Studies on Predicting Flow-Induced Vibration design of heat exchanger tubes

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ABSTRACT

Our research "Studies on Predicting Flow-Induced Vibration of heat exchanger tubes" is a procedures to carry out flow induced vibration, basically in the space of atomic reactor steam generator configuration, is introduced. This studio, started by the Electric Power Exploration Establishment (EPRI) was gone to by agents of major atomic reactor related organizations and examination research facilities. The goals of the studio were to: (1) recognize the irritating issues of stream actuated vibration in steam generator plan; (2) frame the best in class; and (3) characterize work expected to dispense with questions and give further comprehension of stream prompted vibration peculiarities and its implications as connected with steam generator plan and activity. A typical real life case study of flow induced vibration on heat exchanger tube subject to cross flow is presented in this study.

Key: Flow-Induced, Vibration, Heat Exchanger, Tubes, Vortex shedding, Turbulent buffeting, Fluid elastic instability.

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1.0 Introduction

The introductions depicting exploratory and scientific work may helpfully be isolated into three classifications: (1) fundamental lab work on straightforward configurations; (2) model investigations; and (3) field estimations. The members likewise examined two significant targets: the advancement of plan standards and the assessment of field fixes. Likewise, instrumentation issues were regularly referenced.

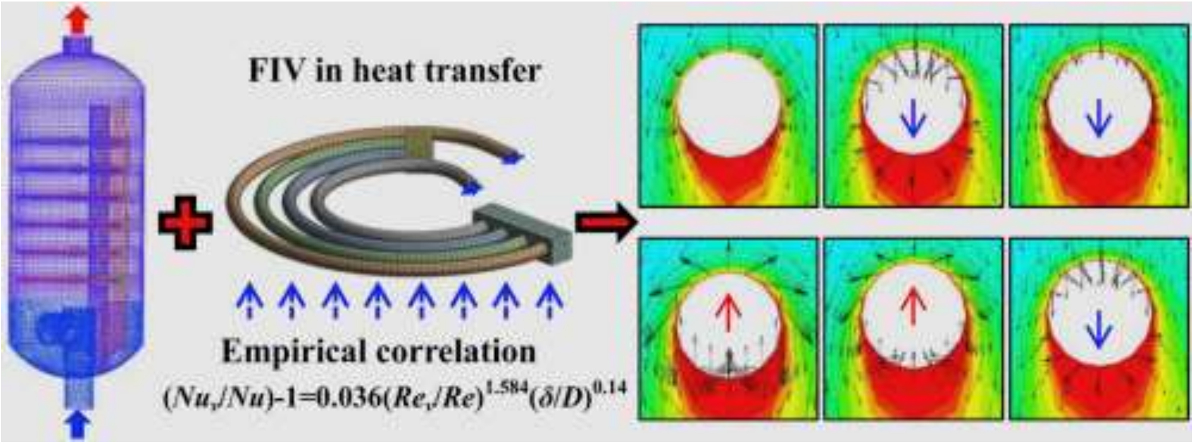

Fig.1: heat exchanger tubes subjected to turbulence

There was no conversation of involvement in no dismantling field fixes, like compound cleaning. Nearly al1 of the essential research facility work has involved estimating the vibratory reaction of a solitary roundabout chamber, common of one found in a steam generator, dependent upon opposite cross stream or estimating the fluctuating lift and drag powers answerable for the vibration. The stream is uniform, at speeds relating to Reynolds numbers somewhere in the range of 10^ and 5 x 10^ and at controlled isotropic choppiness levels of known scale. The chamber might be distant from everyone else or in a cluster, unbending or flexibly mounted.

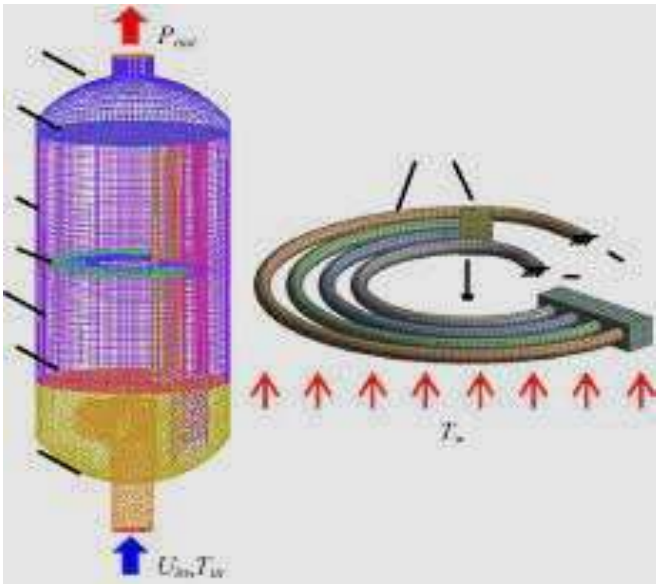

Fig.2: Flow-Induced Vibration of heat exchanger tubes flow.

