Performance evaluation of mixing behavior of two different TDS liquids in pressure exchanger using CFD analysis

Mirali H. Vyas[1] **Prof. Hitesh R. Raiyani**[2] **Sci. Sanjay D. Patil**[3]

[1]ME Student, Department of Mechanical Engineering L.J.I.E.T, Ahmedabad, India
[2]Assistant Professor Department of Mechanical Engineering, L.J.I.E.T., Ahmedabad, India
[3]Scientist, Central Salt & Marine Chemical Research Institute, India

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Abstract - *Desalination is the mainly separation process in which we get the output as brine and fresh sea water. For recycling the brine water different ERDs use to getting fresh water. Pressure Exchanger is a kind of fluid energy recovery device which is based on the positive displacement principle. The main component of the PX is Rotor having several ducts containing fluid. There is no any separator in the duct of the rotor. So that the mixing occurs between the high and low salinity fluids during the mass and energy transportation. CFD analysis is the most suitable method for the mixing performance, for that ANSYS FLUENT software is used for the analysis.*

Key Words: **Desalination, Pressure exchanger, Mixing Behaviour, CFD analysis.**

1. PRESSURE EXCHANGER

The PX technology is different from conventional ERD design, where the brine is passed through the PX unit and its pressure energy is transferred directly to a portion of the incoming seawater feed. This seawater stream, nearly equal in volume to the reject stream, then passes through a small booster pump, which makes up for the hydraulic losses through the SWRO system. This seawater stream then joins the seawater stream from the main high-pressure pumps (HPP) without passing through the HPP. Pressure exchanger consists mainly three parts:

1. Rotor
2. End covers
3. Sleeve

1.1 Challenges of Pressure exchanger

Pressure exchanger is an energy recovery device which is worked on the positive displacement principle. The key component of RPE includes a rotor with several ducts, two end covers and one sleeve. There is no any tangible separator in the duct of the rotor. Due to the high pressurized fluid, the rotor rotates without any electricity.

Pressure exchanger is the recent technology used in the SWRO system as energy recovery device. One of the most important advantages of this devise is that only one rotating member and also no power required for that. It is a fluid-driven member.

There is one challenge for this device is mixing of two fluids and that decrease the efficiency of the plant. In pressure exchanger, if sea water and brine are not separated from each other, salinity and osmotic pressure is increased that affects not only pressure exchanger but whole SWRO system.

2. 3D SIMULATION ON DYNAMIC MIXING IN DUCT

2.1 Geometry model:

Fig. 1 shows a solid model of rotor and end cover. This model or geometry generated using the Creo 2.0 design software. The length of rotor is 101.7mm and diameter is 116mm with 12 ducts.

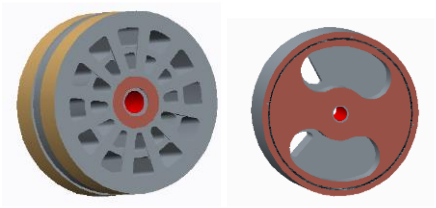

Fig. 1 Rotor and end cover

The 3D simulation model on the basis of above structure is displayed in Fig.2.

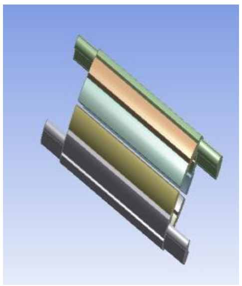

Fig.2 Computation model

2.2 Governing equations and boundary conditions:

The numerical simulation is carried out under cylindrical coordination. And the governing equations are,

Continuity equation,

$$\frac{\partial \rho}{\partial t}+\nabla\cdot\left(\partial \vec{\rho}\right)=0 \qquad (1)$$

Momentum equation,

$$\frac{\partial}{\partial t}\left(\rho\vec{\upsilon}\right)+\nabla\cdot\left(\rho\vec{\upsilon}\vec{\upsilon}\right)=-\nabla P+\nabla\cdot\left(\bar{\bar{\tau}}\right)+\rho\vec{g} \qquad (2)$$

Where P is the static pressure, is the stress tensor, and are the gravitational body force.

Specifies equation,

$$\frac{\partial}{\partial t}\left(\rho Y_i\right)+\nabla\cdot\left(\rho\vec{\upsilon}Y_i\right)=-\nabla\cdot\vec{J}_i+R_i \qquad (3)$$

Turbulence flow,

$$\vec{J}_i=-\left(\rho D_{i,m}+\frac{\mu_t}{Sc_t}\right)\nabla Y_i-D_{T,i}\frac{\nabla T}{T} \qquad (4)$$

Turbulence model: Standard k-ε model

Turbulent kinetic energy,

$$\frac{\partial}{\partial t}\left(pk\right)+\frac{\partial}{\partial x_i}\left(pku_i\right)=\frac{\partial}{\partial x_i}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_i}\right]+G_k+\rho\varepsilon \qquad (5)$$

Turbulent energy dissipation,

$$\frac{\partial}{\partial t}\left(\rho\varepsilon\right)+\frac{\partial}{\partial x_i}\left(\rho\varepsilon u_i\right)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right]+ C_{1\varepsilon}\frac{\varepsilon}{k}\left(G_k+C_{3\varepsilon}G_b\right)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \qquad (6)$$

Rotor speed is given by cell zone condition. The mass flow inlet boundary condition is used on high pressure brine inlet and low pressure water inlet and the pressure outlets condition is used on low pressure brine outlet and high pressure water outlet.

