Work was done on the Tesla valve in this study with a coiled and three-dimensional shape, where a different number of these channels and a direct and reverse flow turbine were used to compare the changes that obtain the amount of pressure and temperatures. With the conception of the technology of transferring heat energy in various heat exchangers, it became necessary to develop our technologies that increase the transmission of this energy, and we must refer to the inventions that contributed to the development of the heat transfer system and the three energy laws. They contributed to the development of some mechanical systems, where the Tesla valve is considered one of the valves that have two directions of flow, the first is direct, in which the pressure value is low, and the other is reverse, which occurs when movement is disturbed due to the direction of the channel in which it can be used. This concept can be used to improve heat transfer.

Where the results establish that an increase in the number of channels positively affects the pressure and thus gives more outlets for the passage of water, a study has shown. In the case of four channels an exit temperature of 304.14 K was obtained, which is the highest temperature reached in cases where the direction of flow is direct. The pressure value was in the case in which the channel is a quadrilateral, and the pressure value reached 209 pa. This data are useful and important because the direct exit score has reached 305.74 K for the Tesla valves, which are designed to give enough time for the heat to transfer to the water. The main principle of the Tesla valve is the reverse direction, which works to obstruct the movement of the fluid, and thus increases the pressure and reduces the velocity of the flow.

Keyword: tesla valve, COMSOL multiphysics, natural circulation loop, heat and mass transfer

1. Introduction

It became necessary to develop technologies that increase the transmission of this energy after the invention of the technology for transferring heat energy in various heat exchangers, and we must make use of the discoveries to develop the three energy laws and the heat transfer system. The Tesla valve is one of the valves that has two directions of flow: the first is direct, where the pressure value is low, and the other is reverse, which happens when movement is disturbed due to the direction of the channel in which it can be used. They contributed to the development of some mechanical systems. Heat transmission can be made better using this idea. Tesla structure is widely used due to its simple structure and special flow mechanism [1]. Therefore, research on the development of the Tesla valve in a coiled and three-dimensional form is relevant.

2. Literature review and problem statement

The paper [1] used CFD and response surface method to analyze and verify the flow field of the configuration of
The aim of the study is to improve Tesla valve. This will make it possible to increase the efficiency of the valve.

To achieve this aim, the following objectives are accomplished:

- to study the effect of the number of channels on the heat transfer;
- to study the effect of the reverse direction on heat transfer.

4. Materials and methods

The Tesla valve simulation study exists in general and in most of the research, but all the shapes used in these studies were flat and two-dimensional as this research paper works on a developed coiled Tesla valve. Where it is possible to use more than one channel in the same channel, as previous research papers are devoid of this concept.

The models were designed using Solidworks (France), a special engineering program for designing complex geometric shapes. Three types of Tesla valves with different channels were taken into account, as shown in Fig. 1.

After the model is designed, a reliability of the mesh assessment must be made, where the number of mesh is increased until reaching a stable state in the extracted results. Where it was determined that, the best number of the mesh was 3200147 as shown in Fig. 2 depending on the exit temperature value, where the temperature at the exit area was 304.14 K, as shown in Table 1.
Energy-saving technologies and equipment

Table 1

<table>
<thead>
<tr>
<th>Case</th>
<th>Element</th>
<th>Outlet temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2376780</td>
<td>306.23</td>
</tr>
<tr>
<td>2</td>
<td>3679807</td>
<td>304.76</td>
</tr>
<tr>
<td>3</td>
<td>4877089</td>
<td>304.15</td>
</tr>
<tr>
<td>4</td>
<td>5220147</td>
<td>304.14</td>
</tr>
</tbody>
</table>

After the process of achieving the fine mesh, the program settings and the required equations must be adjusted. The k-ε model was used for fluid movement and heat transfer. The fluid heat transfer model was used, where the water entry velocity was 0.1 m/s for all cases and the temperature entry of 300 K and that the value of the heat applied to the outer surfaces was 350 K for all cases, where two cases were applied, the first is direct flow and the second is reverse to see the changes that occur in the transfer of heat and pressure.

4.1. Governing equations

The following is the equation for the condition of motion:

$$\frac{\partial p}{\partial t} + \nabla \cdot (p \vec{v}) = S_n.$$  \hspace{1cm} (1)

In (1), the case is one of general motion, while in (2), the case is one of particular motion, as shown by the following form, where (2) is provided in the form of a direction:

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}(p v_x) + \frac{\partial}{\partial r}(p v_r) + \frac{v_r}{r} = S_n.$$  \hspace{1cm} (2)

where $v_x$ is the center velocity, $v_r$ is the extended velocity, $r$ is the winding bearing, and $x$ is the fundamental heading.

Power insurance in an inertial (non-accelerating):

$$\frac{\partial p}{\partial t} + \nabla \cdot (p \vec{v}) = -\nabla p + \nabla \cdot \left( \tau \right) + p \vec{g} + \vec{F},$$ \hspace{1cm} (3)

where $\vec{g}$ is the static strain, $\tau$ is the tensor of tension (illustrated below), and $p \vec{g}$ and $\vec{F}$ are the gravitational body power and extended body powers (those that, for instance, emerge from interaction with the dispersed stage), independently. $\vec{F}$ similarly includes additional model-subordinate source terms, such as unreliable sources and customer-described sources. The strain tensor $\tau$ is given by:

$$\tau = \mu \left[ \nabla \vec{v} + (\nabla \vec{v})^\text{T} \right] - 2/3 \vec{v} \cdot \vec{I},$$ \hspace{1cm} (4)

where the second component on the right side represents the impact of volume extension, $\vec{I}$ is the unit tensor, and $\mu$ is the nuclear consistency.