The objective is to decide the impact of speed, choppiness level, and reproduced quality on the vibratory powers and reaction to confirm logical predications, and to foster plan rules. These examinations have brought about a decent subjective comprehension of the wake conduct of cross over stream around detached round chambers in the sub-, super-, and Trans basic locales and a sensible comprehension of the conduct in straightforward clusters. This work is presently being reached out to gauge the vibratory way of behaving of a few cylinders in a cluster.

The overall issue of vibration of primary components or framework parts created by liquid stream has happened to expanding significance lately. The enormous number of systems fit for delivering vibration is examined exhaustively in this paper. The vortex shedding, jogging and slamming vibrations of designs are covered and shudder is momentarily referenced. The complicated vibration modes created by vortex shedding in tube frameworks of cross-stream type heat exchangers are portrayed exhaustively and the development of commotion by reverberation with acoustic standing wave frequencies of the intensity exchanger vessel is additionally covered.

Process

From the outlook of stream actuated vibrations, U-curves of cylindrical intensity exchangers comprise basically quite possibly of the weakest area. The U-twists have moderately low out-of-plane recurrence empowering them to extricate energy from the shell stream at low stream speeds.

All distributed connections in the writing suggest the presence of an immediate connection between the stream speeds and the occurrence of huge amplitude tube vibrations. Subsequently it is vital to decide the speed profile in the U-twist area precisely. A technique to get a designing arrangement is proposed thus which might be used related to the accessible connections to foresee the chance of vibration dependably. Assurance of the stream profile might be additionally used to work on the evaluations of shell side heat move coefficients.

