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IDENTIFYING THE INFLUENCE OF NUMBER OF BLADES AND DISTANCE BETWEEN BLADES ON TESLA PUMP CHARACTERISTICS

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The main principle of the Tesla pump is to increase the shear stresses as a result of the rotation of the pump blades, and thus increase the kinetic energy of the fluid to form a mass flow. The types of mechanical pumps are many and the ways of their use are wide. Over the years, scientists have contributed to developing types of pumps to get the best pump efficiency. The rotational energy can be converted into a mass flow of the fluid that can be pumped. As the Tesla pump is one of the types that gives a wide impression of fluid mechanics, where the viscosity and shear stress of the fluid will be in the movement of the fluid particles and the formation of a centrifugal force that gives an active flow of the fluid. Tesla pump is one of the primitive pumps that can be modified to study this research paper and know the number of fins used and the optimal distance between them to obtain the best mechanical efficiency of the pump. Where the Tesla pump was designed with variable fins, 3, 6 and 11 fins were taken to compare them, and the distance between the fins was reduced from 10 mm to 5 mm with a change of 2.5 mm, where the changes that occur on the pump can be observed. Where the results proved that the value of the fins increases the flow velocity of the fluid, as the best case was at the fins number 11, where the flow velocity reached 13 m/s. As for the change of distance, it is an inverse relationship as the small distance between the fins impedes the movement of the fluid flow and thus reduces the value of the flow. In the case where the number of turbine blades is 11, shear stresses reached 401 Pa. Which is the best case compared to the rest of the cases. The mechanical movement of the water was significantly increased

Keyword: tesla turbine, open-flow, blades number, blades distance, wall shear

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1. Introduction

Analyzed is a technique that might make inverse cycle-based systems more effective. The major goals are to investigate the flow mixing, define the second phase's function, and determine the real operating range. With the use of a frame motion method and the CFD solution of the Eulerian-Eulerian approach, all the crucial liquid-vapor interactions are identified and described. The results demonstrate an average power production of 0.8 W with a delivered torque of 3.6 mN-m at a rotating speed of about 2000 RPM [1]. If its efficiency increases, the Tesla turbine, a bladeless, radial turbine, may be appropriate for use in a variety of energy systems, such as the Organic Rankine Cycle or combined heat and power systems. Response surface approach was used to carry out the optimization. Efficiency was nearly two times better than the nominal model (from 9 to 17 percent) and empirically verified. Where it studied the change of pressure in relation to the pump and the shapes of the pump, it does not studied the subject of changing the thickness or the number of discs [2]. With diameters of 11.25 and 15 cm, two Tesla turbine prototypes were created. The impact of disc spacing and pressure flow in the spectrum of actual operating circumstances is examined for each turbine. For the turbines with small and large diameters, respectively, maximum efficiencies of 33 percent and 50 percent were attained, while stall torque readings are as high as 0.304 N·m and 0.448 N·m. The subject of altering the thickness or number of discs was not explored; instead, it was studied how the pressure changed in relation to the pump and its shapes [3]. Due to its environmental friendliness and the thermodynamic properties of carbon dioxide, the trans critical carbon dioxide heat pump cycle has garnered a lot of attention. One worrying problem is the significant exergy loss connected to the isenthalpic process in the expansion valve. A Tesla turbine is suggested as an alternative to the conventional expansion valve in a recent research, and it has been shown that the cycle's coefficient of performance is 16.3 percent greater as a result. It used a computer program also carbon dioxide gas as a main substance [4]. The Tesla turbine is a hybrid expander that has recently attracted fresh attention because to the growing popularity of distributed microgeneration. Due to its unusual technology's straightforward structure, which enables great reliability and affordability, Organic Rankine Cycle microgeneration seems to be well suited for it. Maximum adiabatic and shaft efficiencies of 30 % and 9.62 %, respectively, were attained, [5]. Numerical work in an algorithmic way, not with advanced simulation programs, where it studied the effect of the Tesla Turbine on the ORC system. The problems that were encountered through previous research is the failure to analyze the parameters of the Tesla pump, that is, the pump efficiency was not calculated by changing the number of surfaces with an engineering simulation program that informs us of many subtleties as in the experimental work.

