

OPTIMIZATION OF A NONCONVENTIONAL ENGINE EVAPORATOR

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Abstract

The papers deal with the optimization of the evaporator of a nonconventional combustion engine. Lithium bromide liquid (LiBr - an alternative cooling medium) flows in a cooling circuit of a nonconventional energetic unit.

The solved energetic system is defined in the area of trigeneration systems. The mentioned system is a source of electric energy, cold and heat too.

The space geometrical model corresponding to the geometry of the original evaporator is created in the CAD (Computer Aided Design) software CATIA.

Only one half of the evaporator is created because of the decrease in the demand on the computational means. This CAD model is then imported into the preprocessor Gambit. The imported model is repaired and a suitable mesh is then created. The last step is the definition of the types of boundary conditions. The completed computational mesh is then exported from Gambit and imported into the CFD (Computational Fluid Dynamics) software Fluent. Fluent is used for the numerical simulation of the cooling medium flow in an evaporator. The simulation shows the filling of the evaporator cone, the time when the cooling medium starts to pour through the edge of the evaporator cone, the filling of the evaporator ring and finally also the fact that the off-take is able to take away the needed amount of cooling liquid from the evaporator.

Keywords: nonconventional engine, evaporator, numerical simulation, mesh, flow

1. Introduction

A nonconventional combustion engine is one part of a nonconventional energetic system producing electric energy, heat and cold. It is a special type of a combined heat and power unit.

The engine coolant is replaced by the mixture of the lithium bromid liquid with water. The engine used in the system is four stroke compression ignition engine Z8004 with rated power of 77 kW at 2200 min⁻¹.

The aim of the numerical simulation is to acquire information regarding the dimensions and parameters of the evaporator used in the mentioned energetic system. The lithium bromid liquid flow in the evaporator is simulated.

2. Evaporator design and parameters

The CAD software used for the model creation is CATIA V5. The model of the whole evaporator can be seen in the Fig. 1. For the simulation was used only one half of this space because of the symmetry of the geometry what allows to decrease in the requirements on the used hardware and computational time. The inner bigger diameter of the evaporator cone has the value of 293.5 mm and the smaller one the value of 43.5 mm. The height of the evaporator cone is 300 mm. The inner diameter of the bottom outlet pipe is 36 mm and the diameter of the top outlet pipe is 42 mm. The inner diameter of the inlet pipe is 43.5 mm.

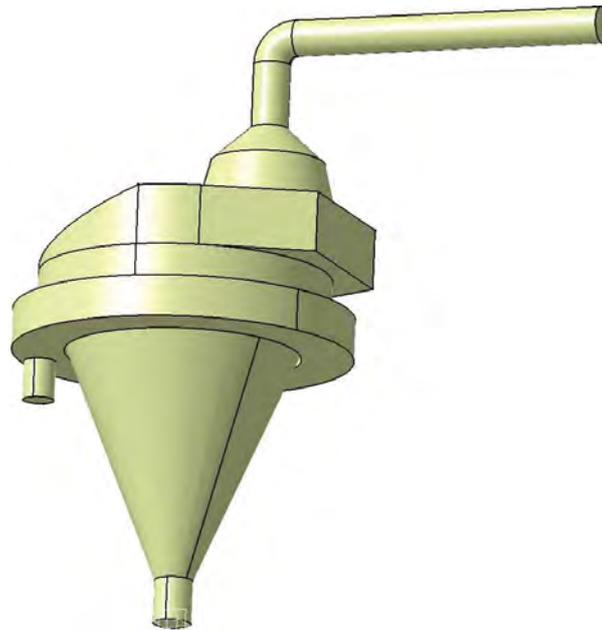


Fig. 1. CAD model of the evaporator

3. Lithium bromid liquid flow simulation

The created model was exported from CATIA as step file and then imported into the GAMBIT, which is used as a preprocessor for the Fluent. In the GAMBIT the types of boundary conditions were set to the specific surfaces. The type of medium was set to fluid. Next step in the GAMBIT was mesh generation. The type of computational elements was tetrahedral cells. The resulting mesh consists of 1844436 cells. The imported mesh into the Fluent with the specific types of boundary conditions (yellow – symmetry, black – wall, blue – velocity inlet, red – pressure outlet) can be seen in Fig. 2.



