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FEA Simulation of Boiling Crisis Effect on Two-Phase Flow

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***Abstract* - Flow transition from one liquid phase to vapour phase and vice versa is encountered in almost all types of power generation systems. As a result, there is certain equipment as well as vessels that are designed for handling such two-phase mixtures of handling fluid. The design of these devices has become critical in order to account for and incorporate the phenomenon of such instabilities. Perhaps the most intriguing aspect is that, despite significant advances in the field of fluid and thermal science research, it is still impossible to predict the arrival and oscillation of these instabilities accurately. Understanding of it, as well as identifying future work to prevent such instabilities in heat. Any mathematical model cannot fully explain the variation in amplitudes of flow parameters caused by such instabilities. This is possibly why these undesirable effects cannot be completely eliminated, but can be minimized so that they do not interfere with system operation. So, the goal here is to categorize flow instabilities, consolidate basic knowledge about them, and identify future work to prevent such instabilities in heat transfer equipment by using numerical simulation. Due to rapid changes in the main variables, the flow excursion instability could cause severe damage in thermo-hydraulic components. This phenomenon is investigated in this paper by simulating the system's transient behavior during the process by using simulation in CFD tool.**

Keywords: Two phase flow, instabilities, CFD simulation.

I. INTRODUCTION

Heat transfer involving phase change operation has been most widely used covering its range of application from household equipment like refrigerator to modern advanced power plant where in boiler is used as essential device for heat generation.

The study of two-phase flow instabilities yielded important results for the design and operation of many industrial systems and equipment, including steam generators, boiling water nuclear reactors, heat exchangers, thermo-syphons, re-boilers, refrigeration plants, and some chemical processing systems. This is the most common type of static oscillation. There are two limiting cases, which correspond to all vapour and all liquid (dotted lines). The characteristic pressure drop of two-phase flow systems may exhibit an N-shape curve for a given set of parameters (Q, Tin, Ki, P). Thus, the operation points would be stable or unstable depending on the external system's characteristic pressure drop. In some cases, the occurrence of instability in industrial systems may cause the system to burn out due to a sudden change in the operation state. When the flow rate is reduced from a single-phase liquid region, the system abruptly transitions to a two-phase state with a high generation of vapour. Two pressurized tanks, two valves, and a heated section comprise the most basic model used to study these types of thermo-hydraulic instabilities. The pressure difference between the two tanks acts as the driving force (external) in this model, and the external characteristic results in a quadratic decreasing curve as the valves open. The slope of the curve is close to infinity when the valve Kin is almost closed and zero when it is fully open. Because the high slope case is equivalent to a large serial array, the flow remains constant even if the pressure drops changes. A parallel array tube heat exchanger, on the other hand, is equivalent to a zero slope.

II. CFD SIMULATION

The cylindrical vessel is of enclosed type having one inlet and one outlet in axial direction. The cylindrical vessel is made of mild steel pipe with internal diameter as 100 mm and outer diameter as 150 mm. To observe phenomena and its effect in very local region consider a test section length as 300 mm. Modeling of cylindrical component made using Creo parametric software and then its CFD simulation carried out in CFD software ANSYS FLUENT.

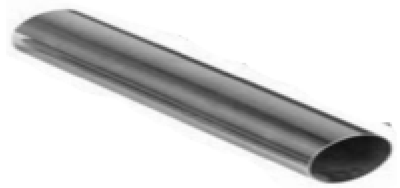

Figure 1: 3D Model of cylindrical vessel

A) Meshing of 3D Model

For the CFD analysis carried out by two methods one considering the geometry of enclosing body as solid and fluid

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as void. Second method in that neglecting the geometry of the enclosing body and considering only fluid volume for analysis. For the first run analysis, both the methods have been considered and results found most near for both of these cases but later in consecutive runs, adopted 1st method for analysis. The meshed model is shown in fig. 2.