2. Literature review and problem statement

An expander ideal for tiny distributed energy systems is the Tesla turbine. The straightforward design has always ensured affordability and dependability. The paper [6] evaluated the fluid dynamics of the rotor, stator-rotor gap, and stator using a 3-D computer model. The findings were consistent with the findings of the analytical 2-D code, which presupposes uniform entrance to the rotor. An unusual expander that produces power by viscous entrainment is the Tesla turbine. Due to its cheap cost and high dependability, it may become a ground-breaking technology in the low power levels. The turbine's geometry has been established, and performance potential has been evaluated. It worked by verifying the angles of flow, not the number of disks, in a two-dimensional manner. The paper [7] attained an efficiency of more than 60 % with the specified shape and under the right fluid-dynamic circumstances. Which presented a brand-new use for a Tesla turbine (TT), one that holds promise for improving the energy efficiency of refrigeration cycles. The Redlich-Kwong equation of state was used to determine if methane was a genuine gas. The impact of the Tesla Turbine on the ORC system was investigated using algorithmic numerical work rather than sophisticated simulation software. The paper [8] used the complicated unstructured grid generation in order to create a low-skewness mesh for a CFD model for the modeling of heat and mass transport via FVM. Using open flow water in a hose and in a weir canal, a study was done to ascertain the Tesla turbine's performance. The highest reported Tesla turbine efficiency occurred at 0° angles, when water flow via a hose was 34.42 percent efficient, while a rectangular weir was 29.45 percent efficient. At angles of 0°, 30°, and 45°, a straight-line connection between power and efficiency is seen. The relationship between the machine's output and efficiency is linear. Where it studied the effect of Tesla Turbine in improving the energy of air conditioning cycles. [9]. For modest waste heat recovery applications, a turboexpander is a Tesla disk turbine. The stator's shape was somewhat involuted, and supersonic flow conditions were present near to the nozzle outlet when the fluid is admitted using a two-convergent-nozzle arrangement. According to preliminary findings, a slight reduction in the tip clearance may result in a significant improvement in the turbine's performance of up to 57 percent, [10]. It studied performance using arithmetic rather than numerical methods, unlike sophisticated simulation tools. In a gas turbine, the pressure energy of the combustion products was converted into mechanical work due to the rotation of the blades, part of which was spent on compressing air in the compressor, [11]. It functioned by two-dimensionally checking the flow angles rather than the number of disks. A turbine without blades that is suitable for low power applications is the Tesla expander. The relevant performance metrics for three working fluids (R404a, R134a, and R245fa) were examined. Both the laminar model and the Langtry-Menter transitional shear stress transport model was used to perform various calculations at various rotation speeds. A small-scale prototype was expected to have a high rotor efficiency (69 percent at 3000 rpm) and the findings revealed a great matching, [12–15]. The problems that were encountered through previous research is the failure to analyze the parameters of the Tesla pump, that is, the pump efficiency was not calculated by changing the number of surfaces with an engineering simulation program that informs us of many subtleties as in the experimental work. The importance of the presented research is to study the parameters of the Tesla pump to see which is better efficiency by changing the number of surfaces and thus its use in many engineering applications.

3. The aim and objectives of the study

The aim of the study is know the number of blades used and the optimal distance between them to obtain the best mechanical efficiency of the tesla pump.

To achieve this aim, the following objectives are accomplished:

– to study the effect of the number of blades on the flow velocity of the fluid;

– to show the effect of distance between blades on fluid flow velocity;

– to depict the effect of the number of pump blades on the shear stress.

4. Materials and methods of research

The design process requires a precise engineering program that is able to design the Tesla pump in a way that suits its insertion in the simulation program, where the Solidworks program was used to design the model as in Fig. 1.

The most important hypotheses that have been worked on is that there is no thermal effect on the fluid density and at the same time it is considered one of the simplifications to obtain results related to pressure and temperatures.

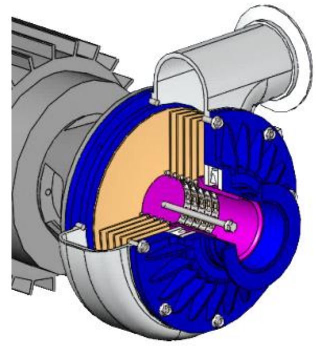


Fig. 1. Design geometry

The simulation program (CFD) works on the fluid model and not on the real design of the pump, as the original model of the pump was converted and transferred to the fluid domain that will be studied as in Fig. 2.

Where it is noted from the previous figure that the model is divided into two parts, the first part represents the shape of the pump and the second part represents the domain surrounded by feathers that were used in the Tesla pump.