Grid (Time=0.0000e+00) Jun 24, 2010
FLUENT 6.3 (3d, dp, pbns, vof, rngke, unsteady)

Fig. 2. Computational mesh with the specific types of boundary conditions

Figure 3 shows the detail of the mesh in the area of the bottom outlet. Next step was the definition of the computational model. Values for the boundary conditions were set. The RNG k-ε turbulent model was used for the flow simulation. This model is enough robust and suitable for the solution of turbulent flows and heat transfer. The renormalized procedure consists of a gradual elimination of small turbulences. Equation of motion is transformed so that turbulent viscosity, forces and nonlinear members are modified. Assuming that the turbulences are related to dissipation ε, then, the turbulent viscosity μ depends on a degree of turbulences and the RNG method constructs this viscosity with the help of iterative elimination of narrow bands of wave numbers. The following equation is used for the iterative process:

$$\frac{d\mu_{eff}}{dl} = \frac{A_l \varepsilon l^3}{\mu(l)^2} \quad (1)$$

The RNG model derived by a statistical method, averaged, is formally of the same form as the classical $k - \varepsilon$ model. The equation for the transfer of motion is in the form:

$$\frac{\partial}{\partial t}(\rho \bar{u}_i) + \frac{\partial}{\partial x_j}(\rho \bar{u}_i \bar{u}_j) = \frac{\partial}{\partial x_j} \left[\mu_{eff} \left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i} \right) - \left(\frac{2}{3} \mu_{eff} \frac{\partial \bar{u}_i}{\partial x_i} \right) \right] - \frac{\partial \bar{p}}{\partial x_i} + \rho g_i + F \quad (2)$$

and, subsequently, transport equations are used:

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}(\rho \pi_j k) = \frac{\partial}{\partial x_j} \left(\alpha_k \mu_{eff} \frac{\partial k}{\partial x_j} \right) + \mu_t S^2 - \rho \varepsilon, \quad (3)$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_j}(\rho \mu_j \varepsilon) = \frac{\partial}{\partial x_j} \left(\alpha_\varepsilon \mu_{eff} \frac{\partial \varepsilon}{\partial x_j} \right) + C_{1\varepsilon} \frac{\varepsilon}{k} \mu_t S^2 - C_{2\varepsilon} \rho \frac{\varepsilon^2}{k} - R. \quad (4)$$

Time step was set to 0.001 s. The velocity in the inlet was set to 0.56 m·s⁻¹.

