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

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IDENTIFYING OF THE EFFECT OF THE NUMBER OF TESLA FUSES IN A COILED COLLECTOR ON DIRECT AND REVERSE HEAT TRANSFER

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1. Introduction

It became necessary to develop of 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 adding diamond obstacles in the Tesla mixer. The results showed that the order of layout parameter weight from large to small was obstacle size > vertical offset > horizontal offset. Stream shakiness in a supercritical liquid based regular dissemination circle (NCL) was at present being researched by [2]. NCLs need an exhaustive plan assessment that considers the exchange of all transient lightness and contact force reactions. The study features the production of NCL combined with two changed Tesla type valves. TV confounds were made from a few slanted plates with focus openings and bending circular segments pointing downwards. An ideal TV astound development (30° plate point, 8 cm curve width) diminished blending time by 36.4 percent while expanding mass exchange coefficient by 50 % as persented by [3]. A fluid cooling plate with a Tesla valve structure with high acknowledgment in microfluidic applications was introduced. Plate has four channels and a valve-to-valve distance of 8.82 mm. Heat move was improved by [4] to the detriment of tension misfortune, attributable to stream bifurcation and blending processes. Contactless apple culling is possible utilizing an apple pluck port in light of negative strain attractions force, which diminishes the gamble of mischief to the apple. Based on a Tesla valve, a strength type pneumatic bravery port was developed in this exploration by [5]. A piezoelectric siphon's discharge might be decreased by utilizing an opposite redirection channel. Tesla valve, which has no moving parts, may make a high-pressure drop during reverse stream. This design's effect on restricting return stream might be utilized in horticultural water system as done by [6]. Non-Return Valves are basic parts that keep the liquid under perception from streaming in reverse. Tesla valves are the most irrefutable non-return valves (NRVs) without moving parts. They work when the pull side tension surpasses the release side strain as shown [7]. Check gadgets were just appropriate for restricted districts, like lines, and do not satisfy the necessities of building ventilation. This exploration offers a clever type of liquid diode plate (FDP) with no moving components that can be endlessly extended concerning region. It might be utilized in an assortment of ventilation circumstances as presented by [8]. The Tesla valve considers unidirectional liquid stream cycling in a circle, making it a compelling device for battling precariousness. Every single supercritical tension and intensity inputs are better settled with the altered Tesla valve. It diminishes temperature and speed motions while keeping up with heat move effectiveness as shown by [9]. Cavitation in a sleeve-managing valve not just builds the energy loss of the entire funneling framework, yet it likewise harms the valve body and the channeling framework. A cavitation model was utilized by [10] to investigate the impacts of different valve center shapes on cavitation. This article explores variable number of these channels and a direct and reverse flow turbine were employed to compare the changes that obtained the amount of pressure and temperatures. Consequently, the Tesla valve was the subject of this research, but in a coiled and three-dimensional shape. The Tesla valve, one of the most significant valve types ever discovered, has not been altered in a way that fits the evolution of components and shapes, or the flow of fluids in general, thus it is required to research modifying the forms of the Tesla valve. The main problem in previous research is that the old version of the Tesla valve was taken based on changing the pressure between inlet and outlet significantly due to the smallness of its channels and its effectiveness on the disturbance of the inlet zone to reduce the pressure difference and thus increase the efficiency of the valve.

3. The aim and objectives of the study

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.

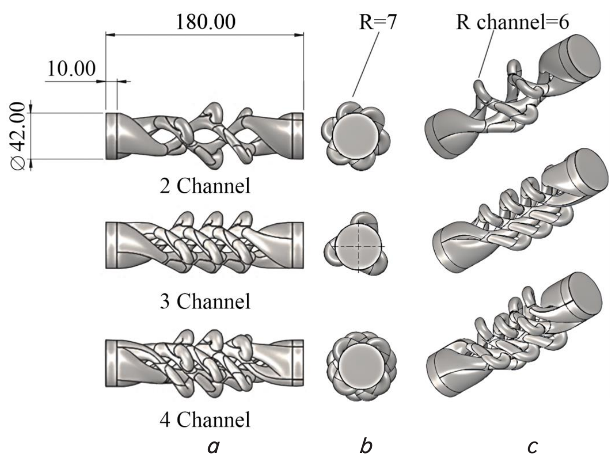


Fig. 1. Geometry design for the three types: *a* – front side; *b* – side view; *c* – 3-D

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 element is 5220147 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.