After the design process, the stage of converting the model to a formula that fits the simulation of the program, where a mesh is made using the ANSYS CFD program, extracting the results, and then increasing the number of meshes to reach a convergence between the results with the increase in the number of meshes, where the number of elements reached 4241397 at a velocity of 13.1 m/s as shown in Table 1.

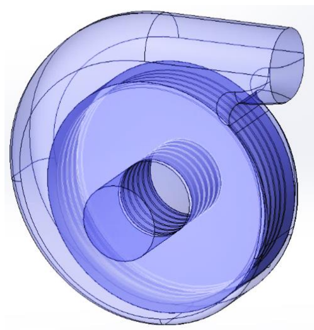


Fig. 2. Compositional fluid dynamic geometry

Table 1

Mesh independency

Case	Element	Node	Max velocity, m/s
1	1120678	214543	15.2
2	2523145	552311	13.9
3	3645322	753452	13.2
4	4241397	1098343	13.1

One of the most important parts in which accurate results must be extracted is the fins, where inflation is done for the fins in order to obtain a combined mesh form that can extract accurate results from it as Fig. 3, 4.

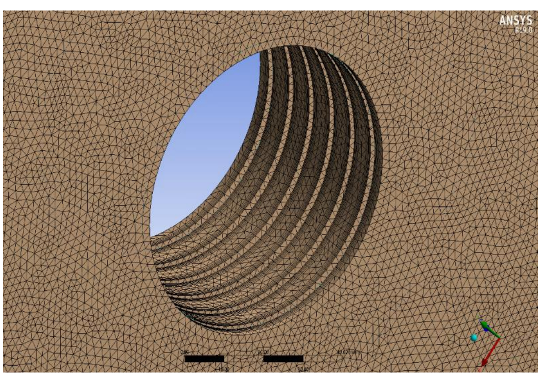


Fig. 3. Fins inflation

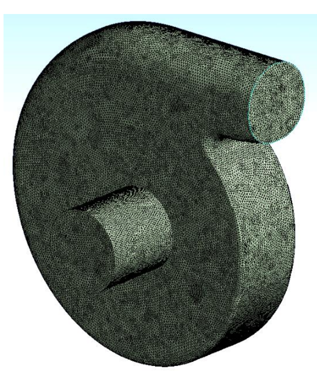


Fig. 4. Mesh geometry

In order for the simulation process to take place completely, the foundations of the settings related to the Boundary Condition must be laid. Where the k-ε standard model was used because it is the best model in which results that match the truth can be extracted. And then the main fluid was placed in it, which is the water represented by the pump. As for the Boundary Condition, it was represented in Fig. 5.

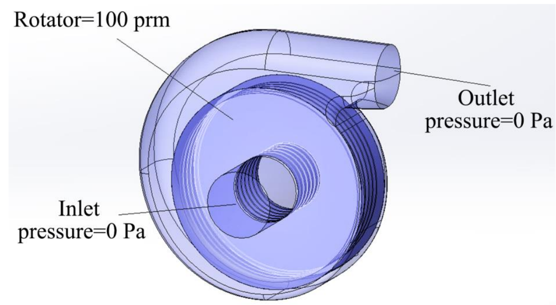


Fig. 5. Boundary conditions

The cases that were studied and compared with each other to get the best case were used. Where the Tesla pump was designed with variable fins, 3, 6, and 11 fins were taken to compare them, and the distance between the fins was reduced from 10 mm to 5 mm with a change of 2.5 mm.

The condition for the state of movement is as per the following:

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

In condition one it is on account of general movement, yet in condition 2 the condition is as a heading, or at least, it is in an extraordinary case, as it is given in the accompanying structure:

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

where x is the fundamental heading, r is the winding bearing, v_x is the middle speed, and v_r is the drawn-out speed.

