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HEAT TRANSFER ANALYSIS OF BAYONET TUBE HEAT EXCHANGER

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Abstract: *At intensive heat-removal in chemical autoclave treatment the bayonet tube heat exchanger is well adaptable equipment in the working zone. Our goal is to create criterion equitation what causes the easy usage to describe the heat transfer of that specific equipment.This paper shows a numerical simulation of bayonet type heat exchanger. This procedure allows to calculate the temperature, pressure, and velocity distribution and to calculate the heat transfer coefficient in case of different geometry and different boundary conditions.*

Keywords: *Bayonet, CFD, heat transfer coefficient*

INTRODUCTION

At intensive heat-removal in chemical autoclave treatment the bayonet tube heat exchanger is well adaptable equipment in the working zone. Detailed examination of such an equipment had been evaluated by many authors [1,2,3], however the casualties in the professional literature are useless to determine the heat transfer coefficient what is one of the decisive parameters in heat transfer. Our goal is to create criterion equitation what causes the easy usage to describe the heat transfer of that specific equipment.

DESCRIPTION OF THE EXAMINED EQUIPMENT

The structure contains two concentric tubes placed in each other. The cooling fluid (here is water) enters into the inner tube, while discharges the end of the tube into the return band. It flows through between the outer and inner tube in an annular place, eventually the water leave the structure at the outer tube's end. Between the two tubes the gap is relative small accordingly the velocity in the annular space is respective high. The Figure 1 shows evolving of the structure. The heat exchanger approximate an axially symmetric model, therefore this will be a reducible calculation. During the numerical simulation only the marked area will be modelled.

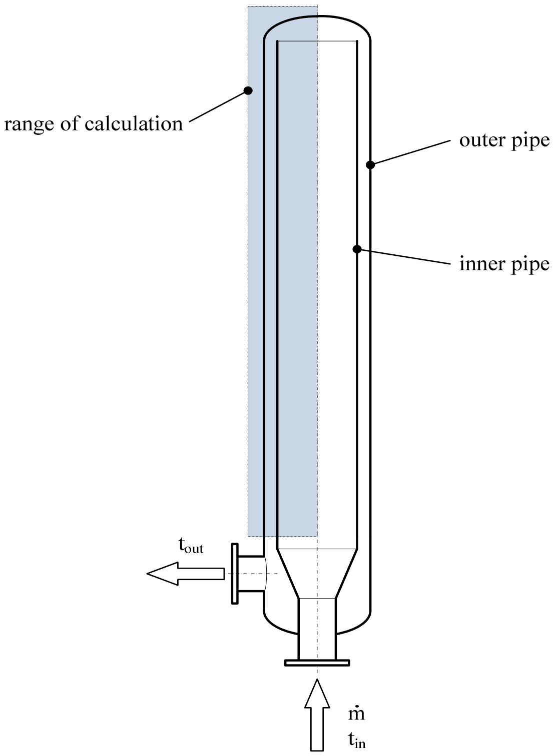

Figure 1. The model of the examined structure

Inside the heat exchanger a dual heat transfer occurs, firstly between the working zone and the outer annular space, secondly between the outer annular space and the inner tube. During the simulation the working zone is considered to a complete mixing space, the temperature of it is constant therefore the heat transfer coefficient of the working zone is also constant.

NUMERICAL SIMULATION

The fluid and thermo dynamics analyze was evolved of the bayonet tube heat exchanger in case of different geometry and different boundary conditions.

A velocity boundary condition was taken into the edge of the inner tube's inlet for four cases. For the outlet the boundary condition was the common as used for the fluid simulations, we take the pressure as the boundary condition (p=atmospherically). As the problem was an axially symmetric, the mesh would be extensive in size, therefore a 5° part of the structure was examined and the boundary condition was periodical. In that case we can draw conclusions for the whole drift space.

A modelled geometry was used for the meshes of the numerical simulation based on the finite element method. The mesh was built up by non-structured, 3D element (Figure 2). With the usage of the three layer structured (prismatic) mesh can be determined the velocity distribution of the boundary layer in the case of solid-liquid phase-boundary. The results are mesh-independent results. In the case of different evolving the necessary nodal points are between 278 000 and 547 000.

