Simulation of Tidal Energy Extraction, Using Fluent Model

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Abstract. This study has been performed to develop our knowledge about marine sources energy extraction. Water in the channel has been simulated in laboratory scale by means of FLUENT software. The turbine tidal flow is generated by a moving disk which applies a pressure decrement with energy dissipation. Free water surface is estimated by means of fluid volume in the model which changes freely. The numerical results illustrate that eddy sequence has been generated after the tidal flow of turbine and a flow acceleration is generated nearby, especially beneath the energy extraction devise. Free water surface drop due to energy extraction is considered in model results that seems a to improve the turbine eddy sequence.
Keywords. Eddy sequence, porous media, VOF.

1 Introduction

Global energy crisis and Unrecoverable of fossil fuels has made the access to new sources of energy to be highly specific because when this crisis peaks, only the countries with a prior preparation and researches on new energies could resist the condition [1]. Marine or oceanic energy is a type of renewable energies which has been noted beside solar and wind energy. Waves' and tidal energy are the most important subsets of marine energy [2]. Tidal energy is a predictable source of energy that depends on the gravity of moon and the sun. One of its most significant benefits is low cost of function and also low pollution for this type of energy. Although the initial costs of manufacturing the tidal energy generation is relatively high, but the obtained energy value is much more beneficiary than other power generation systems such as fossil fuels [3,4].

Through this research a water channel in laboratory scale is simulated in FLUENT software. A moving disk as the energy extraction device is modeled using porous media that is able to generate the proper pressure drop which varies the kinetic energy along the disk. In a prior study, a solid gage was installed, based on assuming free water level to be steady and thus, it does not affect the fluent field. This assumption is not true in real situation especially when tidal farm effects are to be considered. In present study, a real simulation is performed by VOF method in which free water surface could vary [5,6].

2 Main Body

A rectangular field with a 10000mm of length and 1000mm of depth is defined as water zone and presented in figure 1. Depth of free space over the free surface is considered to be 1000 mm.

Calculated field in GAMBIT is meshed with 60000 square cells. A zone with a 500mm of depth height and a thickness of 5mm is divided from water zone and its center is placed at y=-500mm. Downstream path is assumed as no-slip wall. Flow rate of water is 1270 kg/s for water and 0.00001 kg/s for air. Measured pressure is defined by means of a program in C++, using a UDF function. Upper surface of the field is defined as a symmetrical surface. The divided zone is defined as a semi-permeable disk which is estimated by means of porous media model. Iterations are repeated till the solution becomes convergence.

A deformation was observed while drawing two phases and it is presented in figure 2. The vertical column shows air volume fraction. The disk presence makes a closure effect on due which the downstream water level rises. But a significant surface level drop is observed after the moving disk in conformity of theorical predictions. It claims that extraction of energy from tidal flows could lead to significant head drops along the energy extraction zone [7]. In 1.5m distance from the disk, water surface rises due to receding from the disk and the effect of free surface (which is lower than the water surface level of downstream. This head difference makes tidal energy extraction possible.

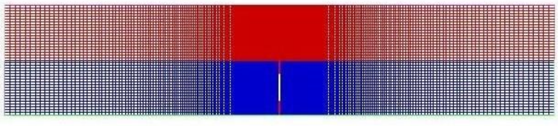

Fig. 1. Structured mesh in 2D model.

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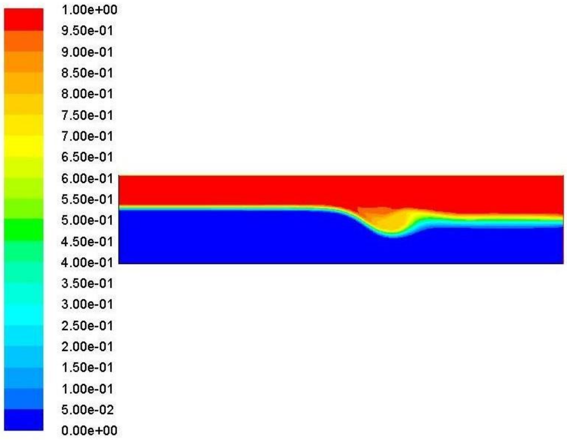

Fig. 2. Rise of the free surface in 2D.

Flow velocity contours are shown in figure 3. Down stream flow of the moving disk produces a momentum dissipation and thus, leads to a eddy zone with no energy right after the moving disk, in where the water velocity highly decreases. Simultaneously, there are significant speed accelerations at the top and bottom of the moving disk. According to continuity law, the upstream water velocity must be more than the velocity of downstream water due to decrement of downstream water surface level. Diagram of horizontal factor of velocity is shown in figure 4, which explains this.