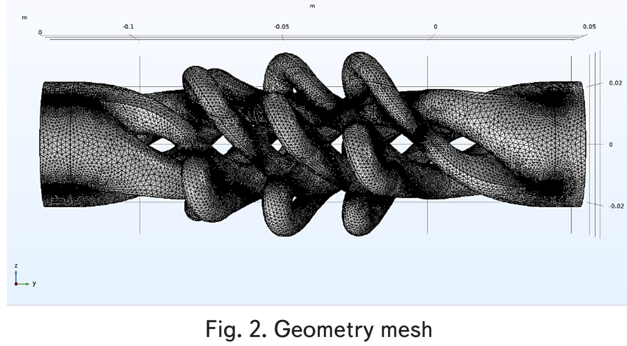


Fig. 2. Geometry mesh

Table 1

Independency of mesh

Case	Element	Outlet temperature (K)
1	2376780	306.23
2	3679807	304.76
3	4877089	304.15
4	5220147	304.14

After the process of achieving the fine mesh, the program settings and the required equations must be adjusted. The coms program was used, a simulation program, where 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 The 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:

$$\partial\rho/\partial t+\nabla\cdot(\rho\vec{v})=S_m. \quad (1)$$

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:

$$\partial\rho/\partial t+\partial/\partial x\ (\rho v_x)+\partial/\partial r\ (\rho v_r)+(\rho v_r)/r=S_m, \quad (2)$$

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):

$$\partial/\partial t\ (\rho\vec{v})+\nabla\cdot(\rho\vec{v}\vec{v})=-\nabla p+\nabla\cdot\left(\bar{\bar{\tau}}\right)+\ \rho\vec{g}+\vec{F}, \quad (3)$$

where p is the static strain, $\bar{\bar{\tau}}$ is the tensor of tension (illustrated below), and $\rho\vec{g}$ and $\vec{F}$ are the gravitational body power and external 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 $\bar{\bar{\tau}}$ is given by:

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

where the second component on the right side represents the impact of volume extension, I is the unit tensor, and μ is the nuclear consistency.

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

$$\partial/\partial t(\rho v_x)+(1/r)(\partial/\partial x)(r\rho v_x v_x)+$$
$$+(1/r)(\partial/\partial r)(r\rho v_r\ v_x)=-\partial p/\partial x+$$
$$+(1/r)(\partial/\partial x)\left[r\mu\left(2\ (\partial v_x)/\partial x-2/3(\nabla\cdot\vec{v})\right)\right]+$$
$$+(1/r)(\partial/\partial r)\left[r\mu\begin{pmatrix}(\partial v\_x)/\partial r+\\+(\partial v\_r)/\partial x\end{pmatrix}\right]+F_x\ ; \quad (5)$$

and

$$\partial/\partial t\ (\rho v_r)+(1/r)(\partial/\partial x)(r\rho v_x\ v_r\ )+$$
$$+(1/r)(\partial/\partial r)(r\rho v_r\ v_r\ )=-\partial p/\partial r+$$
$$+(1/r)(\partial/\partial x)\left[r\mu\left((\partial v_r)/\partial x+(\partial v_x)/\partial r\right)\right]+$$
$$+(1/r)(\partial/\partial r)\left[r\mu\left(2\ (\partial v_r)/\partial r-2/3(\nabla\cdot\vec{v})\right)\right]-$$
$$-2\mu_{(r^r)^{(v_r)}}+2/3\mu/r(\nabla\cdot\vec{v})+\rho\ v_r/r+F_r\ ; \quad (6)$$

$$\nabla\cdot\vec{v}=(\partial v_x)/\partial x+(\partial v_r)/\partial r+v_r/r, \quad (7)$$

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.