Protection of force in an inertial (non-speeding up):

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

where p is the static strain, $(\bar{\bar{\tau}})$ is the strain tensor (depicted under), and $\rho\vec{g}$ and $\vec{F}$ are the gravitational body power and outside body powers (for instance, that emerge from relationship with the scattered stage), autonomously. $\vec{F}$ similarly contains other model-subordinate source terms, for example, permeable media and client depicted 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 μ is the atomic consistency, I is the unit tensor, and the second term on the right hand side is the impact of volume expansion. For 2D axisymmetric calculations, the middle point and expanded power affirmation conditions are given by:

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

and

$$\partial/\partial t(\rho v_r)+1/r\partial/\partial x(r\rho v_x v_r)+$$
$$+1/r\partial/\partial r(r\rho v_r v_r)=-\partial p/\partial r+$$
$$+1/r\partial/\partial x\left[r\mu\left((\partial v_r)/\partial x+(\partial v_x)/\partial r\right)\right]+$$
$$+1/r\partial/\partial r\left[r\mu\left(2(\partial v_r)/\partial r-2/3(\nabla\cdot\vec{v})\right)\right]-$$
$$-2\mu^{v_r}_{r'}+2/3\mu/r(\nabla\cdot\vec{v})+\rho v_r/r+F_r, \quad (6)$$

where

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

What's more, v_z is the spin speed.

5. Results of effect of the number of blades used and the optimal distance between them to obtain the best mechanical efficiency of the tesla pump

5. 1. The effect of the number of blades on the flow velocity of the fluid

The increase in the number of the pump blades increases the friction area of the fluid and thus increases the shear stress between the surface of the blade and the water, as this stress works to move the water atoms and increase the kinetic energy in it and thus increase the mass flow that the pump gives. From Fig. 6 of the flow velocity of the fluid during the rotation of the blades, it is noted that the increase in the number of blades increases the velocity of fluid flow. Where, through Fig. 7, which shows the directions of the water flow as a result of the movement of the existing blades, and because of this movement, a centrifugal process occurs as a result of this effect that helps in the movement of the fluid and the production of the pump factor, Fig. 8.

Where it is noticed that the flow velocity of the 11 blades is greater compared to the rest of the cases where the flow velocity reaches to 13.1 m/s.

5. 2. Effect of distance between blades on fluid flow velocity

The decrease in the distance between the blades generating the pumping process increases the shear stress, but by a certain amount, at a distance of 10 mm, the value of the velocity is 7.84 m/s at the number of blades 6, but as the distance decreases, the shear stress increases significantly to lead to obstruction of the fluid flow and thus its effect is negative on the pump as in Fig. 9.

Through the previous figures, it is noted that the value of the flow velocity at the tips of the blades increases by decreasing the distance, after which it works to obstruct the fluid and thus reduces the flow value of the pump. The Tesla Pump, which has a maximum velocity of 9 m/s and a 5 mm gap between its blades, is the best case scenario when compared to other scenarios.

5. 3. Effect of the number of pump blades on the shear stress

The main principle of the Tesla pump is to increase the shear stresses as a result of the rotation of the pump blades, and thus increase the kinetic energy of the fluid to form a mass flow. Fig. 10 shows that the increase in the number of pump blades increases the shear stress value of the water and thus increases the mechanical movement of the water that works on the mass flow of the fluid.

