Heat transfer distribution on surfaces under an array of impinging jets with various nozzle shape

Abstract

This study analysed the influence of a various nozzle shape and temperature of a cooled surface on the Nusselt's number distribution under impinging cooling system. An impingement cooling system is an array of jets with high velocity fluid which is made to strike a target surface. The setup consisted of a cylindrical plenum with an inline array of impinging jets. Cylindrical, cylindrical elongated, convergent and divergent shape of a nozzles and various heat fluxes $q_w(x)$ on the cooled surface have been considered. The 3D analysis of the heat transfer characteristics were carried out using Computational Fluid Dynamics (CFD) software Ansys CFX, using the Reynolds-Averaged Navier-Stokes approach (RANS). In the present investigation the k–ω shear stress transport (SST) turbulence model was used. Flow and pressure drop characteristics, circularity and Nusselt's number distribution were determined on their basis. The investigation was limited to the steady state assumption and dynamic features of the impinging jets were ignored. The velocity of the flow $\boldsymbol{u} = (u_I,0)$ at the inlet of the supply tube 15 m/s was constant for all analyses and is prescribed to obtain the Reynold's number Re = 4800. To simplify the analysis, the incompressible, viscous fluid flow was considered.

To validate the numerical technique and the solution procedure the comparison of numerical results of an impingement cooling system with experimental were performed which showed satisfying agreement.

At the beginning of the calculations the most effective relative distance OW = Y/D and the relative jet position WR = S/D were determined. Following examinations were focused on a various geometry of the nozzles and a constant heat flux q_w. For the cylindrical ones, the highest averaged Nusselt's number $\overline{Nu} = 4{,}59$ was achieved.

Finally numerical calculations were performed for various geometry of the nozzles and various heat flux $q_w(x)$ from the range 0–5000 W/m^2. For the heat flux 5000–2500 W/m^2 very similar values of the Nusselt's number along the cooled surface were noticeable.

Presented results prove that shape of the nozzles as well as surface temperature distribution have an impact on the thermal stresses reduction of the cooled surface.