

Modeling of heat transfer in helically coiled tube

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INTRODUCTION

Helically coiled tubes are widely used in heat exchangers, steam generators and power plants with organic and nuclear fuel. Chemical industries exploit helical tubes in different configurations, and various geometries are used in pipelines to reduce their axial lengths. Extensive experimental studies on heat transfer and hydrodynamics were conducted previously at the Lithuanian Energy Institute. The present study shows the initial numerical modeling results for helically coiled tubes and compares them with experimental data [1,2].

METHODOLOGY

This study presents a 3D numerical modeling analysis of heat transfer in a helically coiled tube at the conditions of the experiment (Fig.1). Numerical simulations were performed using the CFD software Ansys-Fluent for a turbulent flow regime in the hydrodynamically and thermally stabilized region at $50 < x/d < 100$

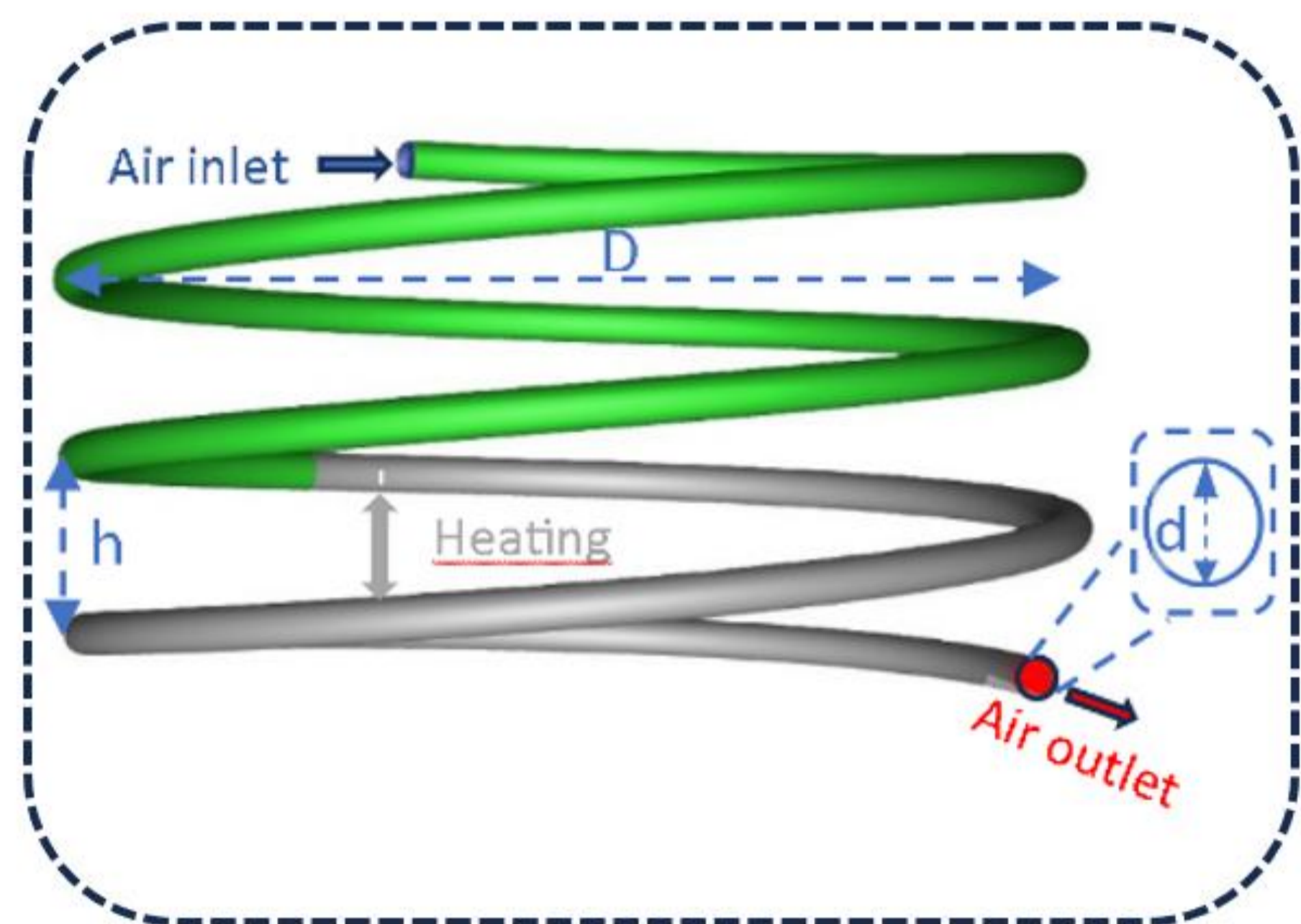


Fig.1. View of helically coiled tube

(x – heated tube length, d - tube inside diameter). The air entered the electrically heated thermal section ($x/d = 100$) through the unheated hydrodynamic stabilization section ($x/d \approx 150$). The geometric parameters of the stainless-steel coil: coil diameter $D = 0.39$ m, tube inside diameter $d = 0.017$ m ($D/d=23$), tube wall thickness = 0.0005 m, coil pitch $h = 0.07$ m. The steady state simulations were performed for a Reynolds number $Re = 11\,900$ at the inlet using two turbulent transfer models: the standard $k-\epsilon$ model (k - turbulent kinetic energy and ϵ - dissipation) and the $k-\omega$ SST (Menter) model (ω - specific dissipation and SST - turbulent shear stress). To ensure the accuracy of the modeling results, a sensitivity analysis was performed using three different meshes. Finally, a 51 million computational nodes mesh was selected for the modeling. As a boundary condition, constant wall heat flux $q_w = \text{const}$ was imposed. A pressure - based coupled solver was used for numerical simulations to reduce iterations number order to 10^2 for full convergence, compared to the typical number of iterations order 10^3 required by decoupled solvers.