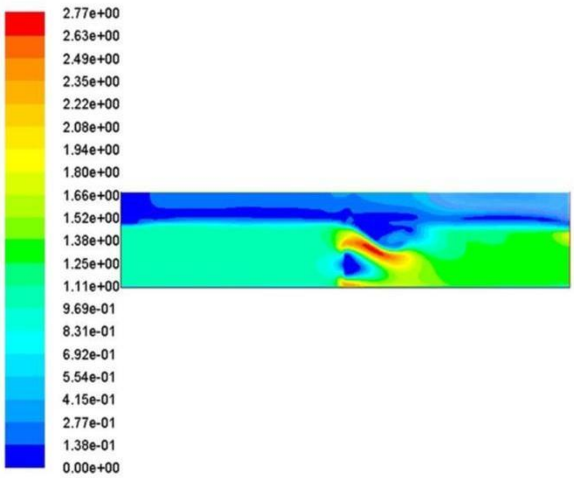

Fig. 3. Flow line curves representing the eddy sequence after the disk.

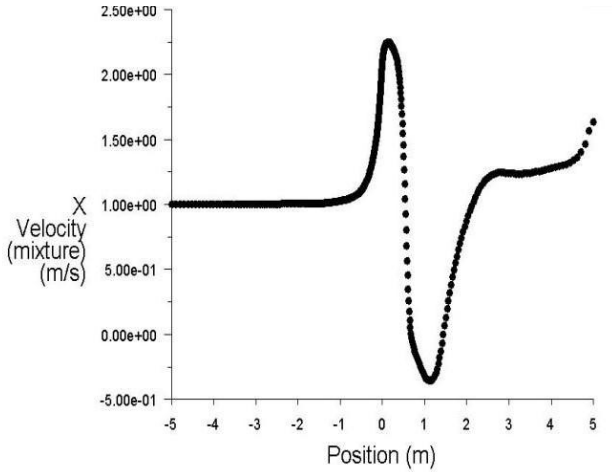

Fig. 4. Horizontal factor of velocity.

Dynamic pressure diagram is presented in figure 5. A severe pressure drops us apparent right after the disk due to closure effect. Pressure increases by increasing the distance from the distance from the disk, in presence of free surface. But it is still lower in the upstream in comparison with downstream. Eddy kinetic energy diagram is obvious in figure 6. The turbulence is generated after colliding the disk and the kinetic energy maximizes at 1.5m from the disk that makes tidal energy extraction possible. After that this energy reduces.

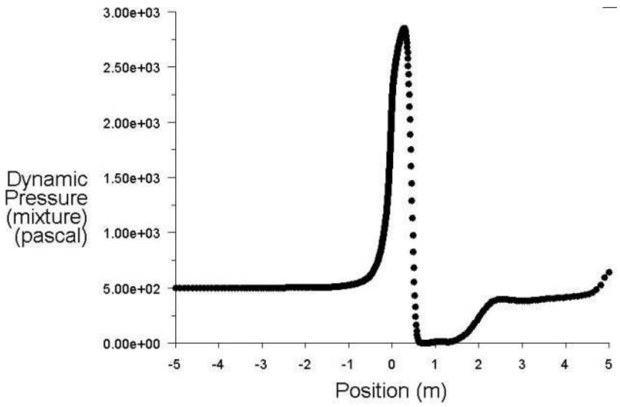

Fig. 5. Dynamic pressure diagram.

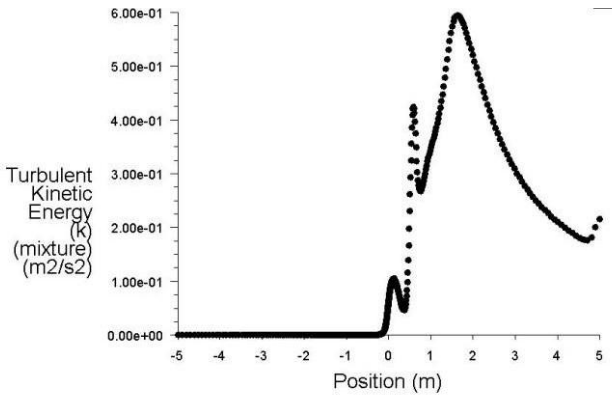

Fig. 6. Eddy kinetic energy diagram.

 https://doi.org/10.1051/e3sconf/202016002002

The 2D model is developed to 3D model. A water channel is generated in GAMBIT with a length of 10000 mm, width of 1500 mm and a height of 2000 mm. Water depth is 1000 mm and there is a 1000 mm air space over the free surface. The structures mesh is made up of 96000 cubic cells. A disk is placed at mi-depth of water with a diameter of 500 mm and a thickness of 5 mm as is presented in figure 7. Input parameters are under 0.001 and the solution becomes convergent at each time step. The free surface rise diagram is presented in figure 8. The free surface inclines about 5 cm from the inlet to the disk proximity. A drop of about 10 cm is generated right after the moving disk. The declined free surface level starts to incline back again at a distance of 1 m from the disk after 1.5 m from disk it gets back to the same initial free surface level. From this distance in, no variation is observed in the free surface level till the end of channel.

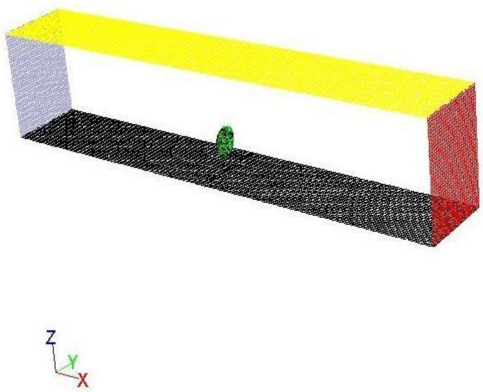

Fig. 7. Calculated field in 3D.