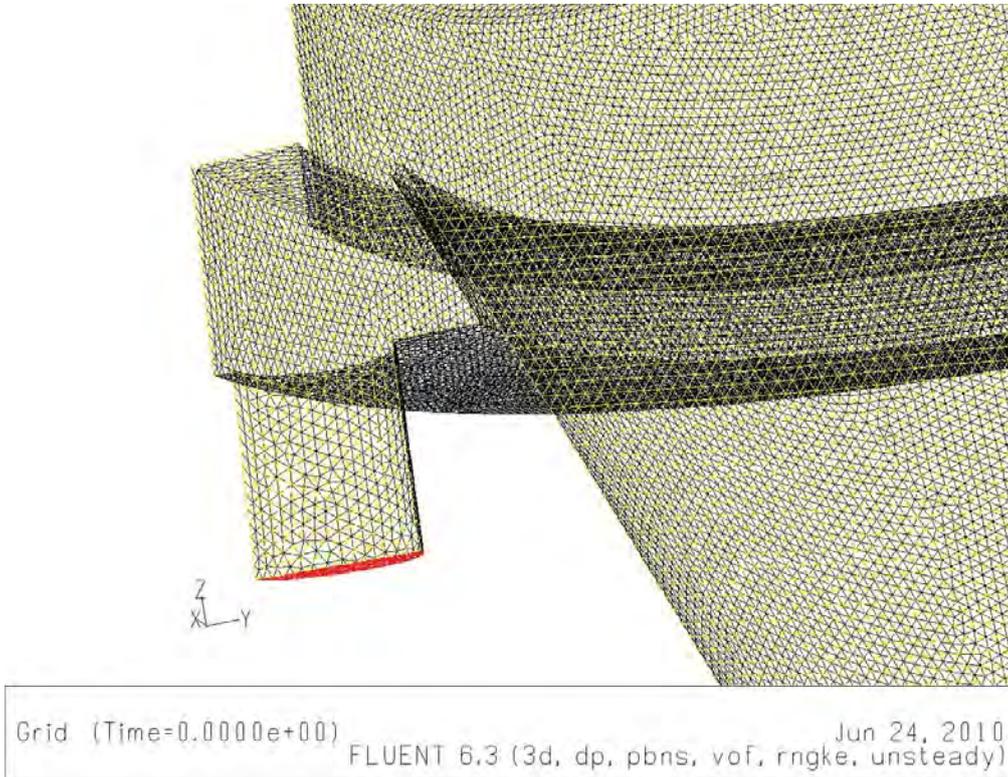


Fig. 3. Detail of the mesh in the area of the bottom outlet

Figure 4 and 5 show the filling of the evaporator cone in the time of 0.1 s and 4 s.