The center point and extended power guarantee conditions for 2D axisymmetric computations are provided by:

$$\frac{\partial}{\partial t} (\rho v_x) + \frac{1}{r} \frac{\partial}{\partial r} (\rho v_r v_x) +$$

$$\frac{1}{r} \frac{\partial}{\partial r} (\rho v_r v_x) = -\frac{\partial p}{\partial x} +$$

$$\frac{1}{r} \frac{\partial}{\partial r} \left[ \mu \left( \frac{\partial v_x}{\partial x} \right) + \frac{\partial v_x}{\partial r} \right] +$$

$$\frac{1}{r} \frac{\partial}{\partial r} \left[ \mu \left( \frac{\partial v_r}{\partial x} \right) + \frac{\partial v_r}{\partial r} \right] + F_r;$$ \hspace{1cm} (5)

what's more $v_z$ is the whirl speed.

5. Results of effect of the number of tesla fuses

5.1. The effect of the number of channels on the heat transfer

The results proved that the increase in the number of channels increases the heat transfer of water by increasing the surface area of the transfer. As the case in which the number of channels is four was obtained an exit temperature of 304.14 K, which is the highest temperature reached in cases where the direction of flow is direct, as shown in Fig. 3.

Fig. 3. Temperature contour:

$a$ – 2 channels; $b$ – 3 channels; $c$ – 4 channels
The increase in heat transfer depends on the amount of pressure, so it is necessary to know the pressure and the results of heat transfer because the pressure must be balanced during heat transfer. The results proved that the increase in the number of channels positively affects the pressure and thus gives more outlets for the passage of water, as shown in Fig. 4.

Therefore, the pressure value was in the case in which the channel is a quadrilateral, and the pressure value reached 209 Pa, which is the lowest pressure value compared to other cases in the direct direction of flow.

5.2. The effect of the reverse direction on heat transfer

The main principle of the Tesla valves is the reverse direction, which works to obstruct the movement of the fluid, and thus increases the pressure and reduces the speed of the fluid that is, it works to give enough time for the heat to transfer to the water. The direct exit score has reached 305.74 K, as shown in Fig. 5.

It is known that the increase in the turbulence of the fluid flow increases the pressure and therefore the opposite direction of the flow has a higher-pressure value than if the direction of flow was direct. The results proved that the pressure value in the reverse direction reached 222 Pa, which is higher than the pressure value in the direct direction of flow, as in Fig. 6.

Fig. 7 shows the temperature values by changing the flow course and the number of channels that were used.
6. Discussion of effect of the number of Tesla fuses

Any heat exchanger's primary function is the amount of heat transfer that takes place there, and this research has shown that adding more channels enhances the quantity of heat transfer by expanding the transfer's surface area. The highest temperature ever recorded in situations where the flow direction is direct was attained in the case of four channels, at 304.14 K (Fig. 3). According to a research, adding additional channels increases the pressure and provides more exits for the movement of water. The pressure value reached 209 Pa in the quadrilateral channel example, which is the lowest pressure value in the direct direction of flow when compared to other instances (Fig. 4).

The Tesla valves, which are intended to allow ample time for the heat to travel to the water, have a direct exit score of 305.74 K (Fig. 5). The reverse direction, which serves to restrict fluid flow and so raises pressure while decreasing flow speed, is the fundamental component of the Tesla valve. The flow in the opposite direction has a higher pressure value than if the flow were straight because increasing turbulence in a fluid flow raises pressure. The results show that the pressure in the reverse direction of flow, which is higher than the pressure in the direct direction of flow, reached 222 Pa (Fig. 6).

Tesla valve is one of the old topics that have been studied, but the form that used is an idea that does not widely discussed even in previous research, which is difficult to be compared with it due to the geometry difference. There is a limitation in the study where is the boundary that is considered to be a short action that cannot be increased or repeated tube cycles.

One of the most important difficulties encountered is the complexity of the shape, which increases the amount of mesh, and therefore requires huge computers that we cannot provide.

The next development that can be done in the future is to control the height of the winding cycle, which helps to obstruct the fluid and increases the efficiency of the winding.

The difference in temperatures between the numbers of channels represents the criterion of efficiency between the shapes and their comparison.

7. Conclusions

1. The main work of any heat exchanger is the amount of heat transfer that occurs in it, and this study has shown that increasing the number of channels increases the heat transfer of water by increasing the surface area of the transfer. In the case of four channels an exit temperature of 304.14 K was obtained, which is the highest temperature reached in cases where the direction of flow is direct. An increase in the number of channels positively affects the pressure and thus gives more outlets for the passage of water, a study has shown. The pressure value was in the case in which the channel is a quadrilateral, and the pressure value reached 209 Pa, which is the lowest pressure value compared to other cases in the direct direction of flow.

2. The direct exit score has reached 305.74 K for the Tesla valves, which are designed to give enough time for the heat to transfer to the water. The main principle of the Tesla valve is the reverse direction, which works to obstruct the movement of the fluid, and thus increases the pressure and reduces the speed of the flow. Increasing turbulence in a fluid flow increases pressure, hence the flow in the opposite direction has a larger pressure value than if the flow was straight. According to the findings, the pressure in the reverse direction of flow reached 222 Pa, which is greater than the pressure in the direct direction of flow.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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