NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 4, ISSUE 8, Aug.-2017

VIBRATION ANALYSIS OF AN EVAPORATOR USING CHEMCAD

SAMEER M. WAGH
Laxminarayan Institute of Technology, RashtrasantTukadojiMaharaj Nagpur University, Nagpur, India, sameerwaghlit@gmail.com

DIVYA P. BARAI
Laxminarayan Institute of Technology, RashtrasantTukadojiMaharaj Nagpur University, Nagpur, India, divyapbarai@yahoo.co.in

MEGHA H. TALWEKAR
Laxminarayan Institute of Technology, RashtrasantTukadojiMaharaj Nagpur University, Nagpur, India, mtalwekar@yahoo.com

ABSTRACT

CHEMCAD is a powerful and effective software tool for chemical process simulation. Evaporator consists of a heat exchanger for boiling the solution with special provisions for separation of liquid and vapour phases.Calandria Evaporator also called as short-tube vertical evaporators are widely used in industries.In this paper, the vibration analysis for acalandria evaporator is carried out using CHEMCAD. The change in the values of cross flow velocity, critical velocity, vortex shedding frequency, turbulent buffeting frequency and natural frequencythroughout the length of tube is noted and graphs are plotted for every vibration mechanism against the tube length. It is observed that these vibration mechanisms increase from inlet to the center but decrease as they approach to the outlet. This kind of analysis is reported to be one of the basic ways to study the vibration mechanisms incalandria evaporator.

KEYWORDS: Vibration analysis, calandria evaporator, CHEMCAD

INTRODUCTION

CHEMCAD is software which is capable of modeling continuous, batch and semi-batch processes. CHEMCAD can simulate both steady-state and dynamic systems. This program is used extensively around the world for the design, operation, and maintenance of chemical processes (Chemstations, Inc., 2007). It can increase productivity and improve engineering decisions in chemical industry.

Vibration of tubes in evaporator is an important limiting factor in evaporator operation. It is required to have a design which is absolutely safe against the failure of tubes due to flow-induced vibration. Danger of failure arises when the frequency of the tube vibration becomes appreciably high.In case of heat exchangers, vibration becomes a problem when the intensity increases to the point that it causes some part of the exchanger to fail mechanically, it upsets the processconditions, or it creates a condition that endangers those who must work in the area.Prolonged tube vibration with large amplitudes leads to the mechanical failure of tubes, which then permits leakage between the shellside and tube side fluids. So, careful designs are made to minimize unwanted vibrations. Most sophisticated thermal design software packages carry out vibration analysis as a routine ingredient of thermal design(Patel, 2013). Design optimization of shell and tube heat exchanger by flow-induced vibration analysis also can be carried out (Gawande et al., 2011).The following flow-induced vibration mechanisms are considered by CHEMCADto investigate themechanical stability of a calandria evaporator.

NATURAL FREQUENCY

One of the variables that affect the natural frequencies is the length of the unsupported spans. It is the frequency at which a system tends to oscillate in the absence of any driving force. It is the frequency at which the tubes vibrate. The natural frequency of the evaporator is an essential step in estimating its potential for its flow induced vibration failure. Calculation of the natural frequency of the heat exchanger is an essential step in estimating its potential for its flow induced vibration failure (Patil et al, 2014)

VORTEX SHEDDING FREQUENCY

When steam flows across a single tube, it produces a series of vortices in the downstream wake due to the separation of flow alternately from opposite sides of the tube. This alternate shedding of vortices produces alternating forces, the frequency of which varies directly with the velocity of flow.For a given arrangement and tube size, the frequency of the vortex shedding for non-vibrating tubes increases as the velocity increases. The vortex shedding can excite tube vibration when it matches the natural frequency of the tubes (Schlunder, 1983). Evaporators are recommended to be designed so that the natural frequency of the tubes is always greater than the frequency of the vortex shedding.

TURBULENT BUFFETING FREQUENCY

Turbulent buffeting is the fluctuating forces acting on tubes due to extremely turbulent flow on shell side of the gas. When basic frequency of turbulence pulsating is proximal or equal to natural frequency of tube, fierce vibration will take place. Turbulence is generated when shell side fluid flow through tube bundle.This turbulence buffets the tubes which selectively extracts energy from the turbulence at their natural frequency. So, there is greater impact of the velocity of the flowing fluid on turbulent buffeting frequency.

As the shell side fluid flows through a bundle of tubes, the velocity constantly changes in magnitude and direction. So, considering the cross-flow velocity and the critical velocity during the study of vibration becomes important.

CROSS-FLOW VELOCITY

The definition for cross-flow velocity usually considered when it comes to flow-induced vibration is based on the minimum flow area through a tube row perpendicular to the primary direction of flow. For an ideal tube bank the selected velocity is well defined.

Critical Velocity:

The critical flow velocity for a tube span is the minimum cross flow velocity at which that span may vibrate with unacceptably large amplitudes. The cross flow velocity should always be less than critical flow velocity. There are many design aspects of the evaporator on which the critical velocity of the shell side depends.

