Modeling local heat transfer of a cylinder in air crossflow

Renoldas Zujus [1], Robertas Poškas [2, 3], Povilas Poškas [2], Evaldas Berneckas [2, 3]

1 Nuclear Engineering Laboratory, Lithuanian Energy Institute, Breslaujos 3, LT-44403 Kaunas – Lithuania Email: renoldas.zujus@lei.lt

2 Nuclear Engineering Laboratory, Lithuanian Energy Institute, Breslaujos 3, LT-44403 Kaunas – Lithuania

3 Department of Energy, Kaunas University of Technology, Studentu 56, LT-51424 Kaunas – Lithuania

INTRODUCTION

Cylindrical pipes are the most frequently encountered shape in heat exchangers, power generators, boilers, steam turbines condensers. Wide experimental studies on heat transfer and hydrodynamics of a cylinder in fluid crossflow were conducted previously in Lithuanian energy institute. This study provides the initial numerical modeling results on local heat transfer of a horizontal circular cylinder in air crossflow and comparison with experimental data [1].

METHODOLOGY

The investigation was performed in the subcritical air flow regime for a heated circular cylinder (Fig. 1) of diameter d = 0.032 m, length l = 0.2m. at a blockage factor k_q = 0.16 (k_q = d/H, where H is the height of the test section), and with an air flow turbulence at the inlet of Tu = 1.2%. The two-dimensional simulations were performed using the ANSYS Fluent code for a Reynolds number Re = 61000 based on the cylinder's outer diameter as the reference geometric parameter, the airflow velocity in the smallest cross-section of the channel (at 90° of the cylinder) as the reference velocity, and the air flow temperature at the inlet as the reference temperature. Three turbulent transfer models were used: the standard k-ε model (k - turbulent kinetic energy and ε - dissipation), the Reynolds stress-Omega model and the k-ω SST (Menter) model (ω - specific dissipation and SST – turbulent shear stress). To ensure the accuracy of the modelling results, the sensitivity analysis was performed using three different meshes. Finally, a 760 thousand computational node mesh was selected for modelling.

