Heat transfer coefficient calculation for analysis of ITER shield block using CFX and ANSYS

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ABSTRACT

In thermal–mechanical analysis of ITER shield block using ANSYS code, it needs the real heat transfer coefficient (HTC) values which are computed by CFX. Because two kinds of HTC values can be gotten from CFX and which has some difference with ANSYS, so it is necessary to estimate the error caused by HTC transferred from CFX to ANSYS. In this paper, HTC values got from CFX was firstly benchmarked with the results got from empirical formulas, then estimated the error caused by HTC transferred from theory and gave the expressions of the error, thirdly benchmark work of ANSYS results in 4 cases was done, then compared the error with former error estimated formula derived from theory. In the end, conclusions will be given based on above benchmark works.

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1. Introduction

Shield blanket is one of the most important components of International Thermonuclear Experimental Reactor (ITER) device [1], which consists of two parts: first wall and shield block [2–4]. In the course of thermal–mechanical analysis of ITER shield block using ANSYS code, which needs the real wall heat transfer coefficient (HTC) value computed from CFX. So it is necessary to understand how to compute HTC in CFX and its difference with the classic HTC definition, then can estimate the error in ANSYS computation using the HTC value get from CFX. In this paper, the benchmark works on HTC problems from CFX to ANSYS were done to estimate the error caused by HTC transferred and give the expressions of the error.

The classic definition of HTC is
\[ h = \frac{Q}{T_w - T_b}, \]
where \( T_w \) is wall temperature, \( T_b \) is the fluid bulk temperature, \( Q \) is wall heat flux. In any 3D analysis, \( Q \) and \( T_w \) are both variant depends on its position. In CFX, two kinds of HTC values can be obtained, one is using CFX default settings and the computing formula is:
\[ h_1 = \frac{Q}{T_w - T_p}, \]
where \( T_p \) is the wall adjacent temperature [6], which is a variant depends on the position. Another HTC values is setting the reference fluid bulk temperature and the computing formula is:
\[ h_2 = \frac{Q}{T_w - T_{b0}}, \]
where \( T_{b0} \) is the reference fluid bulk temperature.

2. Benchmark on HTC computation in CFX

2.1. Computational modeling in CFX

It is used simple modeling in CFX which is shown as Fig. 1 for saving numerical time. The length of the pipe is 600 mm and its inner diameter is 12 mm, the wall heat flux is \( 2 \times 10^5 \) W/m\(^2\) which is uniformly applied on the wall, and the wall roughness is 10 μm. The inlet velocity and temperature is 1 m/s and 140 °C individually. The fluid is water which property is changed with pressure and temperature, in CFX used IAPWS-IF97 material library [6]. The standard k-epsilon turbulence model was used in calculations and used scalable wall function. Hexahedral mesh based on O-block was employed in calculations for good computing accuracy, about 10 nodes was used in boundary layers. We performed steady state thermal hydraulic analysis for this pipe flow.

2.2. Benchmark on HTC results got from CFX

To benchmark the HTC value got from CFX, we will compare it with the results got from empirical formula. In the typical shield block conditions, the Reynolds and Prandtl number are about 56,000 and 1.22 individually, in this condition the fluid in the pipe is turbulence flow. For forced convection in turbulent pipe flow we choose the Dittus-Boelter and Sieder-Tate correlated equations to calculate the HTC values. The empirical formula of...