Evaporator consists of a heat exchanger for boiling the solution with special provisions for separation of liquid and vapour phases. Most of the industrial evaporators have tubular heating surfaces. The tubes upto 6 ft in length are used in these evaporators (Kern,1950).The liquor may be inside or outside the tubes. Steam is used as a heating medium, so the water in the solution is converted into vapour while the concentrated solution is removed as thickened slurry. In this paper, vibration analysis of calandria evaporator is carried out using CHEMCAD. Variation in the various vibration mechanisms of evaporator is studied. Attainability of the vibrations in the calandria evaporator is taken into account while designing. So, this work is useful while analysing vibrations in the evaporator at the initial stage of designing.

PROCEDURE

Vibration Analysis of calandria evaporator is carried out by noting the changes in the values of vibration mechanisms of natural frequency, vortex shedding frequency and turbulent buffeting frequency at inlet, center and outlet parts of tube from the results given by CC-THERM. Also, values of cross flow velocity and critical velocity are noted from the same results. Graphs are drawn depicting the various vibration mechanisms in the shell side throughout the length of the tube in the evaporator.CHEMCAD also shows whether the vibration is present or not in the equipment in the results generated.

RESULTS AND DISCUSSIONS

The values of the parameters at inlet, center and outlet of the evaporator found out by the vibration analysis of the calandria evaporator are shown in Table 1.

Table 1: Vibration analysis of calandria evaporator

Parameters	Inlet	Center	Outlet
Vortex Shedding Frequency (cycles/sec)	5.22	10.99	2.03
Turbulent Buffeting Frequency (cycles/sec)	8.18	17.23	3.18
Natural frequency (cycles/sec)	58.34	58.29	44.78
Critical Velocity (m/sec)	22.93	178.76	108.68
Cross-Flow Velocity (m/sec)	1.37	2.89	0.53

