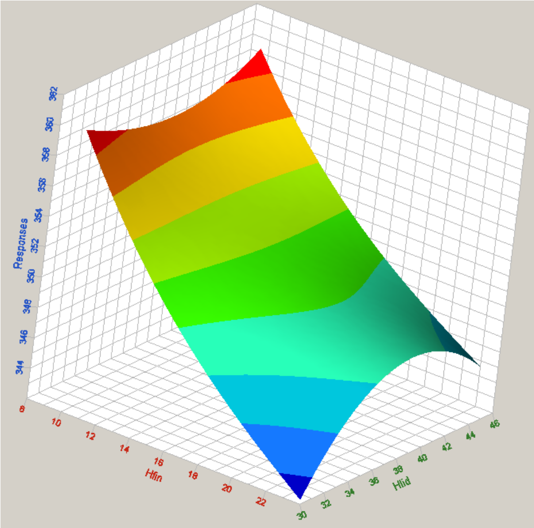


Design of experiment

Result and discussion:

- COMSOL software is used to run 30 models that represent the selected 30 points. The approximation response surface of T_{case} was performed by applying Least Squares Regression approximation method. The approximation of T_{case} for H_{fin} and H_{lid} is shown in Figure.

- The optimum is H_{fin}=23.9mm and H_{fin}=30mm as shown in table



Response surface of T_{case}

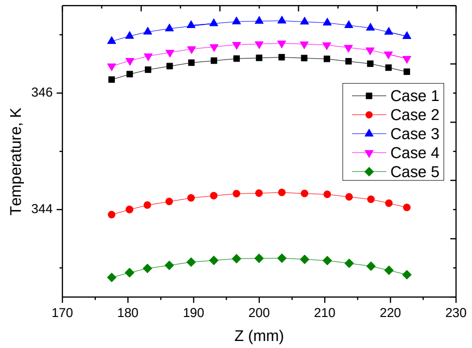
Compare between the predicted Tcase and simulated

Design variables (mm)		T_{case} (K)		
Fin height	Cold lid heigh	predicted	Simulated	Error %
23.9	30	342.3	343.15	0.25

Result and discussion:

- Five different cases were picked from thirty simulations as shown on table.
- As shown the figure that the optimum case is case five which has lowest T_{case}.
- The clearance parameter has a big influence in decreasing the T_{case}.

Case number	Fin height (mm)	lid height (mm)	Clearance parameter (mm)
1	21.5	40	3.5
2	22	30	2
3	22.5	44	9.5
4	23.5	33.5	4
5	23.9	30	0.1



Temperature graph of the center cut-line of CPU

Conclusion

- The 3D slice of an immersed server in a dielectric liquid is simulated using COMSOL v4.3a software.
- This study has been conducted in order to establish the optimum fin height and lid height to minimize T_{case} .
- The fluid behaviour in the server is found to be turbulent based on the Ra. The turbulent model that used for this study is K-ω.
- An optimal Latin Hypercube (DOE) created thirty points for Hfin and Hlid. Genetic Algorithm is used to obtain an optimum value of two parameters from thirty simulations.
- The optimum solution at for H_{fin}=23.9mm and H_{lid}=30mm. The temperature dropped 22% compare to highest T_{case} of the thirty simulations that are performed in this study.

Thank you!
Any Questions?