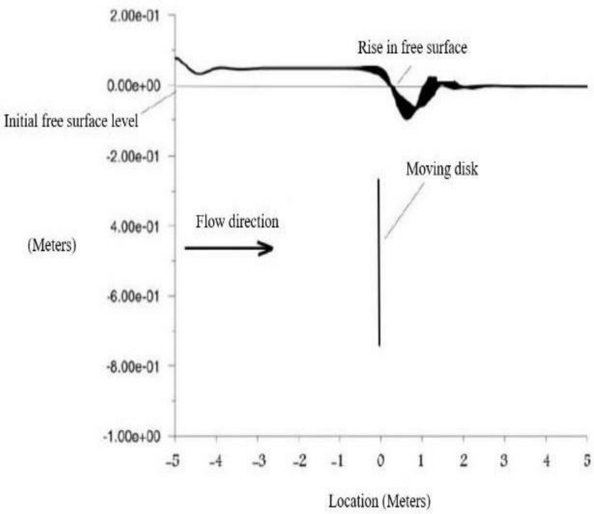

Fig. 8. Rise diagram of free surface.

Velocity contours of flow path on the vertical surface passing the disk center are presented in figure 9. The water velocity increases in the disk proximity due to moving disk closure effect. But a there is an obvious velocity decrement after the disk which dissipates energy in eddy sequence.

Velocity ontours of flow path on the vertical surface passing the disk center are presented in figure 10. When average velocity in eddy sequence is lower than velocity of free flow, the velocity outside of eddy sequence in a closed channel must be more than free flow velocity.

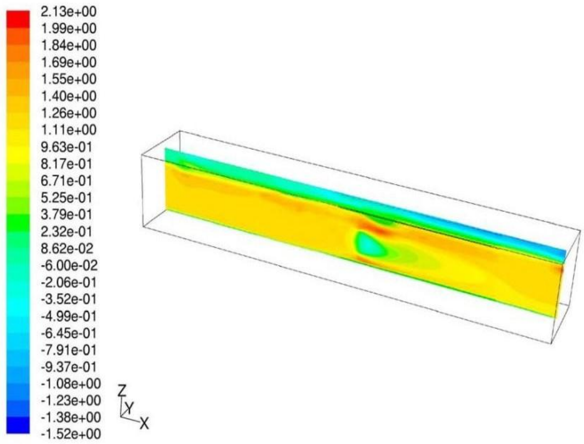

Fig. 9. Velocity contours of flow path on the vertical surface passing the disk center.

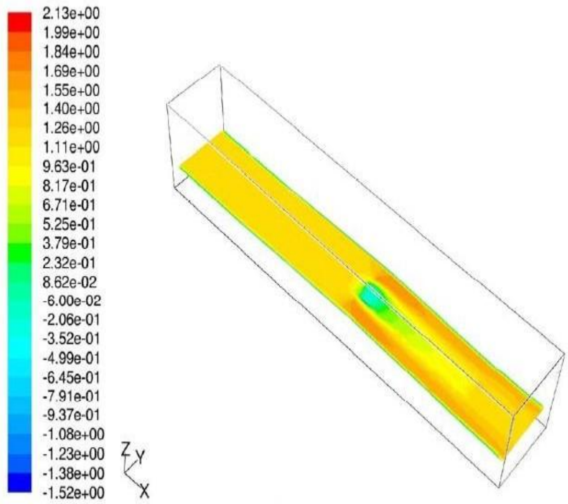

Fig. 10. Velocity contours of flow path on the horizontal surface passing the disk center.

3 Conclusion

Tidal flow energy extraction has some results, shown here:

• A significant drop of free surface level could be occurred due to energy extraction from flowing water. Presence of free surface and its deformation must be considered in development of numerical methods and accurate forecast of energy extraction from tidal flows. Thus, this is related to inappropriate free surface which is considered as a solid border in simulation of tidal flow energy extraction.

• The disk generates a closure and a significant surface level drop could be observed after the disk. Difference of water level at the upstream and downstream makes energy extraction possible in tidal flow.

• Closure ratio is a critical factor in tidal farm considerations. A huge full-scale tidal farm could cause high closure ratios in inclined channels. Due to this, inlet velocity could decrease which is shown in 2D numerical results. Thus, energy flux -that is related to velocity cube- makes the estimated energy to decrease. Although velocity acceleration of flow nearby the device that also causes closure is presented in 2D and 3D simulations, could increase the energy inlet for devices at the down of the flow or could let the distance between the devices to decrease at a tidal farm. Thus, the number of units installed and the longitudinal and transverse distance of turbines in a tidal must be designed accurately.

• In the case, the tidal flow energy alters the limited zone between the seabed and the surface, tidal energy extraction could critically change the flow field characteristics. As a result, tidal energy extraction accessibility is not limited to environmental restrictions and extractable energy is defined is defined by considering tidal energy extraction location.

References

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