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Computational Fluid Dynamics

Worksheet 4 – Conjugate Heat Transfer

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Example problems

a) Forced convection over a heated plate

parameter	*value*
Pr	0.05
Re	500
GY	0

Table 1. *Some relevant chosen flow parameters.*

All boundaries are adiabatic, except for inflow, outflow and coupling.
Inflow velocity is $U_\infty = 0.1$ and inflow temperature $T_\infty = 0.0$.

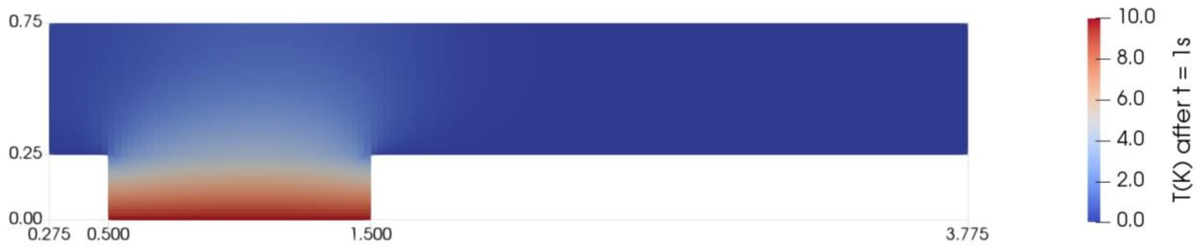

Figure 1. *Temperature distribution after time 1s in combined fluid (upper part) and solid (lower part) domain.*

On *Figure 1.* we can see that the temperature at the bottom of the solid plate is 10 Kand at the inlet 0 K. We also observe that the temperature on the interface is between these values. Due to conduction an area of higher temperature is formed above the plate in the fluid domain. The heat is then transferred with the flow to the left due to convection.

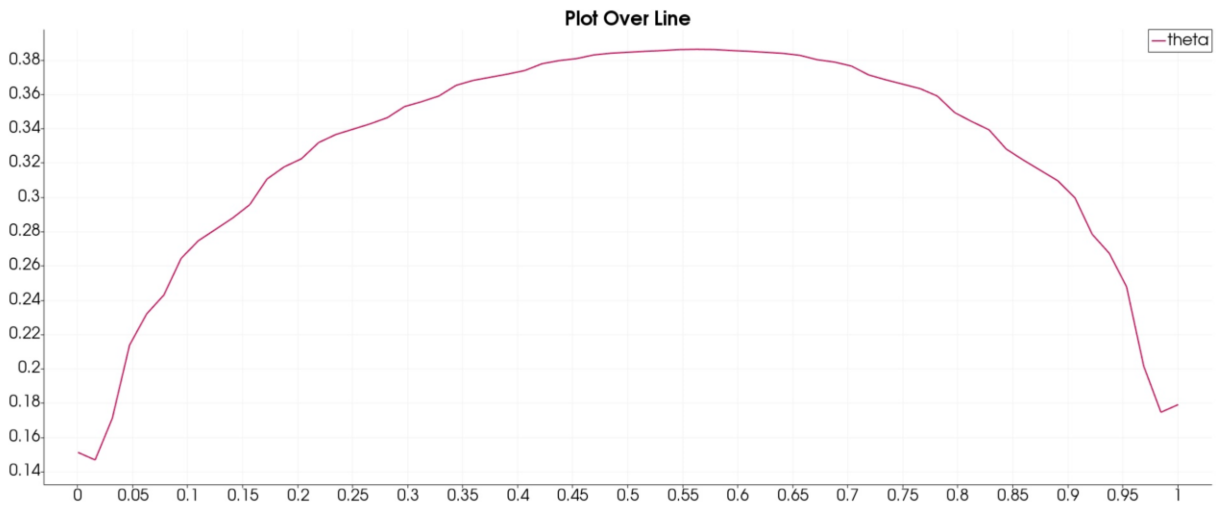

Figure 2. Dimentionless temperature distribution on the interface between fluid and solid domain after time 1s.

On ***Figure 2.*** we observe the distribution of the temperature expressed in dimentionaless units derived from formula $theta = (T - T_{\infty})/(T_{solid} - T_{\infty})$, which in our example reduces to $theta = T/T_{solid}$. This graph of temperature distribution confirms previous observations.

