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SIMULATION OF TEMPERATURE DISTRIBUTION AND HEAT TRANSFER COEFFICIENT IN INTERNALLY RIBBED TUBES

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Abstract

This paper puts forward modelling thermal and flow phenomena in internally rifled tubes. The proposed model is a distributed parameter model based on solving balance equations describing the principles of the mass, momentum and energy conservation. The model enables an analysis of transient-state processes. The aim of the calculations is, among others, to find the distribution of the fluid enthalpy, mass flow and pressure in internally rifled tubes and to determine the heat transfer coefficient. The analysis concerns tubes arranged vertically and operating at supercritical steam parameters. The numerical calculation results will be compared to values obtained from CFD modelling.

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Keywords: supercritical boiler; internally rifled tubes; mass, momentum and energy conservation equations; thermal load

1. Introduction

Both internally rifled and smooth tubes are now in common use in many industrial devices and processes. They are widely used in refrigerating engineering (small-diameter tubes in particular) and in power boilers. Owing to such solutions, the heat exchanger size can be reduced and the permissible tube wall temperature is not exceeded in flows threatened with a boiling crisis, i.e. in cases where departure from nucleate boiling (DNB) occurs. The application of rifled tubes with internal spiral ribs in power boilers makes it possible to avoid many costly failures arising from the

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material overheating. The issues related to lengthening the life of the boiler components, including thick-walled elements, and to improving their efficiency are presented in [1].

The use of internally rifled tubes with spiral ribs in the boiler evaporator involves a change in thermal and flow processes. The fluid moves spirally inside the tubes, which helps to intensify the heat transfer, and – if a boiling crisis occurs – makes it possible to maintain the water film on the tube surface. This is due to the centrifugal force arising in the fluid, which throws heavier droplets onto the wall. The process enables steady collection of a large heat flux even for a high content of the gaseous phase in the fluid and, as a result, makes it possible to keep a safe temperature of the tube wall.

In the case of supercritical boilers, rifled tubes are placed in zones with the highest local thermal load. Such a solution is adopted in circulating fluidized-bed (CFB) boilers, where the wing walls are made of internally rifled tubes with spiral ribs, and where the spiral tube arrangement of the furnace chamber waterwalls is not applied due to enhanced erosion caused by the circulating material.

This paper presents the calculation results of thermal and flow phenomena occurring in internally rifled tubes for a medium with supercritical parameters. The results were obtained by means of a numerical analysis and CFD modelling. It also presents the mass, momentum and energy conservation equations with distributed parameters. The equations were used in an in-house program written in the Fortran language and intended for numerical calculations [2]. The CFD modelling was carried out using the Ansys Fluent software package [3].

Nomenclature

A	surface area, m^2
c	specific heat, J/(kgK)
d	diameter, m
g	gravitational acceleration, m/s^2
G	mass flux, $kg/(m^2s)$
h	enthalpy, J/kg
k	thermal conductivity, W/(mK)
L	length, m
m	mass flow, kg/s
p	pressure, Pa
q	heat flux, W/m^2
r	radius, m
t	temperature, °C

Greek letters

α	heat transfer coefficient, $W/(m^2K)$
Θ	temperature, °C
ρ	density, kg/m^3
τ	time, s
φ	tube inclination angle, deg

Criterial numbers

Nu	Nusselt
Pr	Prandtl
Re	Reynolds