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MODELING AND PERFORMANCE EVALUATION OF MIXING BEHAVIOR OF TWO DIFFERENT TDS LIQUIDS IN PRESSURE EXCHANGER USING CFD ANALYSIS

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ABSTRACT: *A rotary pressure exchanger is a kind of fluid energy recovery equipment which is based 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, so that the mixing occurs between the high and low salinity fluids and during the mass and energy transportation. Mixing between the high and low salinity fluid has become an important criterion of the performance of pressure exchanger because it affects the whole system. In this project we propose to model PX-45s having rotor length 101.7mm and to analyze the mixing occurs between the two different fluids.*

***Key Words*:** Reverse engineering, Pressure exchanger, CFD analysis, mixing behavior

I. INTRODUCTION

Water is most critical substance of the earth. Water is the basic name of the most valuable compound that is made of 2 particles of h2 and one particle of o2.This brilliant compound exists in its fluid state/frame at an ordinary temperature, furthermore, by and large unadulterated water happens as a boring, unscented and bland fluid. Water truth be told is one of nature's most profitable and superb blessings to humanity which is required for the survival of all the living things on the earth. Truth be told, Earth is an exceptional planet in our sun-powered framework because of the presence of this most valuable compound which help in supporting life on Earth. Desalination is the process to improve the water quality with minimum cost. Desalination is defined as the process of removing dissolved salts and other chemicals from seawater, brackish groundwater or surface water. In the desalination process we gave energy and feed water as input source and we get the fresh water and reject brine as output.

II. ENERGY RECOVERY DEVICE

Pressure exchanger is one of the most useful device in the desalination plant. 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

III. MODELLING OF PRESSURE EXCHANGER

There are two types of engineering, forward engineering and reverse engineering. Forward engineering is the process of moving from high-level concept or speculation and coherent designs to the physical implementation of a system. In many situations, there may be physical part without any technical details such as drawing or without any engineering data. The process of reverse engineering is known as the process of acquiring a geometry CAD model from digitizing existing products or parts. As parts or product becomes more erratic or free form in shape, designing in CAD becomes more challenging. So RE gives an answer to this issue in light of the fact that the physical model is the wellspring of data for the CAD demonstrates. In RE process first collect the data from the physical model and then reconstruct CAD model using the design software like Creo, Solidworks etc. Here we are used CREO modeling software to generate the 3D model of pressure exchanger.

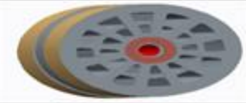
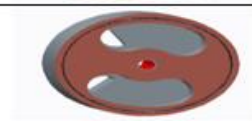
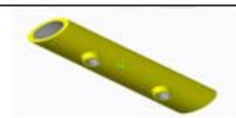
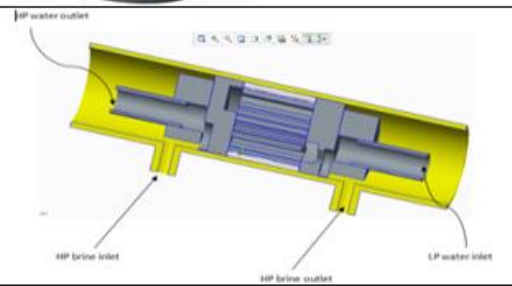
Sr no	Name of part	3D model
1	Rotor	
2	End cover	
3	Outer vessel	
4	Sleeve	
5	Sectional view of assembly	

Table 1. Component of PX-45s

IV. 3D SIMULATION ON DYNAMIC MIXING IN DUCT

4.1 Geometry model:
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.

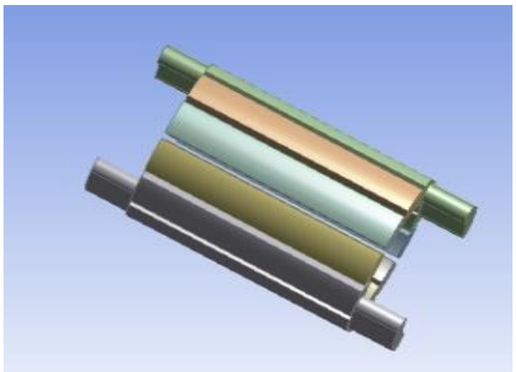


Figure 1. Computation model

4.2 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,

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

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

Specifies equation,

$$\frac{\partial}{\partial t}(\rho Y_i) + \nabla \cdot (\rho \vec{\upsilon} Y_i) = -\nabla \cdot \vec{J_i} + R_i \quad (3)$$

Turbulence flow,

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

Turbulence model: Standard k-ε model

Turbulent kinetic energy,

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

Turbulent energy dissipation,

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

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.