b) *Natural convection in cavity with heat-conducting walls*

parameter	*value*
Pr	0.01
Re	10 000
GY	-9.81

Table 2. *Some relevant chosen flow parameters.*

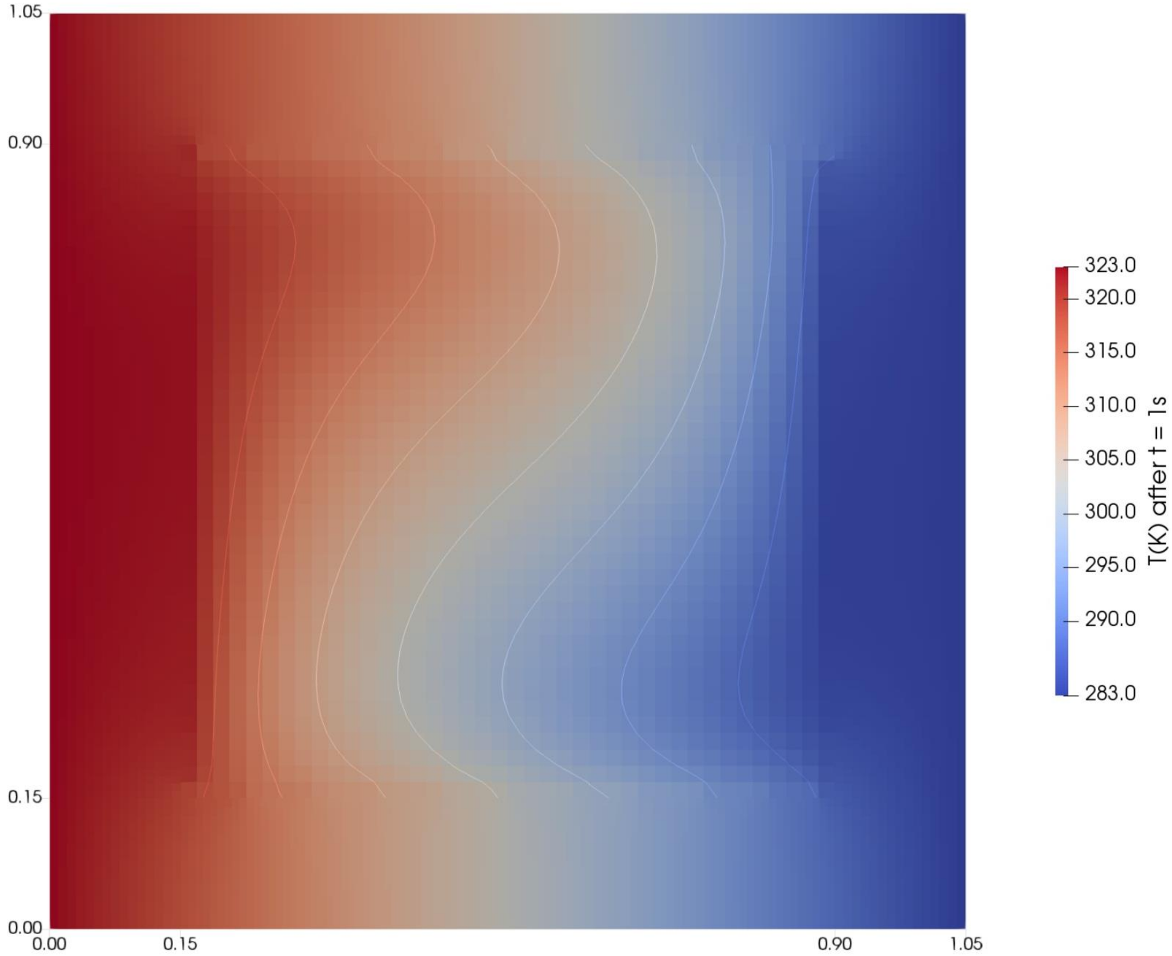

Figure 3. *Temperature distribution in combined fluid (inner) and solid (outer) domains after time 1s. Isotherms additionally pronounced in fluid domain.*

On ***Figure 3.*** we can see that the temperature at the left hot solid wall 323 K and at the right cold wall it is 283 K. We also observe that the heat is transferred uniformly inside the solid domain due to conduction. At the beginning we observe similar behaviour in the fluid domain with almost vertical isotherms near the walls. As the flow develops, however, convection starts to dominate in the flow. The warm fluid accumulates at the top and cold fluid at the bottom and the flow is well structured. This is also confirmed in ***Figure 4.*** where streamlines depict pattern typical for laminar flow.