RESULTS AND DISCUSSION

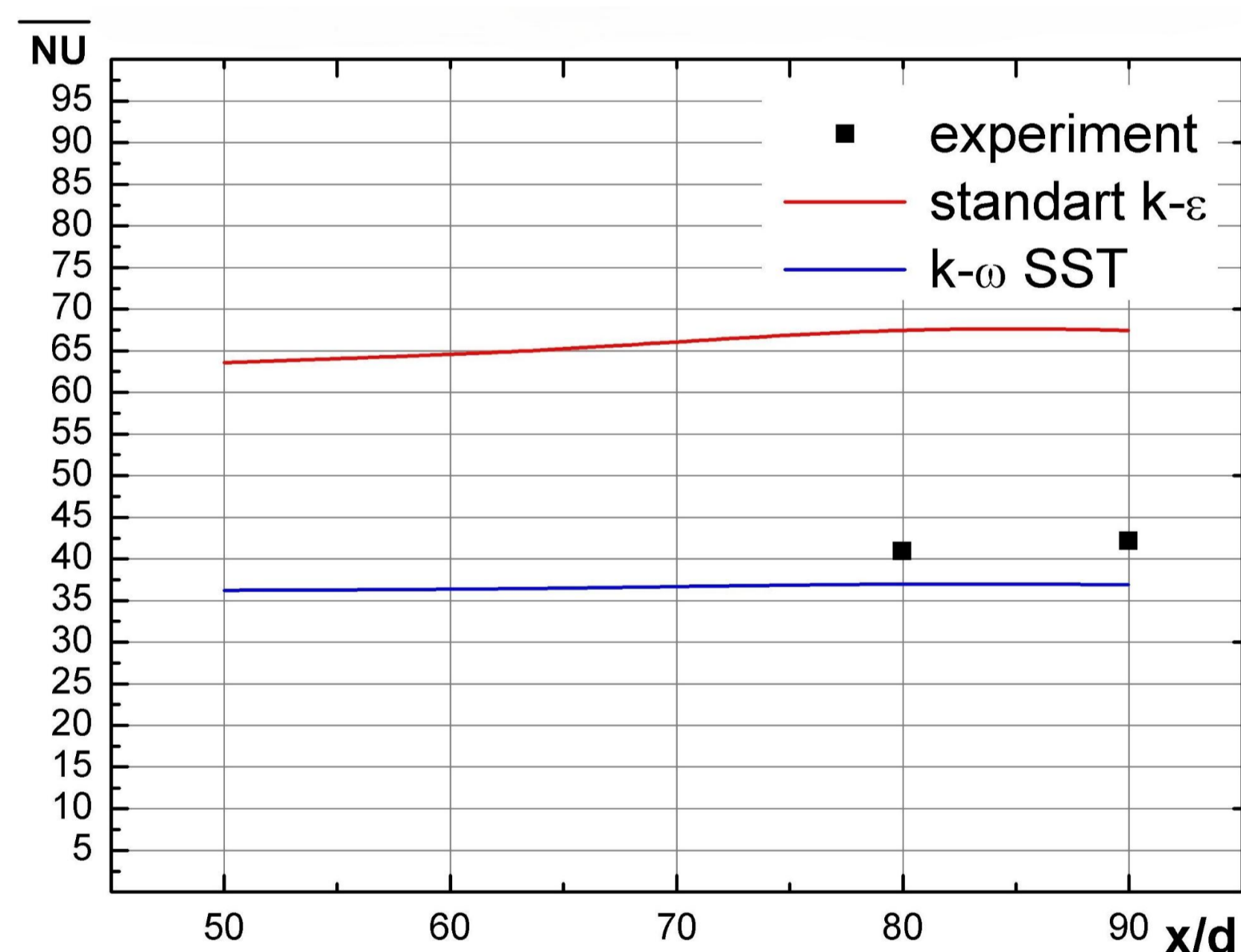


Fig. 2. Average over the tube perimeter heat transfer

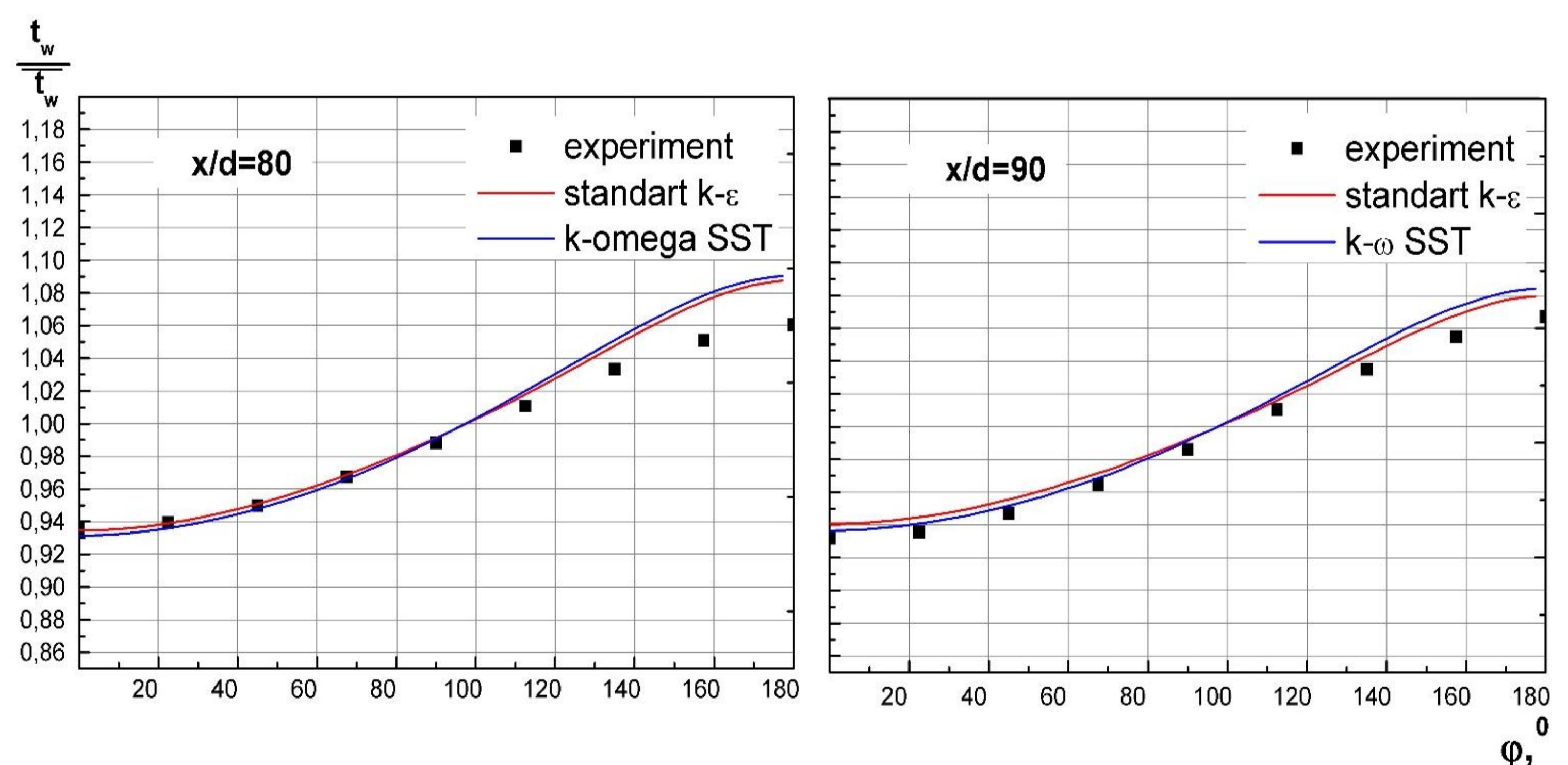
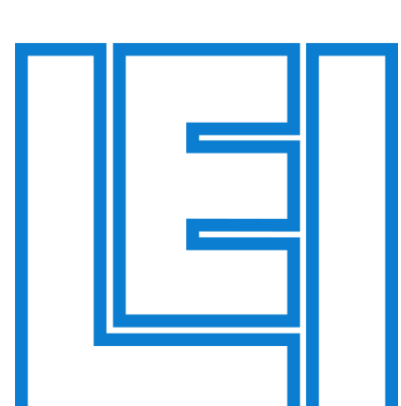


Fig. 3. Relative wall temperature t_w/t_w^0 variation over the perimeter of the tube

The modeling results of both turbulent transfer models were compared with experimental data (Fig.2 and Fig.3). In the case of the $k-\epsilon$ turbulent transfer model, simulated results showed an unsatisfactory agreement with the experimental data: the modeled Nusselt number (\overline{Nu} , averaged over the tube perimeter) was about 60 % larger than the one obtained in the experiments. This was caused by an overestimation of the turbulent transport in the model, which resulted in a decrease in the average wall temperature around the perimeter of the tube. However, the relative local temperature variation around the perimeter was like the experimental one. In the case of the SST $k-\omega$ turbulence model, the comparison showed that the modeling results reasonably well agree with the experimental \overline{Nu} in the thermally stabilized region ($50 < x/d < 100$). Here averaged over the perimeter \overline{Nu} being only 5 - 10% smaller than the experimental one. The relative local temperature variation around the perimeter was close to the experimental one. The methodology and results presented here will serve as a reference for future wider research on heat transfer in helically coiled tubes of different geometric variations.

REFERENCES

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- [2] Poskas P. And Mikaila V., Local heat transfer in coils, Proceedings of the First Baltic Heat transfer Conference, Göteborg, Sweden, 1991, pp. 524 – 531.



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