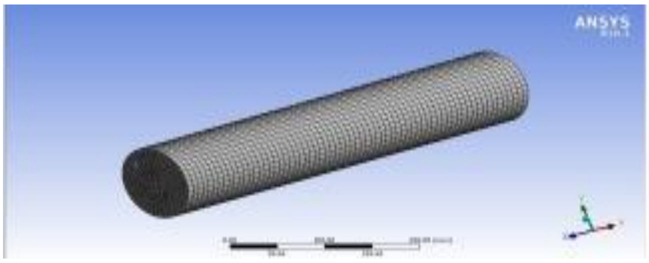


Figure 2: Mesh Model of cylindrical vessel

B) Boundary Conditions

- Velocity = 0.5 m/s
- K-epsilon flow model
- High Temperature at surface ≥ 200 ^{o}C
- Pressure Difference at outlet = 0

C) Assumptions used for simulations

The numerical model used to describe the evolution of the system is based on the following assumptions

- Steady state conditions and incompressible fluid flow.
- No leakage losses.
- Thermodynamic equilibrium between phases.
- Two-phase homogeneous model

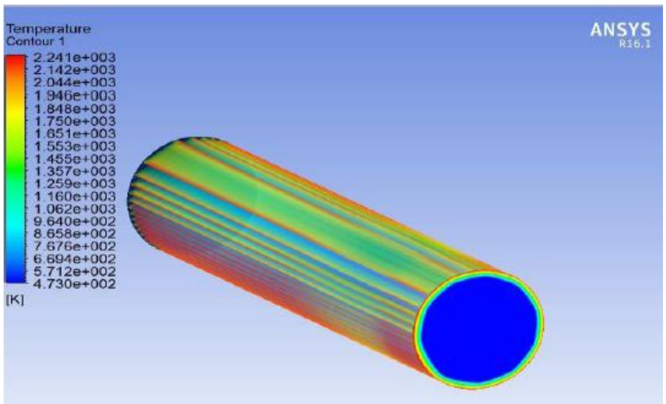
D) Post Processing

The numerically simulated thermal field of distilled water is used as a working fluid and therefore change in thermo-physical properties are subjected to change as simulated by software. The numerically simulated thermal field of boiling regime was analyzed to investigate the phenomenon of boiling crisis at 473K, 573K, and 723K at atmospheric pressure which gives the information about variation of temperature along the radial direction which is very complex and nearly impossible to predict by simple experiment.

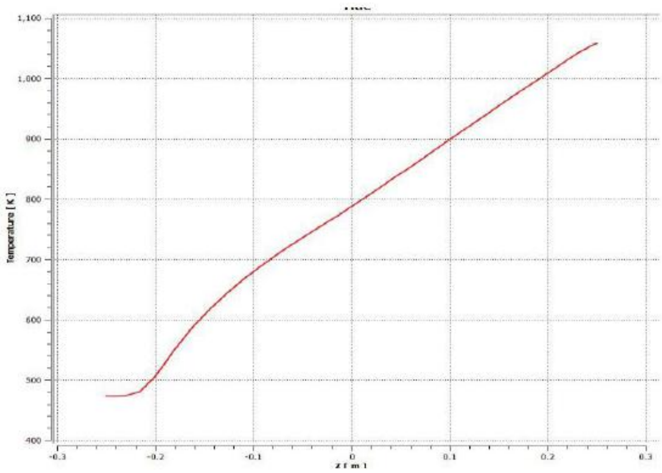
III. RESULT AND DISCUSSION

The numerically simulated thermal field of boiling regime was analyzed to investigate the phenomenon of boiling crisis at 473K, 573K, and 723K at atmospheric pressure which gives the information about variation of temperature along the radial direction.

A) Temperature Distribution

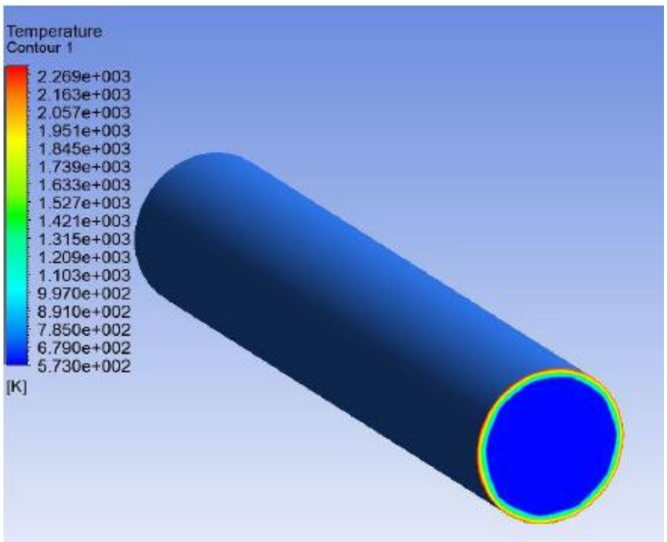


(a)



(b)