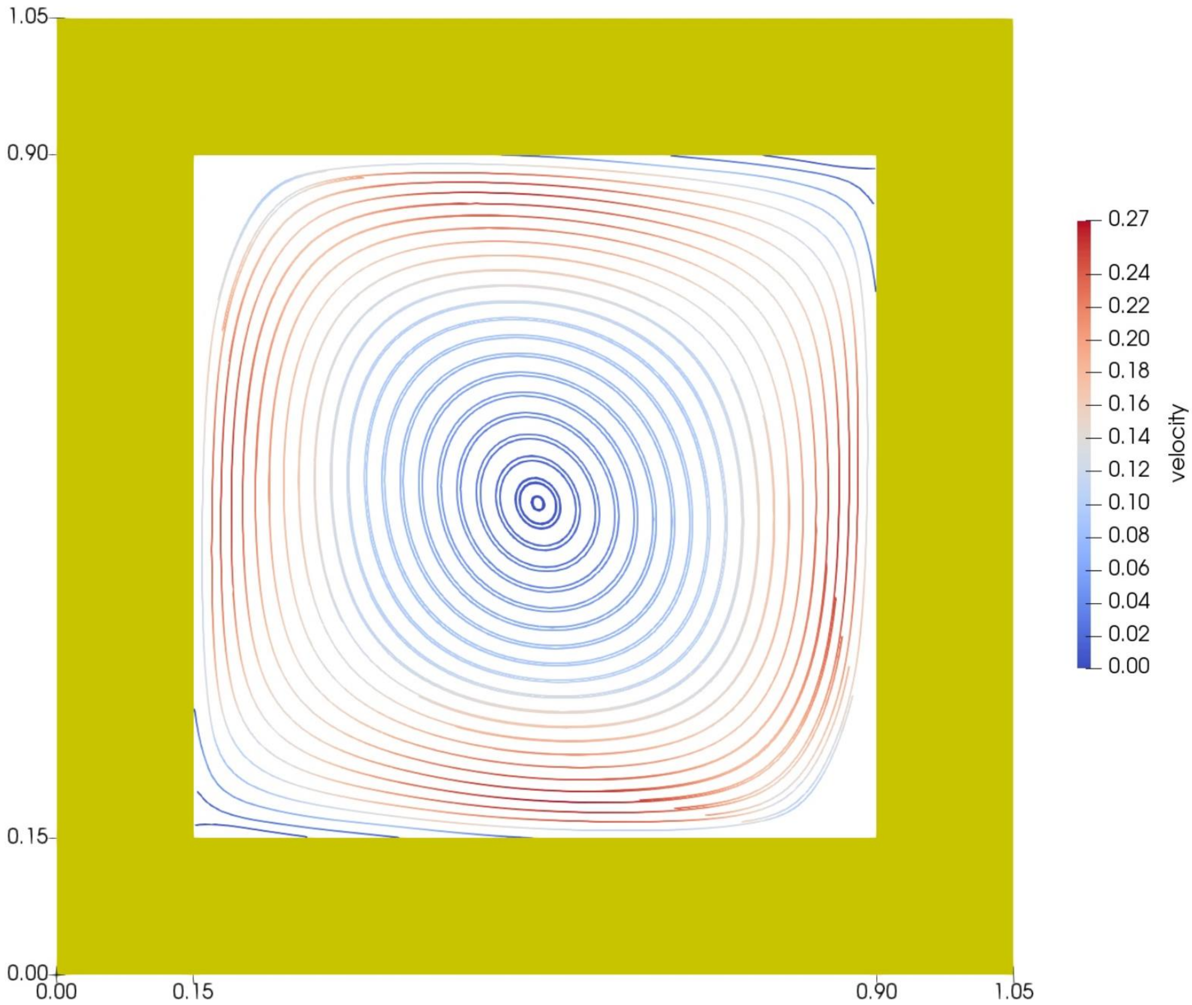

Figure 4. *Stream lines in fluid domain after time 1s. Solid domain marked in yellow / green.*

c) 2D heat exchanger

parameter	*value*	
	fluid 1	*fluid 2*
Pr	0.1	0.1
Re	100	100
GY	-9.81	-9.81

Table 3. *Some relevant chosen flow parameters for fluid 1 and 2.*

All boundaries are adiabatic, except for inflow, outflow and coupling.
Inflow velocity in fluid 1 on the left is $U_\infty = 5$ and inflow temperature $T_\infty = 6$.
Inflow velocity in fluid 2 on the right is $U_\infty = -5$ and inflow temperature $T_\infty = 1$.