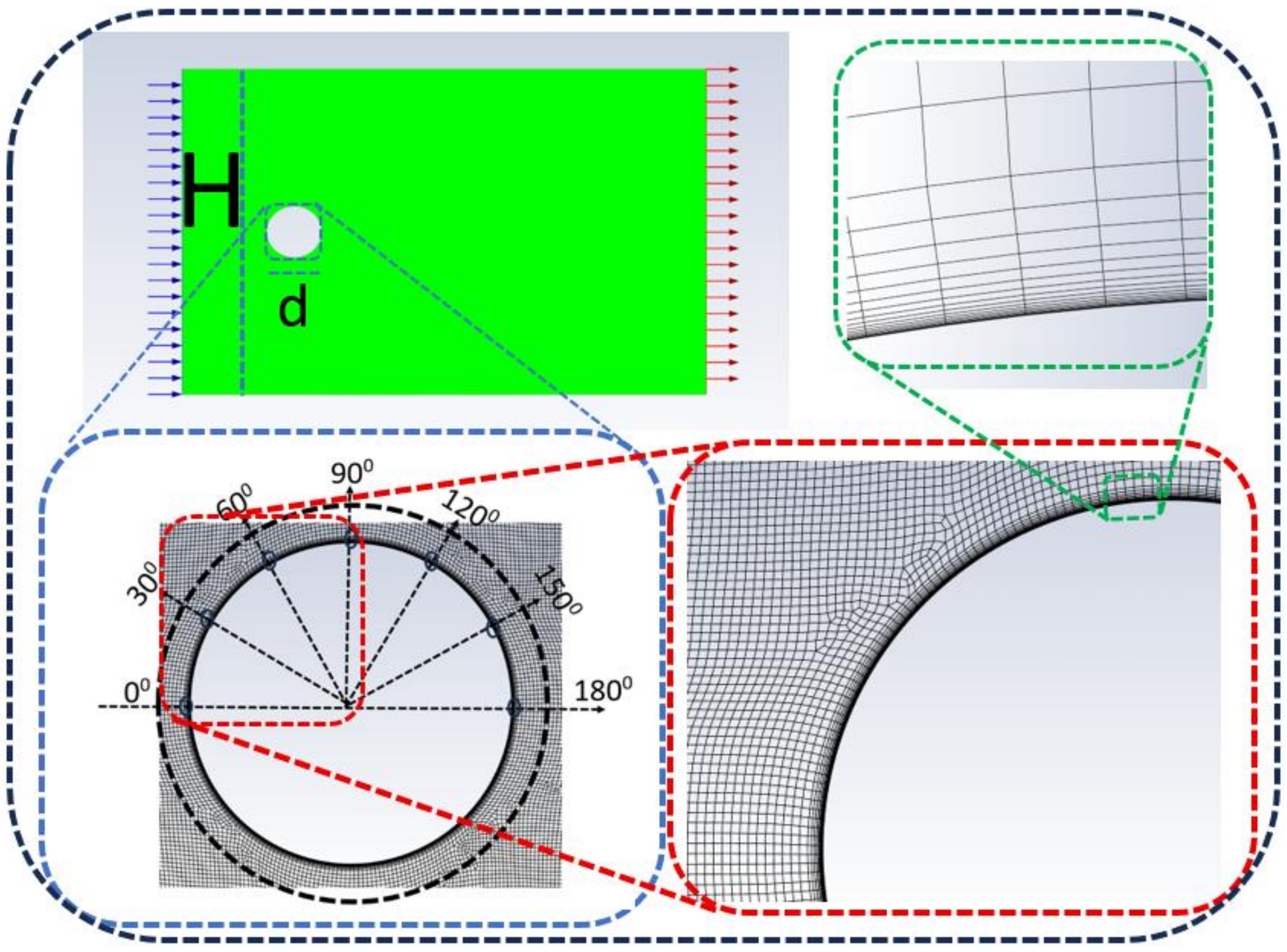

Fig. 1: View of domain flow over cylinder

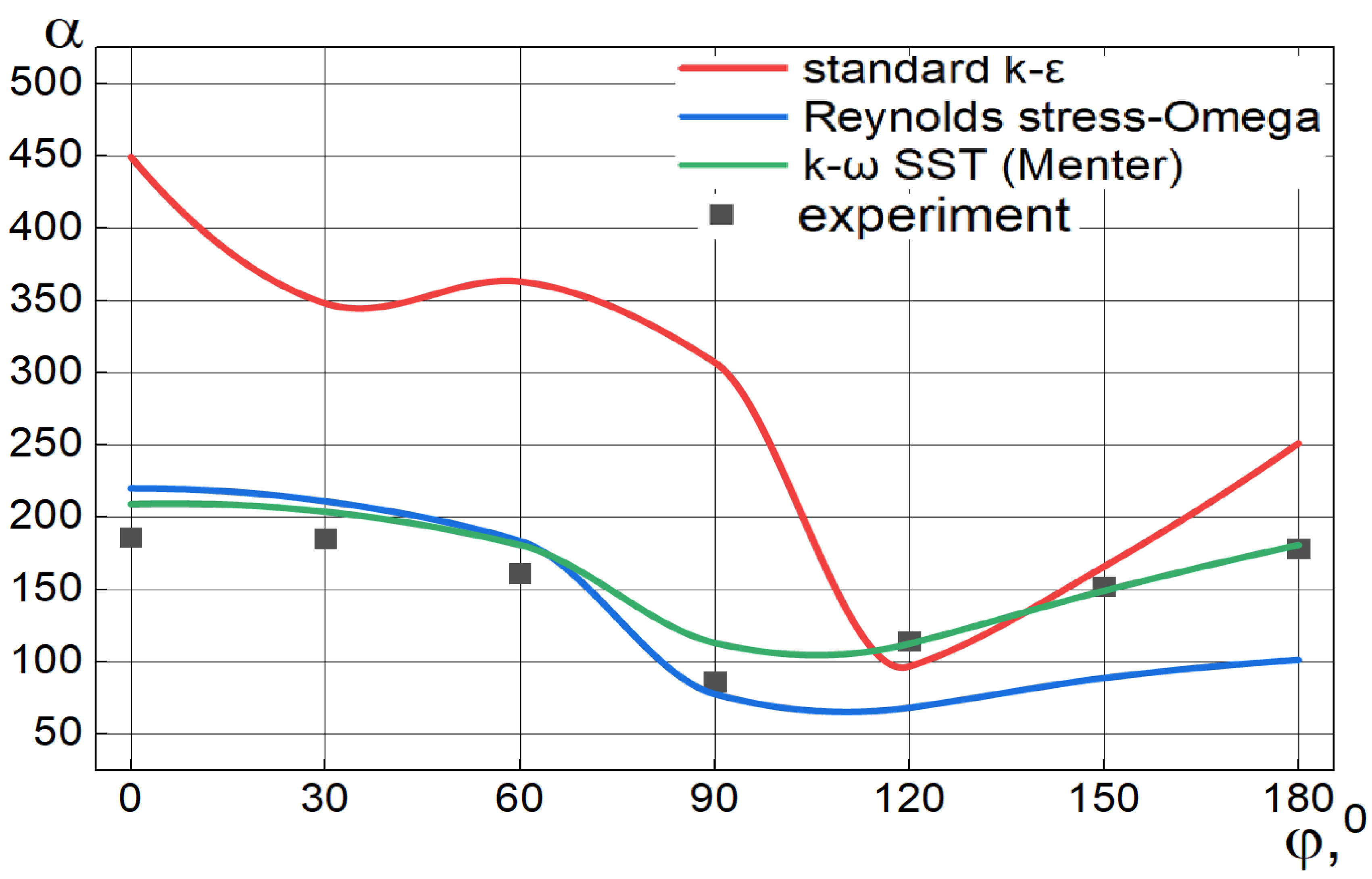

Fig. 2: Variation of local heat transfer over a cylinder

RESULTS AND DISCUSSION

The modelling results of all three turbulent transfer models were compared with experimental data (Fig.2). In the case of the k-ε turbulent transfer model, simulated results showed an unsatisfactory agreement with the experimental data: the modelled heat transfer coefficients α over the cylinder perimeter in the frontal part of the cylinder were higher by up to 250 % compared to the ones obtained in the experiments This was caused by an overestimation of the turbulent transport in the model, which resulted in the decrease in the wall temperature in the frontal part of the cylinder. However, the local heat transfer coefficients α around the rear part of the cylinder did not exceed the experimental ones more than 40 %. In the case of the Reynolds stress-Omega model, the comparison showed a moderate agreement between the modelling results and the experimental data in the frontal part of the cylinder. Here, the heat transfer coefficients α were 15 –19 % higher than the experimental ones. However, in the rear part of the cylinder, heat transfer decreased by up to 40 % compared with the experimental values. In the case of the SST k-ω turbulence model, the comparison showed a reasonable agreement with the experimental data in the frontal part of the cylinder. Here, the heat transfer coefficients α were higher than the experimental ones by 10 –13 %, but at the vicinity of the separation point (90°), this difference increased to 30 %. A very good agreement of the data was noticed in the rear part of the cylinder, where the difference was only up to 2 %. The methodology and results presented here can serve as a reference for future wider research of heat transfer of a cylinder in crossflow and not only of the circular shape.

REFERENCIES

[1] Zukauskas A. And Ziugzda J., Heat transfer of a cylinder in crossflow, Hemisphere Publishing Corporation, Washington – New York,1985.

LITHUANIAN ENERGY INSTITUTE

Contact information:

Renoldas Zujus

Researcher, Nuclear engineering laboratory

Lithuanian Energy Institute, Breslaujos st. 3, LT-44403, Kaunas

renoldas.zujus@lei.lt

+370 615 49366