Figure 3: For 473 K temperature Distribution a) Contour of 3D model b) Along a non-dimensional radial thickness



(a)

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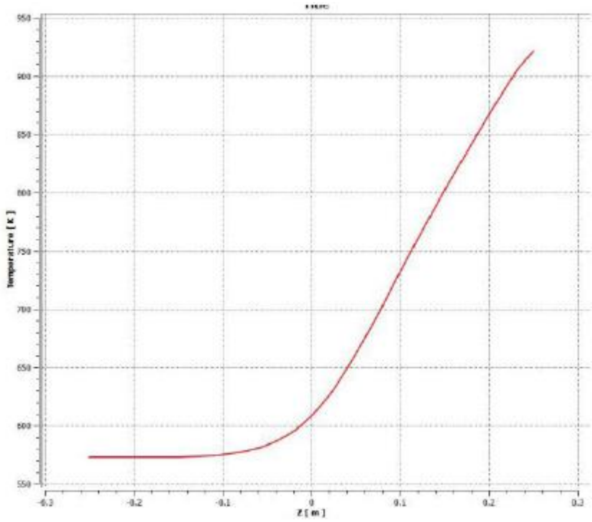
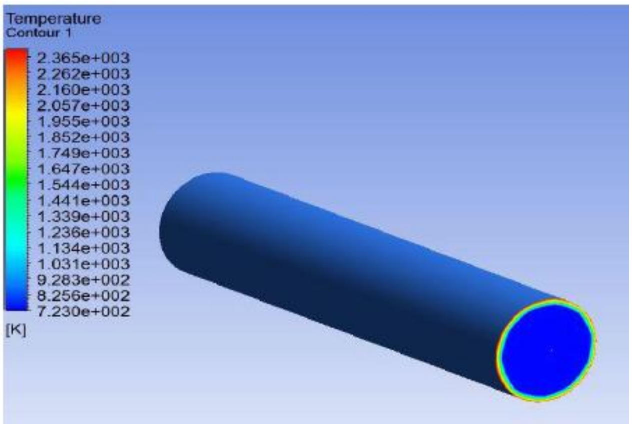
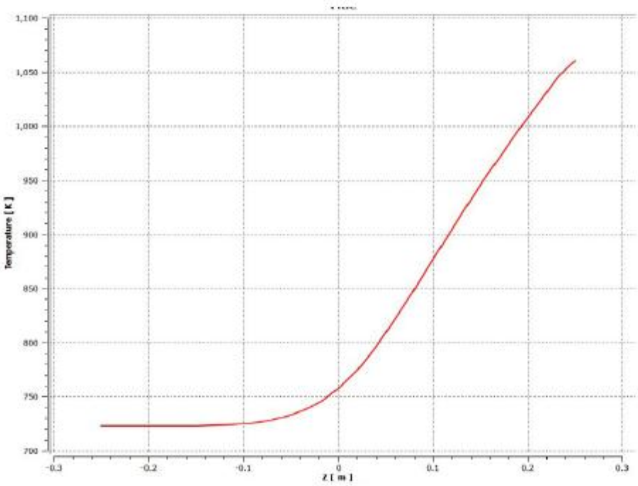


(b)

Figure 4: For 573 K temperature Distribution a) Contour of 3D model b) Along a non-dimensional radial thickness



(a)



(b)

Figure 5: For 723 K temperature Distribution a) Contour of 3D model b) Along a non-dimensional radial thickness

During the increasing of the mass flow rate, the delays in the propagation produce a positive curvature of the enthalpy profile and, in consequence, the pressure drop is higher if compared to the steady-state case. On the other hand, when the flow is decreasing the negative curvature of the enthalpy profile will produce lower values of the pressure drop. These changes in the characteristic curve are of particular importance.

IV. CONCLUSIONS

In this Paper the transient evolution was simulated for several conditions. In these simulations is possible to see that for an unstable point the system can evolve to both lower and higher flow rates. The dynamic changes of the characteristic pressure drop vs. flow rate curve due to delays in the propagation of the enthalpy information were studied. From CFD analysis it is very clear that after certain radial location there will be sharp rise in temperature. This location is known as critical location. This critical location becomes farther and farther with increase in temperature. This because at higher temperature bubbles are having higher energy and they are accumulated at farther distance forming a film at farther distance. The magnitude of rise depends upon flow properties, thermo-physical properties and surface geometry as well as fluid –surface interface properties. The rise of temperature past the critical location follows either nonlinear function or combination of non-linear function.

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