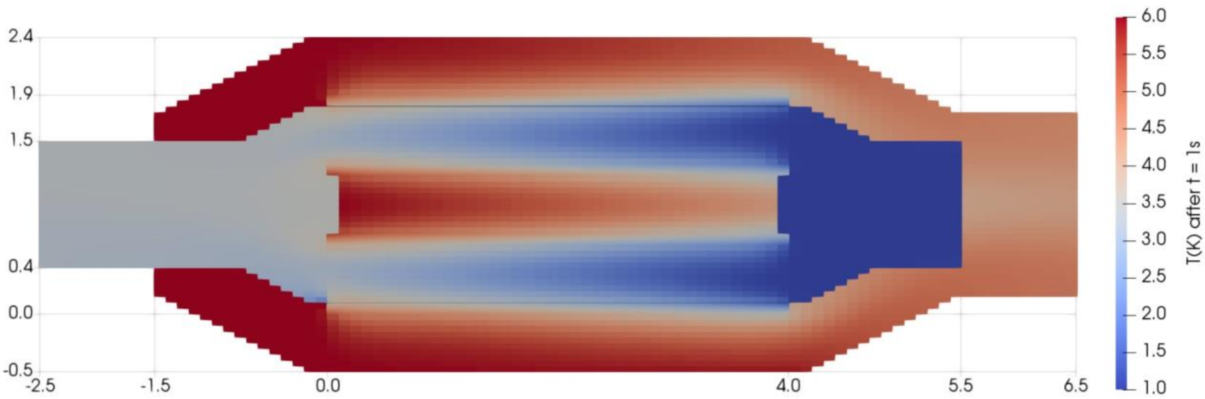

Figure 5. *Temperature distribution in heat exchanger after time 1s.*

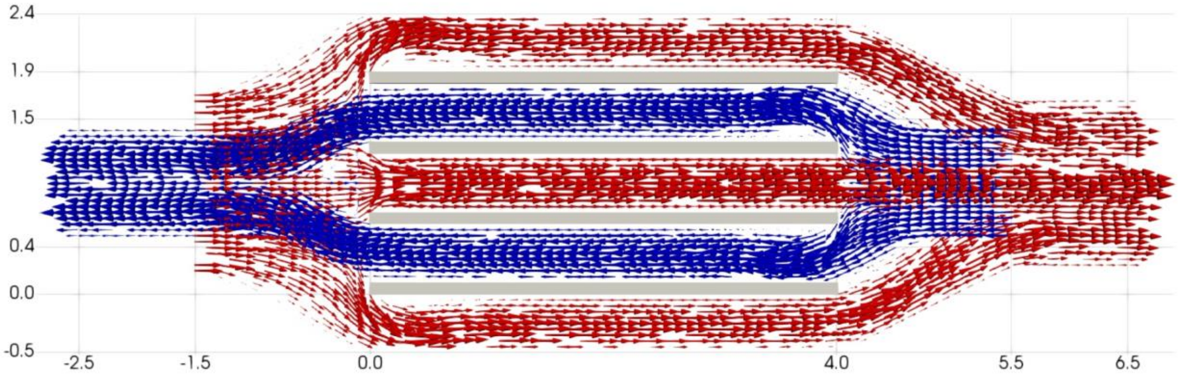

Figure 6. *Velocity vector field in heat exchanger after time 1s – scaled with velocity magnitude – fluid 1 (red) and fluid 2 (blue).*

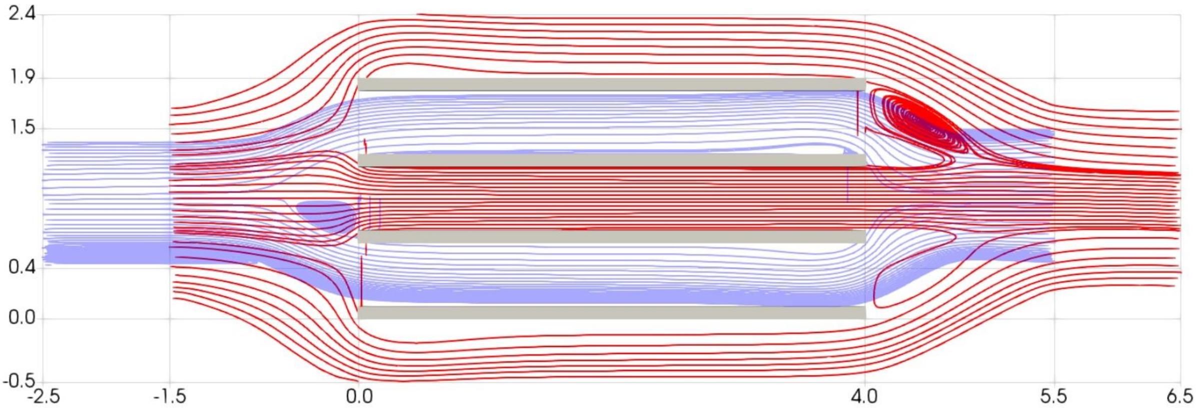

Figure 7. *Streamlines in heat exchanger after time 1s – fluid 1 (red) and fluid 2 (blue).*

On the ***Figure 6.*** And ***Figure 7.*** above we can see the direction of the flow of cold fluid 2 (blue) and warm fluid 1 (red). Now comparing with ***Figure 5.***, where we see the temperature distribution in both domains, we notice that indeed, target cold fluid 2 gets warmed up by fluid 1 due to conduction via solid enclosures. Due to our choice of Prandtl number, heat conduction is dominant in comparison to heat convection in the fluid, and therefore we don't see much improvement in heat transfer, when we „turn on“ the gravity. The graphs are very similar fort he case with or without gravity.