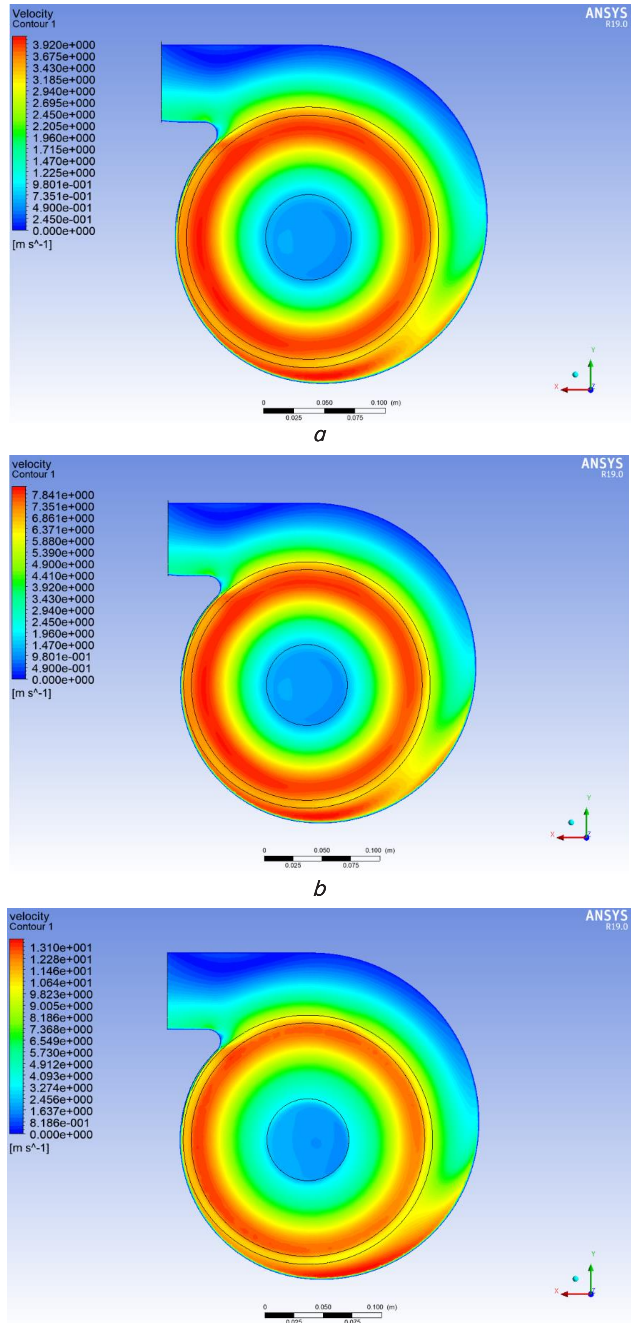


Fig. 6. Velocity contour at: *a* – 3 blades; *b* – 6 blades; *c* – 11 blades

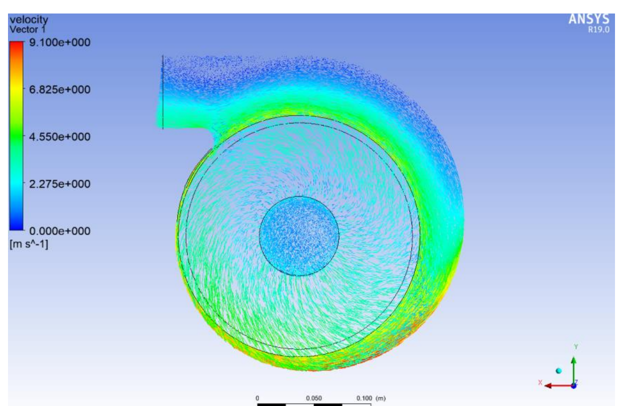


Fig.7. Velocity vector at 6 blades

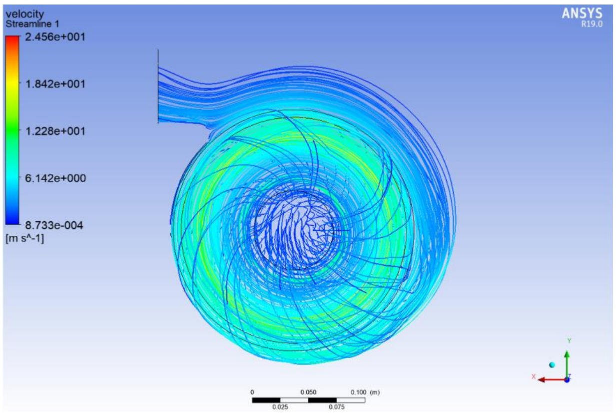
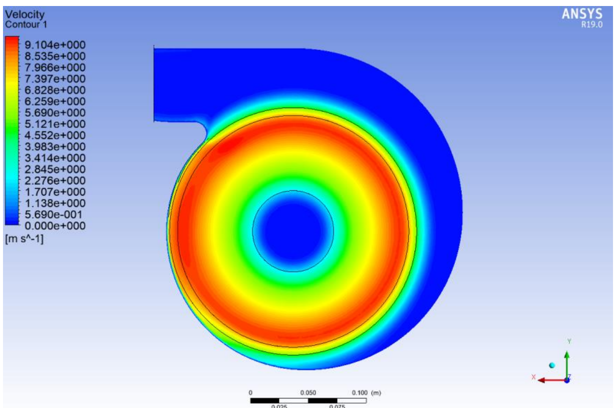
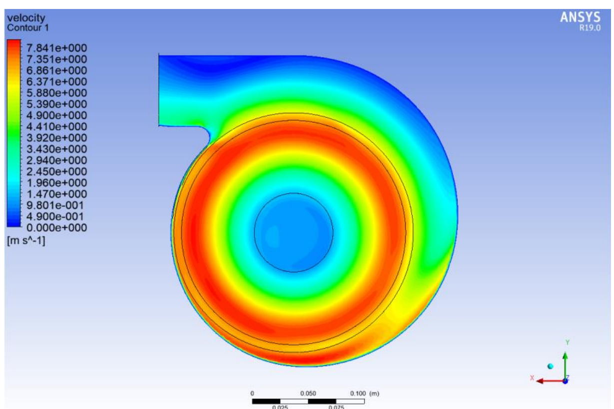


