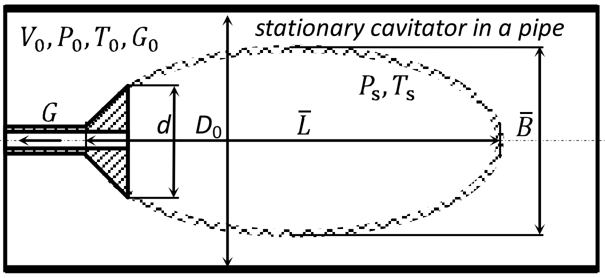
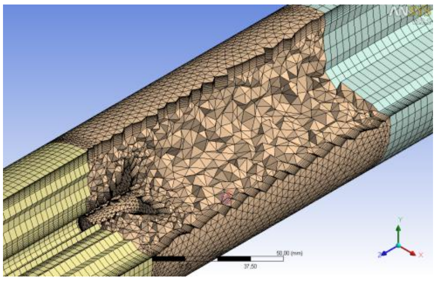
Modeling of steam extraction during hydrodynamic supercavitation on a stationary cone in the constrained stream

Likhachev D. S., Harbin Institute of Technology, goodwizard@yahoo.cn

Aim of research is to create mathematical model for experimental relationships $\overline{\mathrm{L}}, \overline{\mathrm{B}} = \varphi(\chi, \mathrm{d}/\mathrm{D}_0, \mathrm{Fr}, \mathrm{Re}, \mathrm{T}_0/\mathrm{T}_\mathrm{s}, \mathrm{G}/\mathrm{G}_0)$, which will describe data in a wide range of stream constrain coefficients with satisfactory accuracy, including influence of forced steam extraction and phase changes on the cavity boundary. Where $\chi = 2\,(\mathrm{P}_0 - \mathrm{P}_\mathrm{s})/\rho \mathrm{V}_0^2$ – cavitation number, ρ – liquid density; d/D_0 – degree of flow constrain; $\mathrm{Fr} = \mathrm{V}_0/\sqrt{\mathrm{gd}}$ – Froude number, where g – acceleration of gravity; $\mathrm{Re} = \mathrm{V}_0\mathrm{d}/\nu$ – Reynolds number, where ν – kinematic viscosity; $\mathrm{T}_0/\mathrm{T}_\mathrm{s}$ – degree of underheating; G/G_0 – steam extraction rate. Index 0 – inlet parameters, index s – saturation.





Inlet section to the left and outlet section to the right meshed using sweeping method, as central part using patch-independent tetrahedral method. Every solid wall have inflation layer of 10 prismatic elements to accurately resolve shape of boundary layer near the wall. Overall mesh quality is suitable for CFD simulation, and coarse indeed to meet system requirements of personal computer.

Two-phase steady-state simulation with help of ANSYS 12.1 uses water and water steam with real properties and compressibility calculated prior to solution. Both phases are continuous in this simulation; therefore effect of natural steam entraining is not simulated. Flow is considered to be homogeneous and isothermal. Full buoyancy model is chosen. Calculation of saturation pressure P_s and temperature T_s is done with help of set of equations IAPWS-IF97, which is coupled with solver through user variables. Series of numerical experiments conducted to resolve multifactor response. Influence of each factor T_0,°C (25; 45), V_0, m/s (14;16), G, kg/s (0.1; 0.2) coupled with other two factors, total for eight experiments.

Solutions have a good correlation with experimental data. Observation of qualitative behavior for solution results can be generalized in following statements:

1) Cavity length increases with growth of inlet temperature. Temperature growth considerably increase influence of heat-mass transfer processes on sizes of the cavity. Preliminary analysis shows that with coefficient of flow constrain fixed ($\mathrm{d}/\mathrm{D}_0 = 0.5$ in this example), increasing of liquid temperature at inlet of evaporation chamber results in development of cavity sizes, because steam mass flow inside the cavern increases with upstream temperature rise. Moreover, temperature growth at inlet increases saturation pressure of steam, and that consequently, leads to low cavitation number flow (relative cavity length enlarge).

2) Cavity length decreases and become thin with growth of specific steam extraction rate. Increasing steam extraction ratio results in diminishing of the cavity relative length, and cavitation number calculated basing on pressure in the cavity is enhanced. Cavity length reduction during steam extraction leads to activation of reverse stream and non stationary of cavern surface.

3) Cavity length increases with growth of inlet velocity. This in obviously stated in equation for cavitation number $\chi = (\mathrm{P}_0 - \mathrm{P}_\mathrm{s})/\rho \mathrm{V}_0^2$, denominator rise gives smaller χ, which is associated with longer cavity. Therefore, this result shows compliance with fundamental theories.