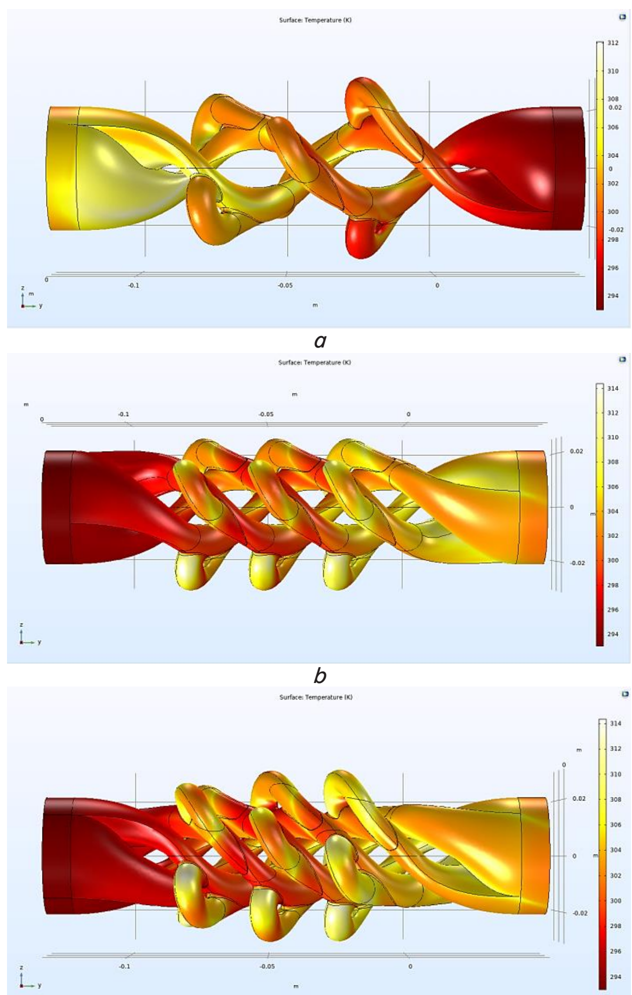
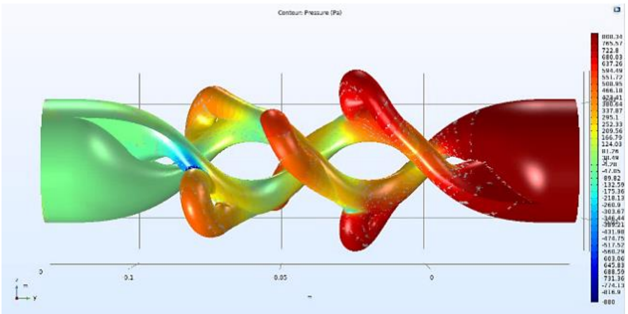
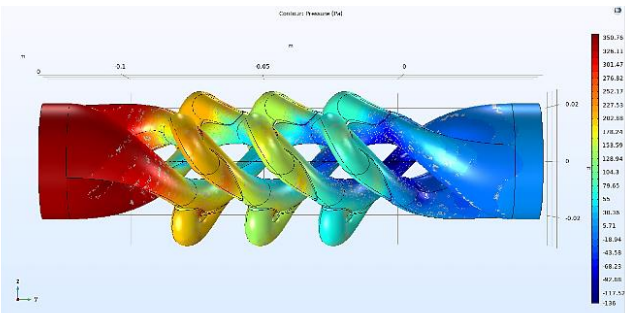


Fig. 3. Temperature contour:
a — 2 channels; *b* — 3 channels; *c* — 4 channels

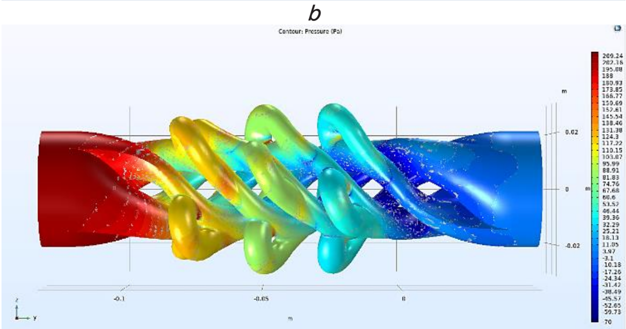
The increase in heat transfer depends on the amount of pressure, so it is necessary to know the pressure and the results of heat transfer because the pressure must be balanced during heat transfer. The results proved that the increase in the number of channels positively affects the pressure and thus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