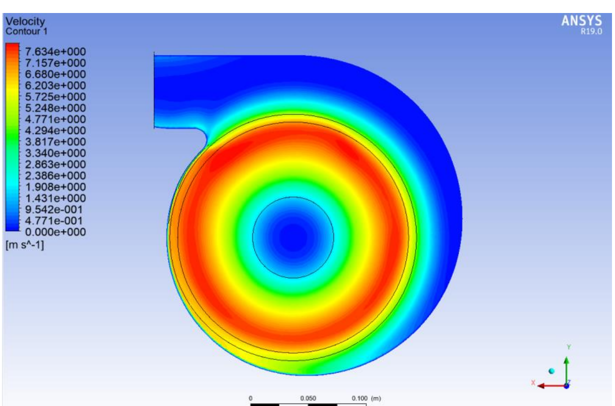
Fig. 8. Velocity streamline at 6 blades



a

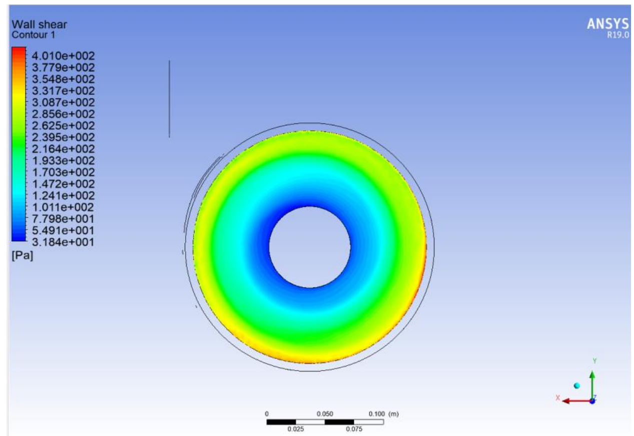


b

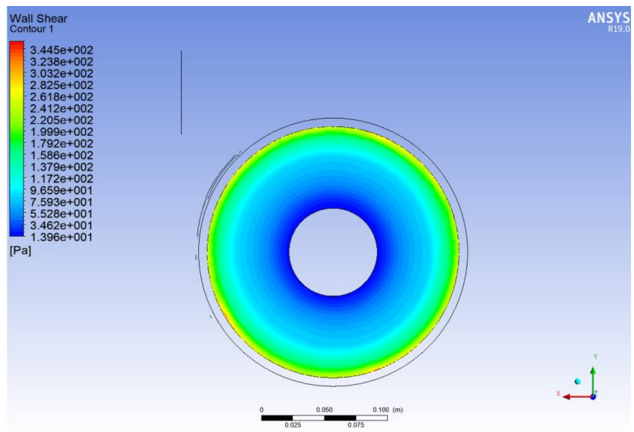


c

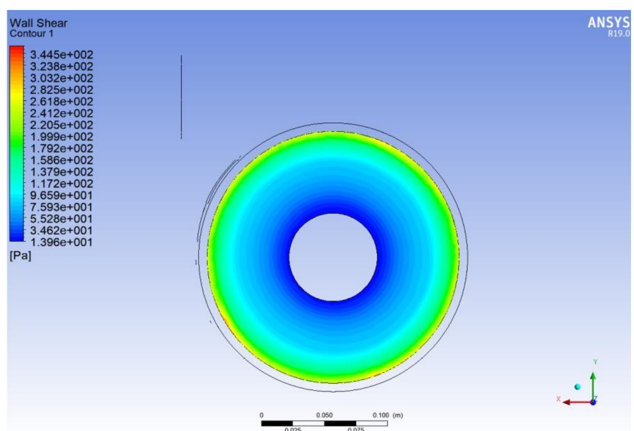
Fig. 9. Velocity contour at distance between blades: *a* – 10 mm; *b* – 7.5 mm; *c* – 5 mm