4.3 Meshing of Computational model:

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

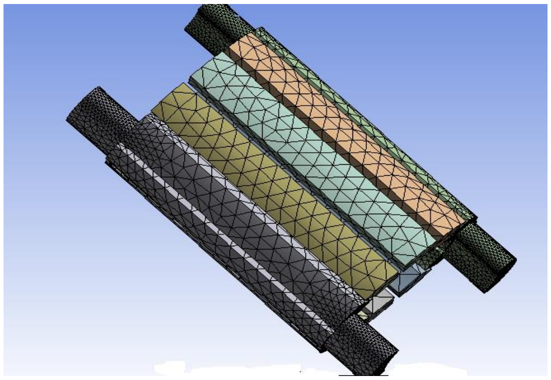


Figure.2 Meshing of model

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

4.4 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.

V. RESULTS AND DISCUSSION

5.1Mixing formation in the duct:

Fig. 3 shows the species concentration on the duct at the diverse time point. The red territory represents to the saline solution zone whose concentration is max. The blue territory represents the water area whose concentration is min. and transition between the two colors is the mixing zone.

As the circumstances go, the length of the mixing section is expanding, and mixing section moving to the center of the duct. After the species concentration on the outlet face is consistent, which implies the steady fluid plug generated.

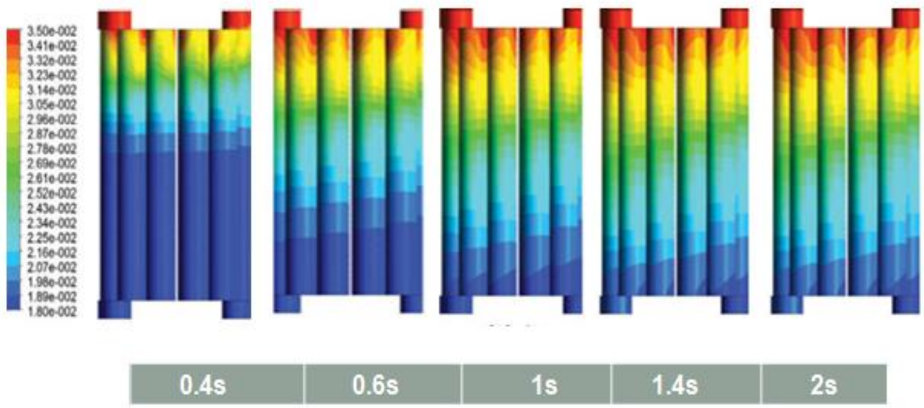


Figure 3. Mixing formation

5.2 Liquid piston in the duct:

At the same time the liquid piston is pressurized to move down to the end cover. The less concentrated water is nearly pushed out of the channel. At that point after another seal area , the water enters the duct while the highly concentrated water is pushed out of the channel .It is obviously observed that development of the liquid piston separates the fresh water and brine to prevent from over mixing with each other. It's clearly visualizing from fig 5.5 that liquid bearing is relatively consistent after some time and it's never influences the fresh sea water because if it's not constant and expanding time to time, so it's dangerous to the smooth operation of the PX.

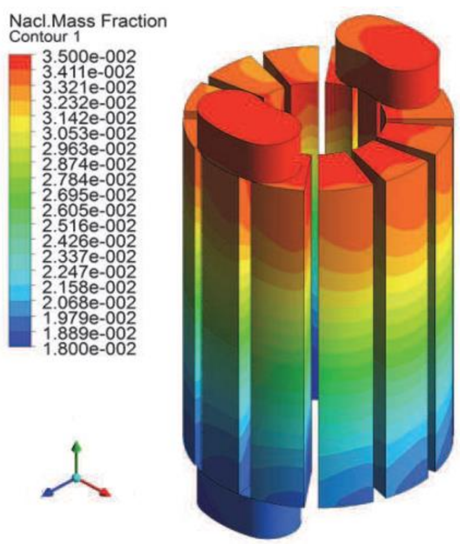


Figure 4. Concentration distribution in the duct

VI. CONCLUSION

In the desalination system, PX is the most useful device for the energy recovery. Pressure exchanger has only one moving part. The Pressure exchanger captures water energy from high pressure reject stream of sea water RO processes and transfers this energy to low pressure feed water over with 98% efficiency. It also requires as much low pressure pump as conventionally used. It eliminates the high pressure pump in the system and also reduces the power consumption.

CFD is the most effective tool to describe the mixing zone which is created in the duct of the rotor. So that CFD is done for this device to understand the working of the mixing zone. From the result of the object I conclude that the mixing rate is not affected the fresh sea side water in the pressure exchanger. So that using the PX-45s series pressure exchanger, we get the effective output without increasing the osmotic pressure and the salinity. Mixing rate is constant as time increasing after 2s and is 2% which is acceptable for the device. This mixing zone is working as a liquid piston which separates both fluid brine and sea water.

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