a



b



c

Fig. 4. Pressure contour:
a – 2 channels; *b* – 3 channels; *c* – 4 channels

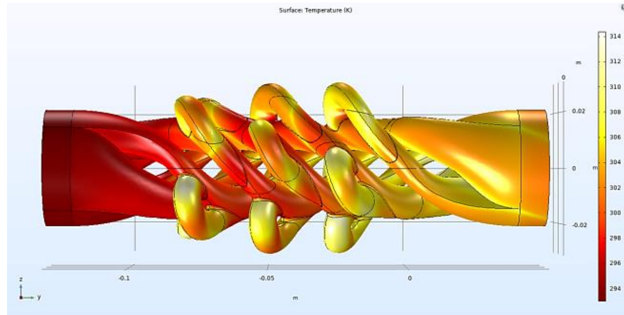
Therefore, the pressure value was in the case in which the channel is a quadrilateral, and the pressure value reached 209 Pa, which is the lowest pressure value compared to other cases in the direct direction of flow.

5. 2. The effect of the reverse direction on heat transfer

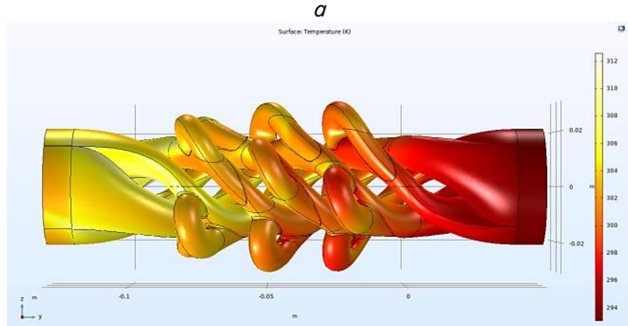
The main principle of the Tesla valves is the reverse direction, which works to obstruct the movement of the fluid, and thus increases the pressure and reduces the speed of the flow that is, it works to give enough time for the heat to transfer to the water. The direct exit score has reached 305.74 K,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

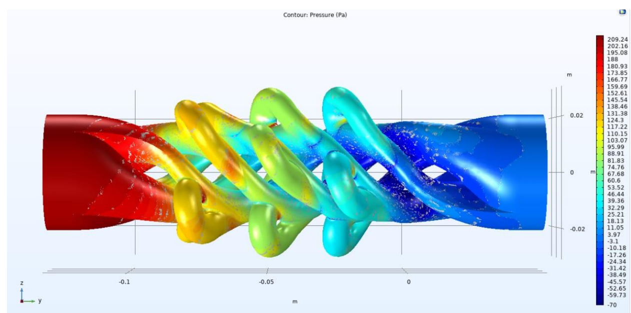


a

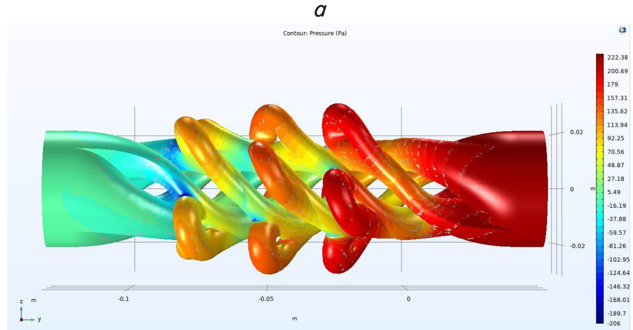


b

Fig. 5. Temperature contour:
a – Direct direction; *b* – Reverse direction



a



b

Fig. 6. Pressure contour:
a – direct direction; *b* – reverse direction

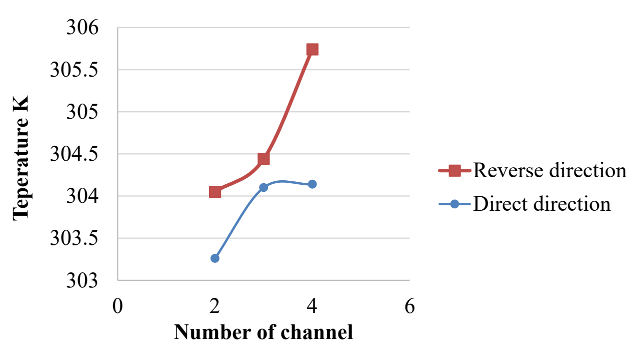


Fig. 7. Temperature distribution

The results proved that the best case is when the flow is reverse and the number of channels is four.

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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