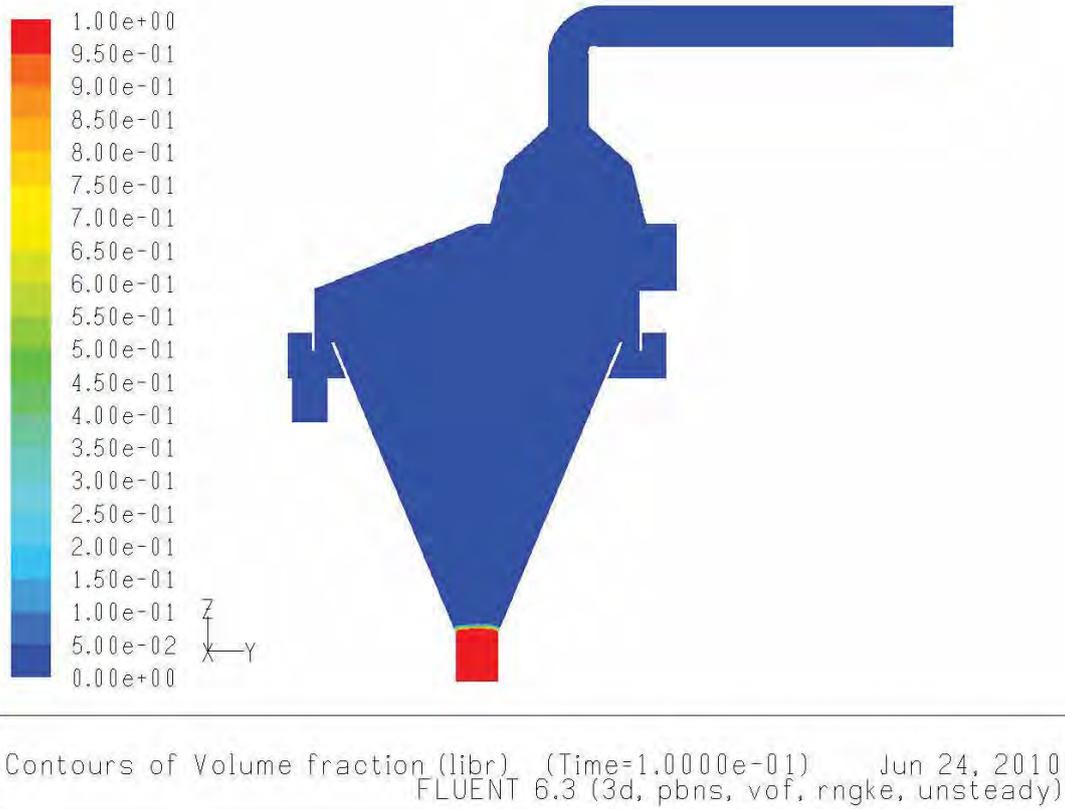


Fig. 4. Coolant level in the time of 0.1 s

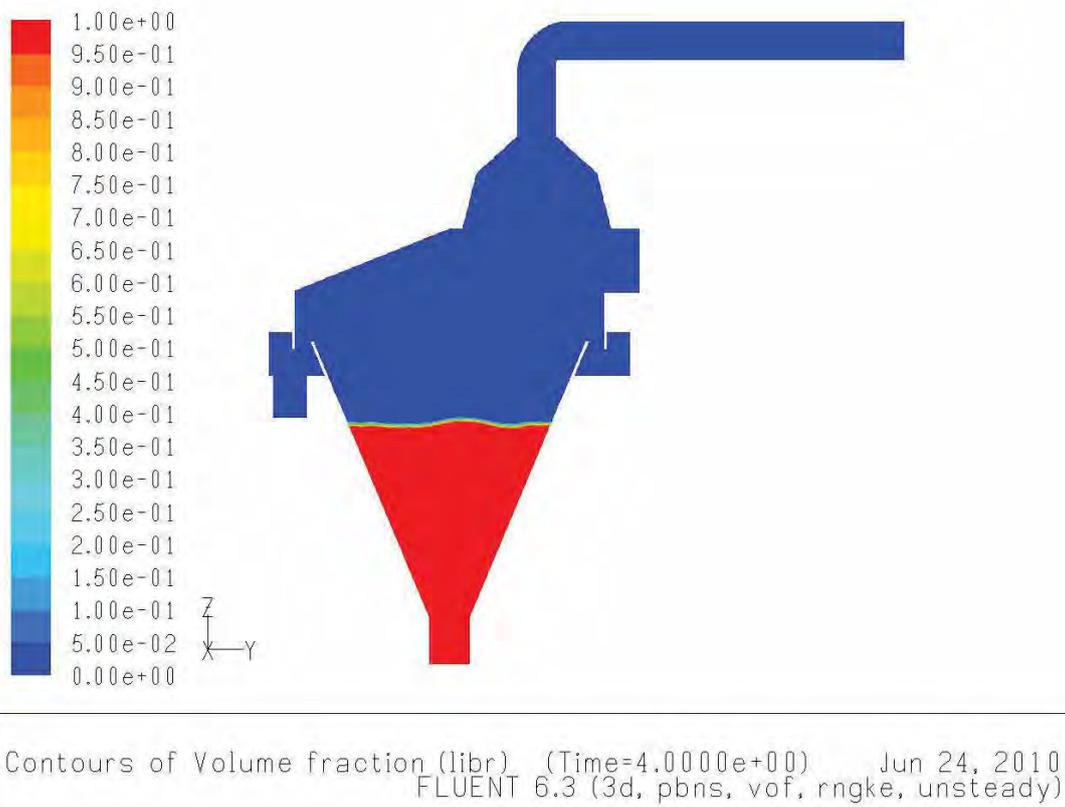


Fig. 5. Coolant level in the time of 4 s

From the Fig. 6 it can be seen that the lithium bromid liquid starts to pour through the edge of the evaporator cone in the time of about 10 s after the starting of the calculation.