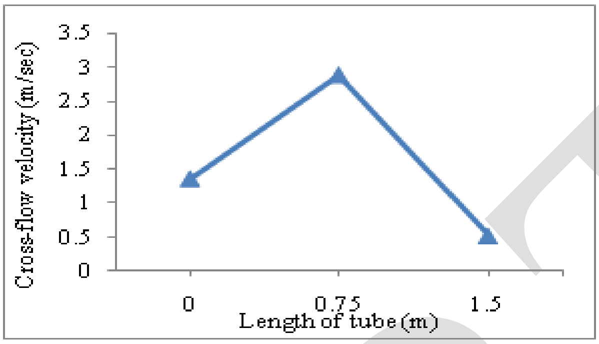

Figure 1: Cross-flow velocity vs length of tube

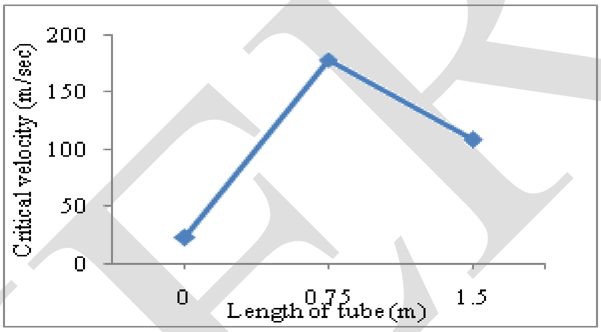

Figure 2: Critical velocity vs length of tube

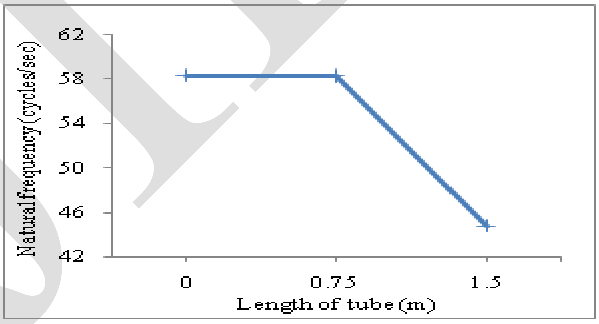

Figure 3: Natural frequency vs length of tube

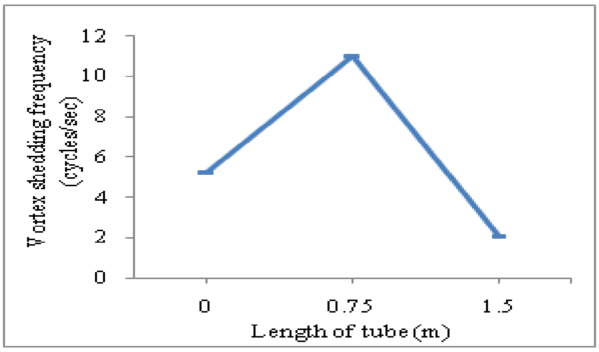

Figure 4: Vortex shedding frequency vs length of tube

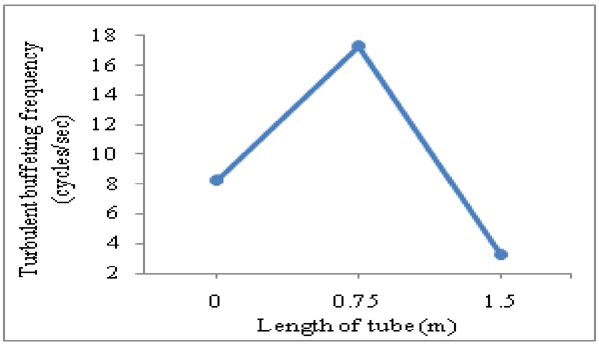

Figure 5: Turbulent Buffeting Frequency vs length of tube

Figure 1 depicts the cross-flow velocity against the length of tube for calandria evaporator at inlet, center and outlet of the shell side. It is observed that the cross flow velocity increases from inlet to center and then drastically decreases as it approaches to the outlet.The presence of pass partition lanes aligned in the cross flow direction, clearance between the bundle and the shell, tube-to-baffle hole annular clearances, etc. reduce the net flow rate of the shell side fluid in cross flow (Schlunder, 1983). The reduction in mass flow rate in the cross-flow direction of the shell leads to a decrease in the cross-flow velocity through the length of the heat exchanger from center towards the exit.

Figure 2 shows the critical velocity against the length of tube for calandria evaporator at inlet, center and outlet of the shell side. It is observed that the critical velocity increases from inlet to center and decreases from center to outlet.The length of tube is itself very less in case of calandria evaporator. So, the natural frequency of the tube is more. The vibration damping in such a shell of a calandria evaporator is also high because of less tube span. The critical velocity of a shell is directly proportional to the damping forces. Thus, the critical velocity in shell of calandria evaporator is more at the center. However, it tends to decrease a little from center to the outlet of the shell.

Figure 3 represents the natural frequency against the length of tube for calandria evaporator at inlet, center and outlet of the shell side. It is observed that the natural frequency is nearly constant from inlet to center and decreases from center to outlet.The natural frequency of the tubes is inversely proportional to the weight of the fluid inside it. There is more liquor in the bottom of the tubes. The weight of the fluid inside the tubes is more and thus, the natural frequency decreases.

Figure 4 indicates the vortex shedding frequency against the length of tube for calandria evaporator at inlet, center and outlet of the shell side. It is observed that the vortex shedding frequency increases from inlet to center and decreases from center to outlet.The vortex shedding frequency is directly proportional to the cross-flow velocity of the fluid in the shell. As we have already seen that the cross-flow velocity first rises from inlet to center and decreases till the outlet, the vortex shedding frequency also first rises from inlet to center and decreases till the outlet. The graph has similar characteristics to that of cross-flow velocity.

Figure 5 depicts the turbulent buffeting frequency against the length of tube for calandria evaporator at inlet, center and outlet of the shell side. It is observed that the turbulent buffeting frequency increases from inlet to center and decreases from center to outlet.The turbulent buffeting frequency is directly proportional to the cross-flow velocity of the fluid in the shell. As we have already seen that the cross-flow first rises from inlet to center and decreases till the outlet, the turbulent buffeting frequency also first rises from inlet to center and decreases till the outlet. The graph has similar characteristics to that of cross-flow velocity.

CONCLUSIONS

From the vibration analysis of calandria evaporator, it is found that thetube length has major impact on cross-flow velocity, criticalvelocity, turbulent buffeting frequency, vortex sheddingfrequency, tube natural frequency. The vibration analysis of the calandria evaporator indicated that the cross-flow velocity, critical velocity, vortex shedding frequency and turbulent buffeting frequencyincrease from the inlet to center and decreases as they approach to the outlet.But, natural frequency is nearly constant from inlet to center and decreases from center to outlet.

REFERENCES

I. Chemstations, Inc., CHEMCAD Version 6 User Guide (2007).

II. Patel, B. M. (2013). Vibration analysis of AES type shell and tube heat exchanger by HTRI software.*International Journal of Advanced Engineering Research and Studies, III/I*, 94-97.

III. Gawande, S.H., Keste, A.A., Navale, L.G., Nandgaonkar, M.R., Sonawane, V.J., Ubarhande, U.B. (2011). Design Optimization of Shell and Tube Heat Exchanger by Vibration Analysis.*Modern Mechanical Engineering*, 1, 6-11.

IV. Patil, R. V., Bhutada, S.S., Katruwar, N. R., Rai, R. R., Dhumke, K. N. (2014) Vibrational analysis of shell and tube type of heat exchanger in accordance with tubular exchanger manufacturer's association (Tema) norms.*The International Journal of Engineering and Science*, 3, 59-64.

V. Schlunder, E.U. (1983).*Heat Exchanger Design Handbook*, Dusseldorf:VDI-Verlag GmbH.

VI. Kern, D.Q. (1950).*Process Heat Transfer*, Kogakusha: McGraw-Hill.