a



b



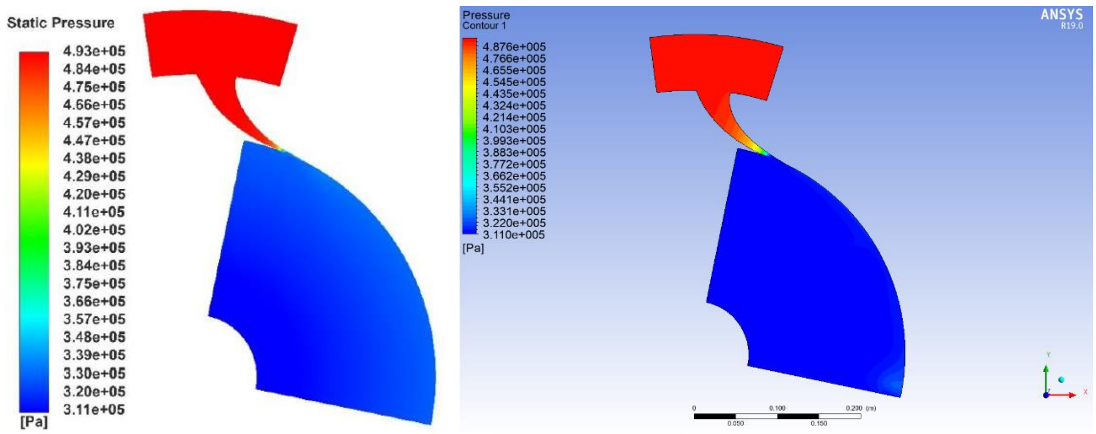
c

Fig. 10. Wall shear contour at: *a* – 3 blades; *b* – 6 blades; *c* – 11 blades

Where the shear stress for the walls in the case where the number of turbine blades is 11 reached 401 Pa, which is the best case compared to the rest of the cases.

A comparison was made with the simulation program from previous research [6] to ensure the validity of the results that were worked on.

Where a two-dimensional section of the Tesla pump was taken, and pressure was introduced in the vortex entry area at a rotational speed of 3000 rpm. At the same conditions of the previous research, a simulation was made, as the results represented a good convergence in terms of contours, as in Fig. 11.



a *b*

Fig. 11. Pressure contour at: *a* — Previous research [6]; *b* — CFD work

Where the error rate reached 1 % compared to the previous research and this gives clear evidence of the validity of the solution presented.

7. Discussion of effect of number of blades used and the optimal distance between them to obtain the best mechanical efficiency of the tesla pump

It is noted that the increase in the number of blades increases the velocity of fluid flow, and because of this movement, a centrifugal process occurs as a result of this effect that helps in the movement of the fluid and the production of the pump factor Fig. 5–8. The shear stress increases significantly to lead to obstruction of the fluid flow and thus its effect is negative on the pump. The increase in the number of pump blades increases the shear stress value of the water and thus increases the mechanical movement of the water that works on the mass flow of the fluid Fig. 9. Where the shear stress for the walls in the case where the number of turbine blades is 11 reached 401 Pa, which is the best case compared to the rest of the cases Fig. 10.

Because of the lack of such research studies, this encouraged us to do such work, and it was not easy to compare it with other works that were somewhat far from our work, so we just be content with mesh independency.

The limits that are encountered are the thickness of the surfaces, because the smaller the thickness of the surfaces, the greater the amount of mesh. Therefore, large computers are needed to solve such simulations.

The disadvantages of this study can be noted in the long time in runs time of simulation and it can be eliminated in the future by using faster Workstation or CPU.

It is possible to develop surfaces in the future by conducting experimental experiments to see the variables that occur as a result of changing the numbers of surfaces.

8. Conclusions

1. An increase in the number of blades on a water pump works by increasing the shear stress between the surface of the blade and the water. This stress works to move the water atoms and increase the kinetic energy in it and thus increase the mass flow that the pump gives. The tesla pump has 11 blade is the best case compared with other cases because it has 13 m/s maximum velocity.

2. The decrease in the distance between the blades generating the pumping process increases the shear stress, but by a certain amount, at a distance of 10 mm, the value of the velocity is 7.84 m/s at the number of blades 6, but as the distance decreases, the shear stress increases significantly to lead to obstruction of the fluid flow and thus its effect on the pump. The tesla pump has 5 mm gab between blades is the best case compared with other cases because it has 9 m/s maximum velocity.

3. The value of the flow velocity at the tips of the blades increases by decreasing the distance and tons, after which it works to obstruct the fluid and thus reduces the flow value of a pump. The tesla pump has 11 blade it is the best case compared with other cases because has 400 pas maximum shear wall.

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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The study was performed without financial support.

Data availability

Data will be made available on reasonable request.

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