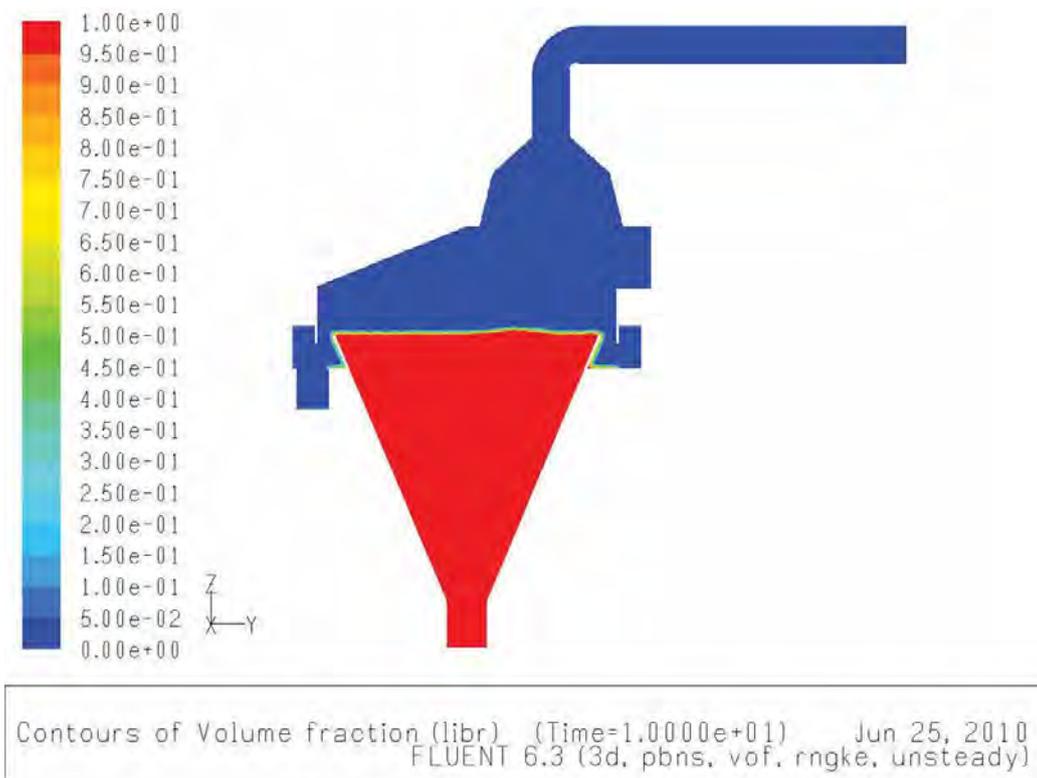


Fig. 6. Coolant pours through the edge of the evaporator cone in the time of 10 s

Figure 7 shows the filling of the evaporator ring after the coolant poured from the cone.

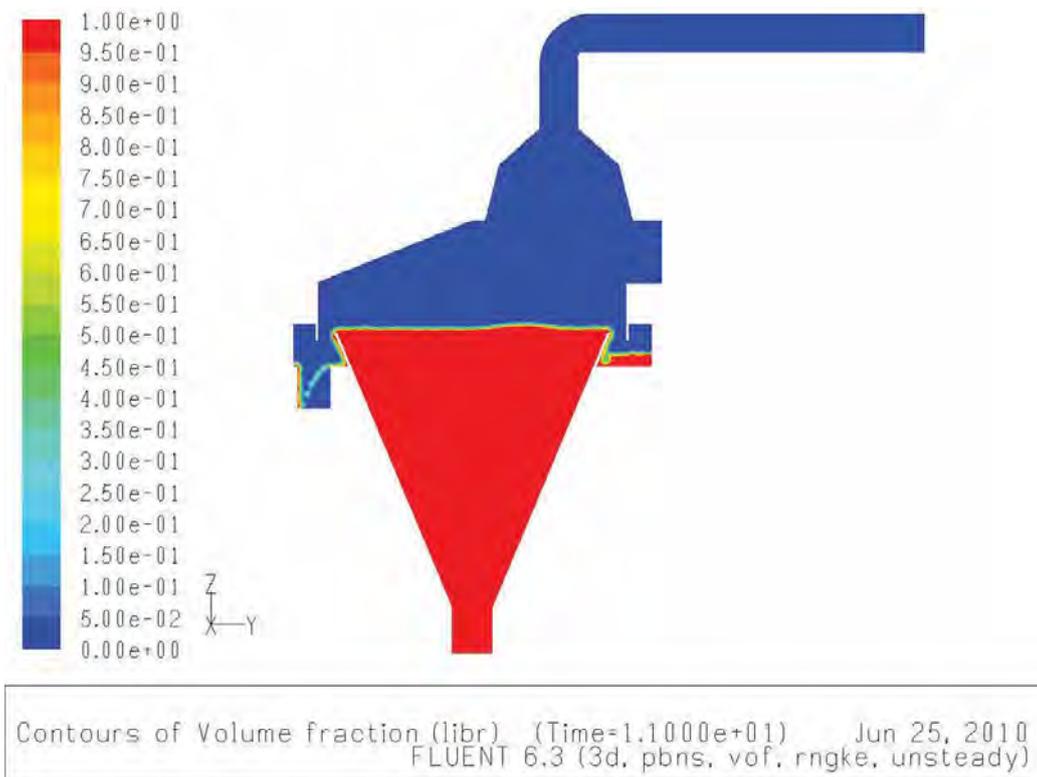


Fig. 7. Filling the evaporator ring in the time of 11 s

In the Fig. 8 and 9 it can be seen the off-take capability to take away all needed amount of coolant from the evaporator.

