Numerical analysis of heat dissipation in electric motor of the ESP in the Skid system

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The recent development of Electric Submersible Pump (ESP) in the Skid, installed in the seabed downstream of the wellhead in a marine oil production system, is an alternative to the conventional system with the set installed at the bottom of the producing well. This configuration facilitates interventions in case of failure due to their positioning.

The ESP in the Skid provides the necessary energy to the fluids, allowing them to flow, overcoming the load losses along the flowline and riser, being delivered to the floating unit at a suitable pressure. The pump is driven by an electric motor whose cooling must be efficient to ensure the continuity of its operation. Heat withdrawal is effected by the fluid being produced by the pump.

Therefore, the purpose of this work is to understand the influence of the heat transfer in the annular space formed by the electric motor and capsule of the ESP in the Skid system, in the phenomenon of cooling of the electric motor. With this objective is used the Computational Fluid Dynamics (CFD) to solve the single-phase flow, turbulent with convection heat transfer in an annular geometry, represented by Figure 1. The geometry used is represented by two concentric cylinders of external diameters, internal, and length, as shown in Figure 1. The diameters ratio () is 0.69, the is 0.27306 m and the length is 23.36.

![Figure 1 - Schematic of the geometry used for simulation. (a) - Entry section; (b) - Capsule wall; (c) - Motor wall; and (d) - Exit section.](image)

Due to a previous analysis of turbulence models and geometry, the simulations are performed in a 3D geometry and considering the κ-ε enhanced turbulence model. The fluid used has Prandtl equal to 7 and Reynolds equal to 133758, 108281, 82803 and 70064. Considering the fluid temperature equal to 62.5 °C at the inflow plane, the outer wall with 4 °C and the internal wall with 130 °C.

The analysis of the motor cooling phenomenon is performed through the Nusselt dimensionless number, represented by Figure 2. The results are compared with the Gnielinski's completely developed Nusselt correlation for the validation of the simulations, represented by Figure 3. It is also analyzed the effect of the eccentricity on the motor cooling process, highlighting if this effect influence or not the number of Nusselt.
Figure 2 - Nusselt number as a function of dimensionless length of the domain and four values of Reynolds number.

Figure 3 - Nusselt number as a function of Reynolds number obtained by simulations and the correlation.

Therefore, through Figure 3 it is highlighted that the result of the simulation is close to that found by the correlation, so the results of the simulation correctly represent the phenomenon analyzed. Through the curve of heat flux of the motor in the pipe, which has the same behavior of the Nusselt curve (Figure 2), it is possible to emphasize that the electric motor has lower temperatures at the base and larger at the top. Because, for the constant temperature condition in the motor, the heat flux presented higher results at the beginning of the pipe and lower at the end. Therefore, if the process with constant heat flux condition in the motor were analyzed, the temperature would have an inverse behavior. That is, lower values at the beginning and higher values at the end.

The lower temperatures in the initial part of the motor are caused by the development of the boundary layers, which intensifies the phenomenon of heat transfer between motor and fluid. From the point where these boundary layers develop, the motor temperature and the other parameters of heat transfer by convection tend to be constant, thus highlighting why this system has higher temperatures at the top.