2.3 Meshing of Computational model:

The meshing of the computation model is displayed in Fig. 3.

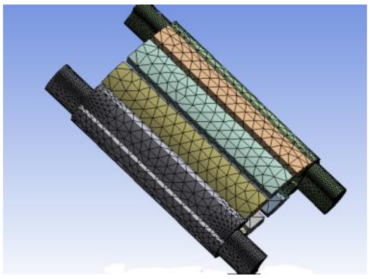

Fig.3 Meshing of model

In the above figure for the meshing of the components, the nodes of the system is define as 11418 and the elements of the system is 49035 and the type of the mashing is tetrahedron. The element quality of the mashing is min: 0.22 and max: 0.99

2.4 Simulation scheme:

The governing equations were conducted using the ANSYS Fluent 14.5 for CFD. The pressure based solver was chosen to solve the equations and gravitational acceleration was considered in the simulation.

The PISO pressure-velocity coupling algorithm, the standard pressure was chosen. In the discretization scheme, for Turbulent kinetic energy and dissipation energy First-order upwind was selected while Second-order scheme was chosen for moment equation and species transport equation.

The contact surfaces between the rotor and end covers were used as an interface. The sliding mesh (SM) technique was used for simulation of the rotor motion.

3. RESULTS AND DISCUSSION

3.1 Mixing formation in the duct:

Fig. 4 shows the species concentration on the duct at the different time point. The red area represents the brine area whose concentration is max. The blue area represents the water area whose concentration is min. and the transition between the two colors is the mixing zone.

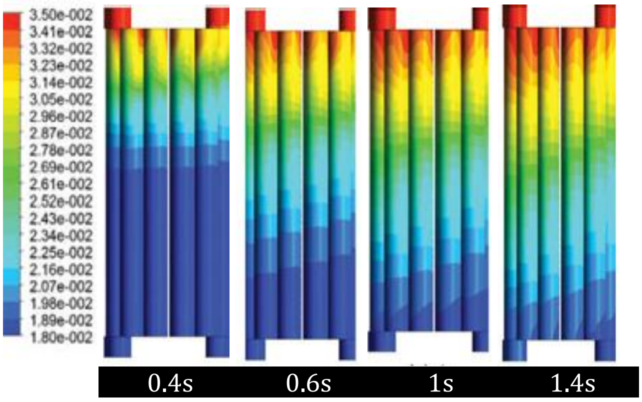

Fig.4 Mixing formation

As the times goes, the length of the mixing section is increasing, and mixing section moving to the middle of the duct. After the species concentration on the outlet face is constant, which means the steady fluid plug generated.

3.2 Liquid piston in the duct:

Fig 5 shows that one imaginary liquid piston is generated as mixing zone. Liquid piston is reciprocally moves in the duct of rotor .the rotation starts from the seal zone and then the high pressure brine flows into the duct.

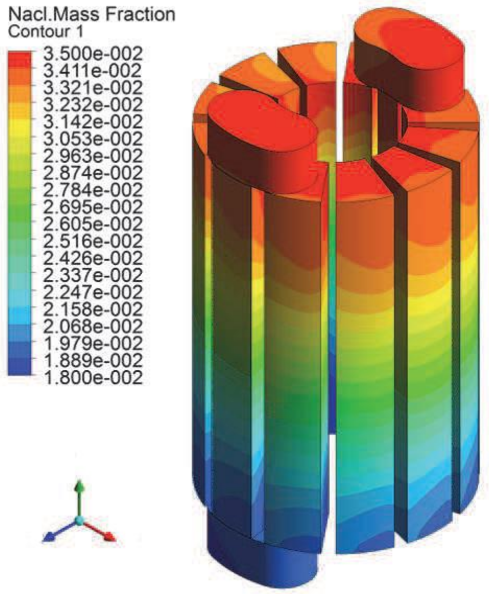

Fig.5 Concentration distribution in the duct

At the same time the liquid piston is pressurized to move down to the end cover. The less concentrated water is almost pushed out of the duct. Then after another seal area , the water enters the duct while the high concentrated water is pushed out of the duct .It is clearly seen that movement of the liquid piston separates the fresh water and brine to prevent from over mixing with each other.

4. CONCLUSION

The effective control of the mixing is very important in the pressure exchanger system.As per result of CFD, mixing zone works as a one imaginery liquid piston which is reciprocally moves in the duct of the rotor.the movement of the mixing zone separates the fresh water and brine.

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