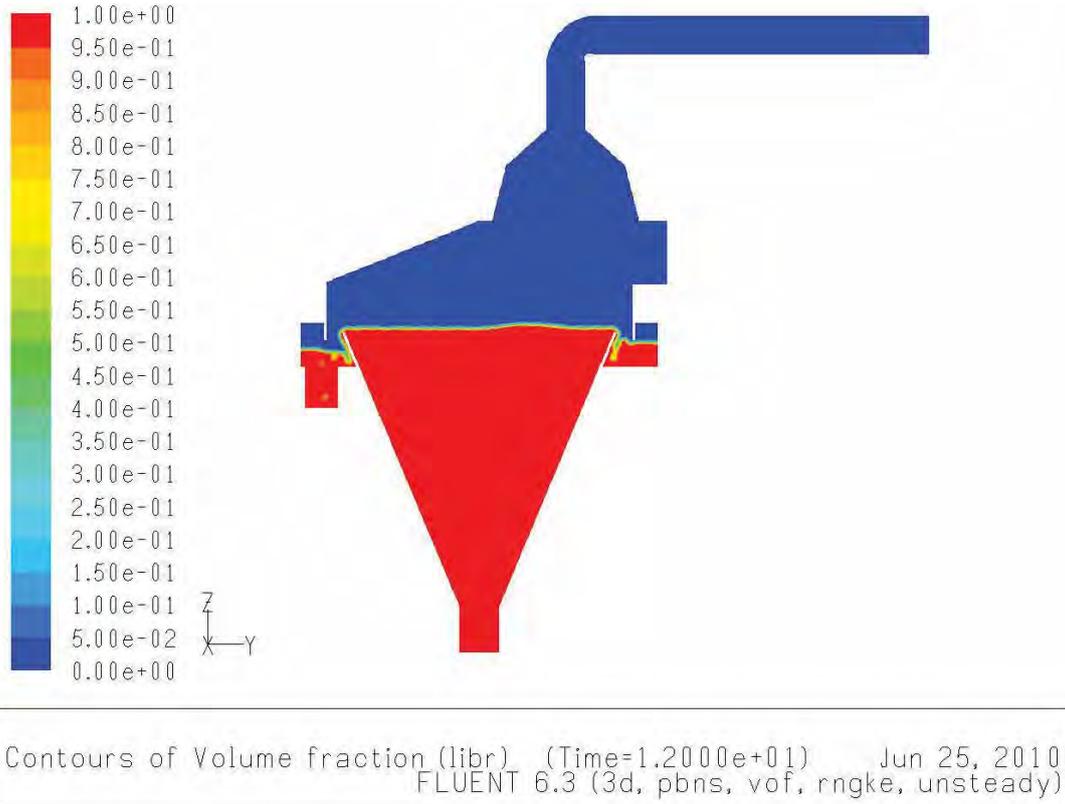


Fig. 8. Flow in the evaporator in the time of 12 s

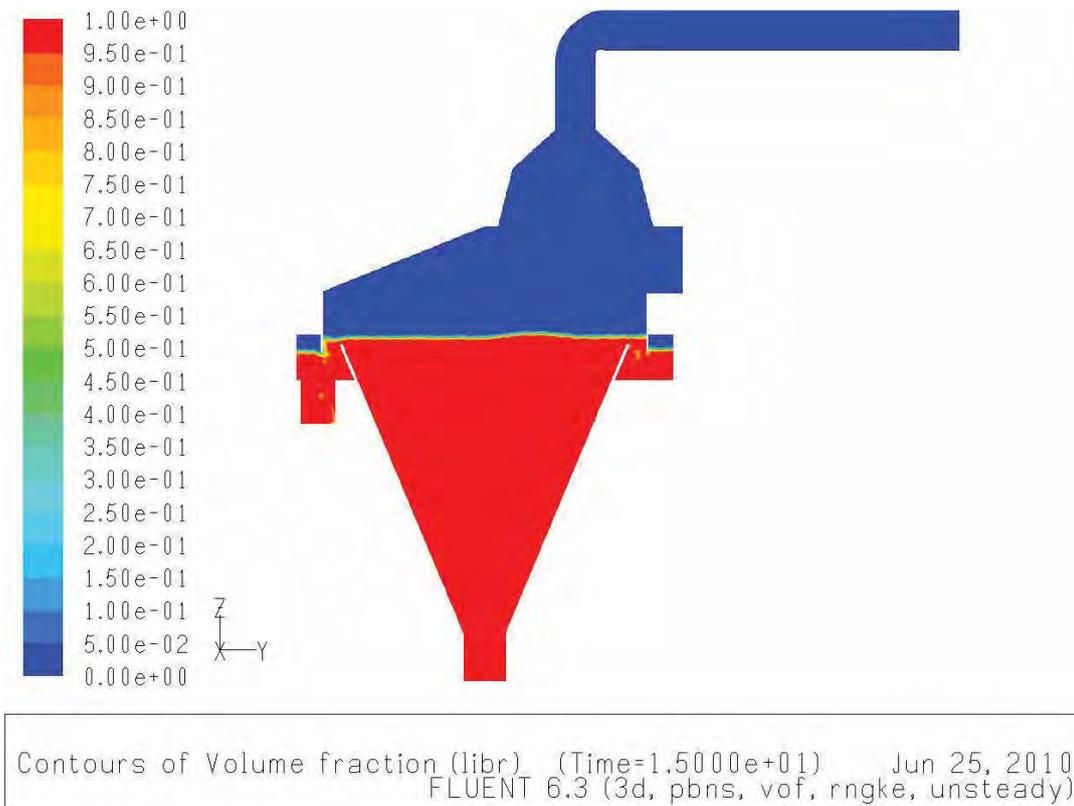


Fig. 9. LiBr volume fraction distribution in the time of 15 s

Figure 10 shows the turbulent intensity distribution in the time of 15 s.

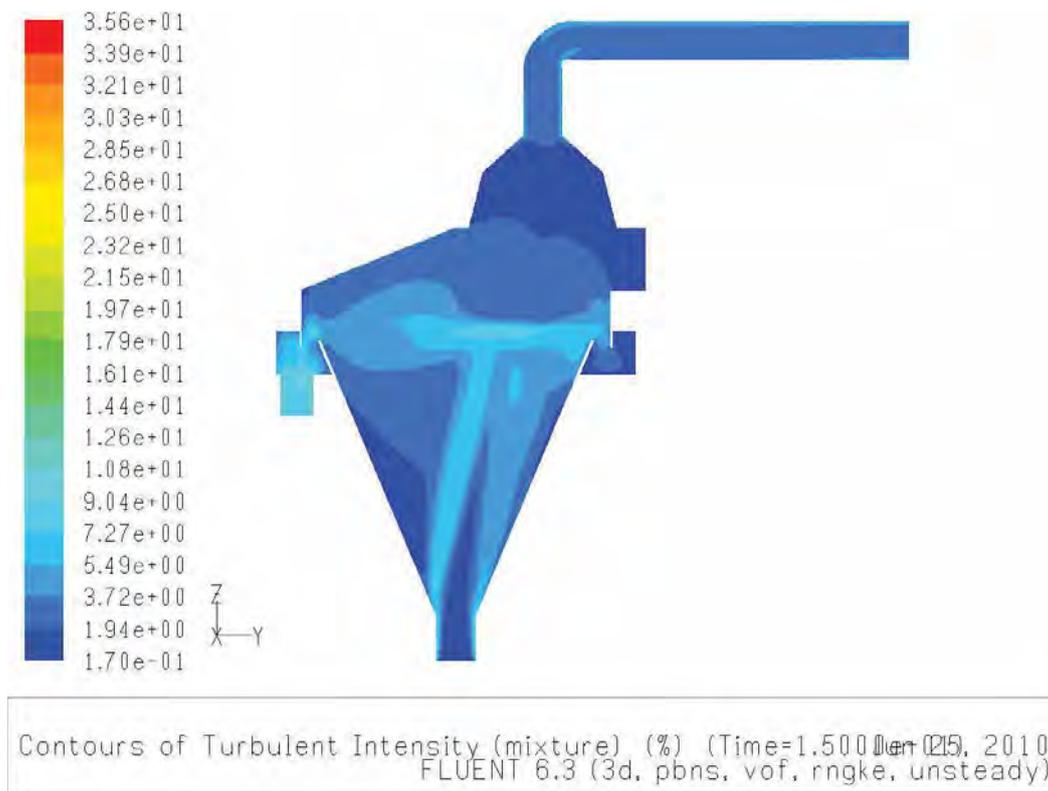


Fig. 10. Turbulent intensity in the time of 15 s

4. Conclusion

The simulation shows that the cooling liquid starts to pour through the edge of the evaporator cone in the time of about 10 s after the starting of the calculation. Other information gained from the simulation is that the off-take should be able to take away all needed amount of coolant from the evaporator.

Acknowledgements

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