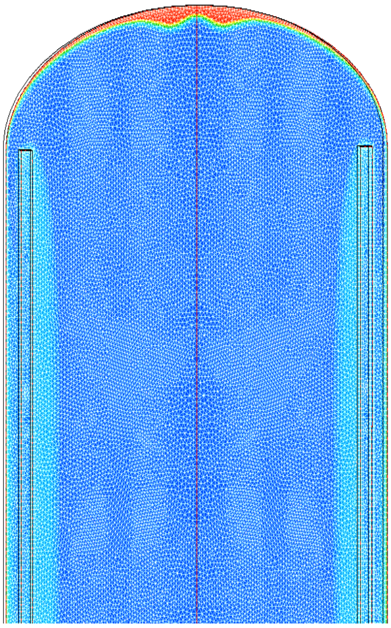

Figure 2. The applied mesh

During the numerical simulation the following conservation equitations become necessary to solve:

Continuity equitation:

$$\frac{\partial u_i}{\partial x_i} = 0 \qquad (1)$$

Momentum conservation equitation (i=1…3):

$$\frac{\partial \rho u_i}{\partial t} + \frac{\partial u_j \rho u_i}{\partial x_j} = -\frac{\partial \sigma_{ij}}{\partial x_i} + \rho g_i \qquad (2)$$

Energy conservation equitation:

$$\frac{\partial \rho c_p T}{\partial t} + \frac{\partial u_j \rho c_p T}{\partial x_j} = -\frac{\partial}{\partial x_i} K \frac{\partial T}{\partial x_j} + \dot{q} \qquad (3)$$

During the application of the $k-\varepsilon$ *model the following equitation become necessary to solve in general form:*

$$\frac{\partial \rho k}{\partial t} + \frac{\partial u_i \rho k}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\frac{\mu_t}{\sigma_k}\frac{\partial k}{\partial x_i}\right) + G_s + G_t - \rho\varepsilon \qquad (4)$$

$$\frac{\partial \rho \varepsilon}{\partial t} + \frac{\partial u_i \rho \varepsilon}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\frac{\mu_t}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_i}\right) + C_1\frac{\varepsilon}{k}(G_s + G_t)(1 + C_3 R_f) - C_2\frac{\rho\varepsilon^3}{k} \qquad (5)$$

where:

$$G_s = \mu_t\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_i}{\partial x_j} \qquad (6)$$

$$R_f = -\frac{G_t}{G_s + G_t} \qquad (7)$$

The value of the empirical constants in the equitation:

$C_1=1.44$, $C_2=1.92$, $C_3=0$,

$\sigma_k=1$, $\sigma_t=0.9$.

To solve the problem the SC/Tetra software was used, this software is basically a finite element method CFD software.

RESULTS, CONCLUSIONS

During the simulations the outlet temperature, the overall pressure loss, the heat transfer coefficient in the outer annular space was calculated in case of different geometry (diameter, clearance) and different boundary conditions.

The Figure 3 and Figure 4 allowed determining if the inlet velocity is high it results high heat transfer coefficient. Increase of the dimension of the clearance results decreasing of the heat transfer. The increasing velocity in the clearance results significant high heat transfer coefficient, but it results also the overall pressure loss. This property can be determined both geometry.

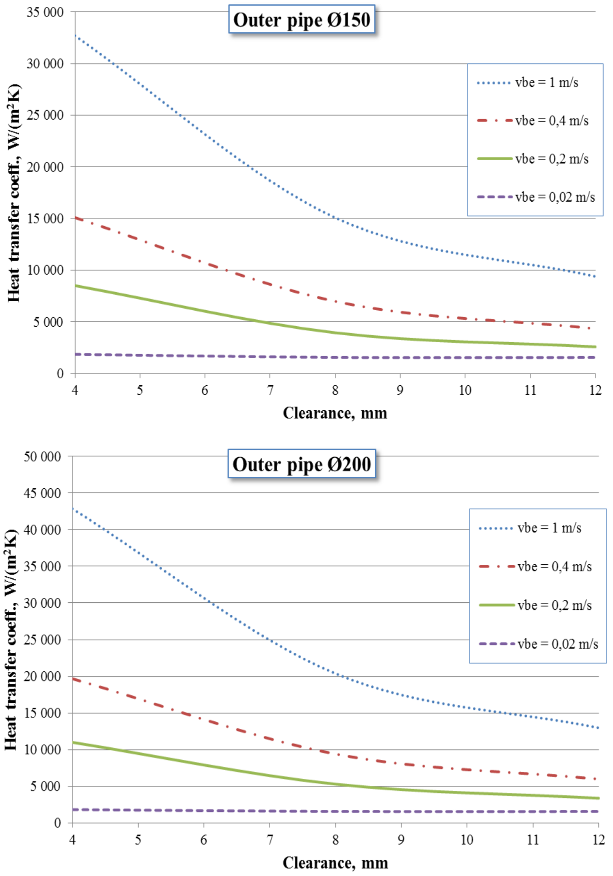

Figure 3. The heat transfer coefficient in the outer annular space

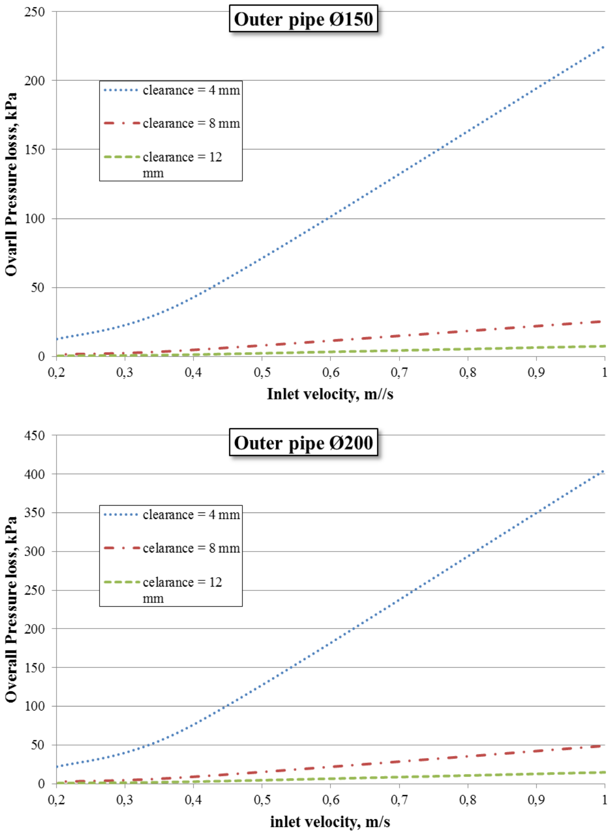

Figure 4. The overall pressure loss

Our goal was to define equitation what is applicable to calculate the heat transfer coefficient in the annular space. Utilizing the results of the simulation we would like to determine the following criterial equitation's constants with an error minimization method [5]:

$$Nu = A \cdot \left(\frac{D_b}{d_e}\right)^B \cdot \mathrm{Re}^C \cdot \mathrm{Pr}^D \qquad (8)$$

The specific dimension is the outer tube's inner diameter in the criterial equitation in all case. The equivalent pipe diameter can calculate with the $d_e = 4F/K$ *(F: flow section/area, K: wetted perimeter). With that procedure we got the following results:*

A=0.0089 B=1.0624 C=0.824 D=0.326

The Figure 5 contains the difference between the value of the heat transfer coefficient, and additionally the results what we got with the created equitation. The errors in all case are below 6%.

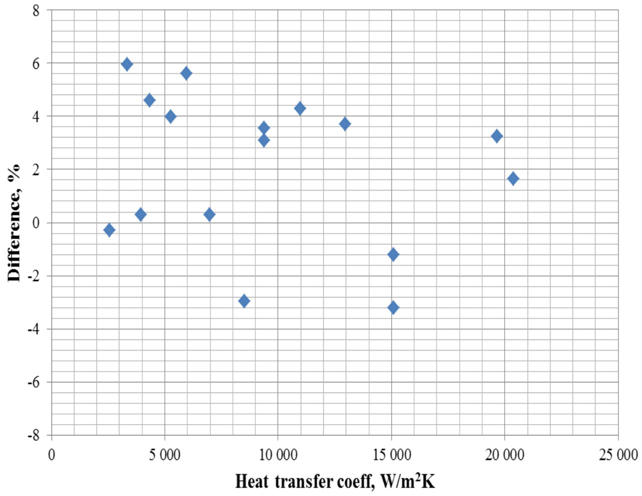

Figure 5. The difference between the heat transfer coefficient and the value of the criterial equitation

Summary

In that article the simulation of the Bayonet tube heat exchanger was presented in case of different parameters The results of the simulation runs a criterial equitation was created, what describes the heat transfer in the annular space in an adequate way in case of different geometry.

Acknowledgement

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