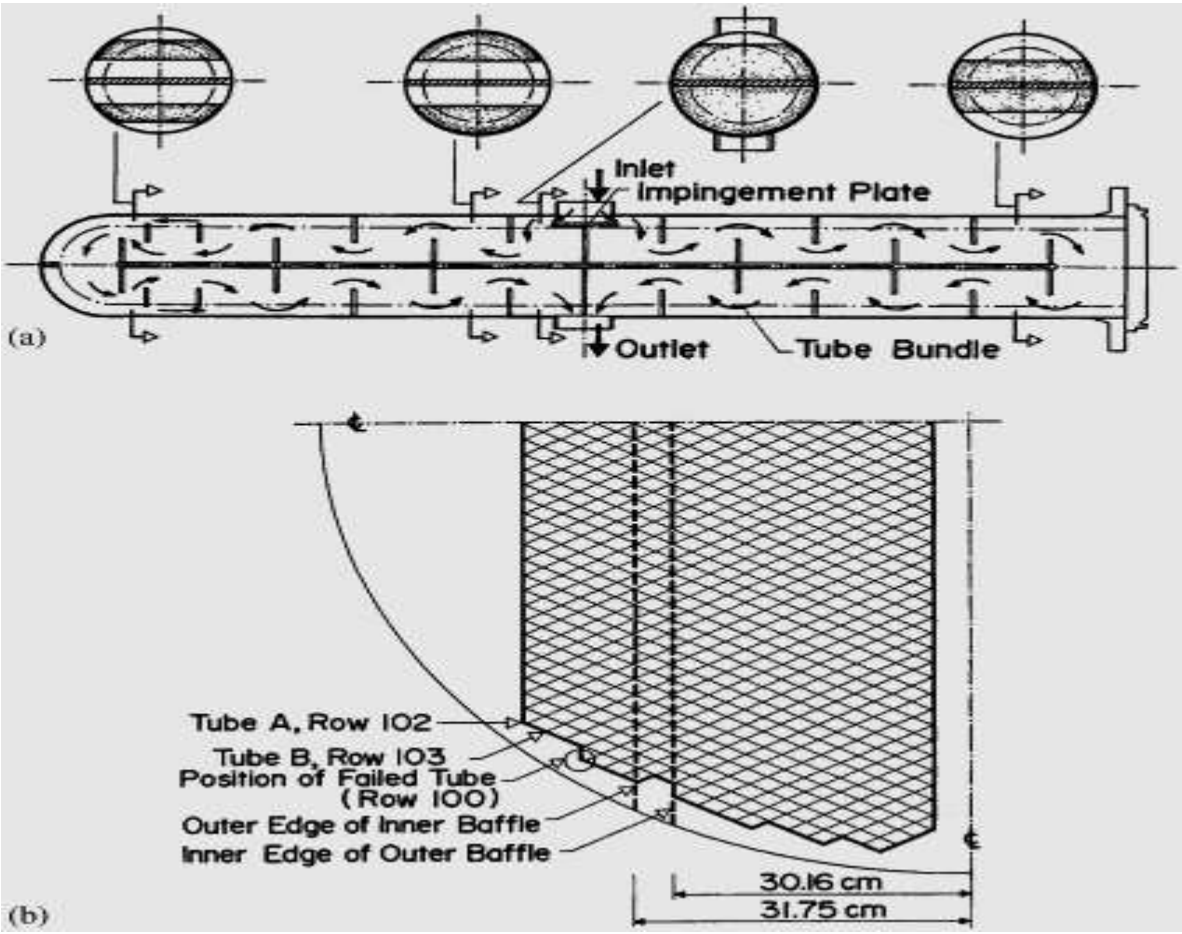

Fig.4: Heat exchanger tubes with baffle support subjected to cross flow

Stream prompted vibrations are generally perceived as a main issue in the plan of current cylinder and-shell heat exchangers. Tube disappointments brought about by unnecessary vibrations are somewhat ordinary and frequently pricey to fix. While impressive headway has been made in the advancement of prescient apparatuses, numerous vulnerabilities actually remain. This paper surveys our condition of comprehension of the cross stream excitation components and presents plan rules. Additionally examined are the exploration needs in this field.

2.0 Case Study: - FIV Check for Shell & Tube Heat Exchanger Straight Tube Material 304 S.S (18cr, 8 Ni)

This is a straight tube BEM Type Heat Exchanger. It has total 38 number of straight tubes. The O.D of tube is 15.870 mm and thickness is around 1.6 mm. he length of the tube is 2500 mm. The material of tube is 304 stainless steel (18cr, 8Ni). The tube type is plain, tube pattern is 60^o and pitch is 20 mm. The channel or bonnet is of material is 304 stainless steel (18cr, 8Ni). Also the Channel Cover is of same material. The Tube-sheet Joint is Groove/expand. The fluid allocation on shell side is Water and on Tube side it is Ammonia. On shell side the total fluid quantity is 6752.2 Kg/hr, whereas on tube side 164.05 kg/hr. The pressure (abs) on shell side is 500 Kpa. And on tube side it is 5719.0 Kpa. The Baffle is Double Segmental Type.

Table 1- FIV Check for Shell & Tube Heat Exchanger Straight Tube 304 Stainless steel.

Input Parameters	Straight tube
Tube outside diameter(mm)	15.87
ıside diameter(mm)	12.67
Tube material density (kg/mm^3)	8×10^{-6}
Tube pattern(degree)	60
Tube length(mm)	2500
Pitch(mm)	20
Shell side fluid	Water
Shell side fluid density (kg/mm^3)	1×10^{-6}
Shell side fluid cross flow velocity (mm/s) (U)	250
Tube side fluid density (kg/mm^3)	7.3×10^{-10}
Permissible stress value of tube material (N/mm^2)	55

Input data for the program is been taken from table-6.7. To check flow induced vibration response, Identify the tube span with pinned- pinned condition between two baffles.

2.1 Design Solution for Shell & Tube Heat Exchanger Straight Tube 304 Stainless steel.

Table 1:- Design Solution for Shell & Tube Heat Exchanger Straight Tube 304 Stainless steel.

Flow Excitation Mechanism	**Program Output**	**Hetran V8.0**	**Design acceptance**
I. Vortex shedding			
Strouhal Number S_u	0.684	0.6	
Lowest Natural Frequency, (Hz)	1.526	1.5	No Resonance
Vortex shedding Frequency, (Hz)	10.77	11	
Reduced Damping Parameter Cn	16.4	Not Available in Hetran	
Check for lift & Drag lock-in (i) $\frac{U}{fn*D} < 1$ Check for reduced damping(ii) **Cn>64** Check for lift dirc lock-in (iii) $\frac{U}{fn*D} < 3.3$	Ok Ok Ok	Not Available in Hetran	Ok; Both Lift & Drag direction lock-in are avoided.
Maximum Tube deflection (mm) **Acceptance Criteria** $y_{max} < 0.02D$	0.3174	Not Available in Hetran	Accepted
II. Turbulent buffeting			
Maximum Mean square response (mm) **Acceptance Criteria** $y_{rms} < 0.01$	0.25	Not Available in Hetran	Accepted
III. Fluid elastic instability			
Critical velocity (mm/sec) **Acceptance Criteria** $\frac{U}{U_{cr}} < 1$	500	505	Accepted

The program has checked vibration excitation response for all three mechanisms:-

2.2. Vortex shedding Check.

It shows lowest natural frequency as 1.526 Hz. The vortex shedding frequency is 10.77 Hz. The strouhal number is 0.684. The program has checked the phenomenon for vortex shedding and there is no resonance for this input parameters. Also it shows the vortex shedding frequency is in unacceptable range. The reduced damping Cn is 16.4. The tool checks the lift & drag lock-in criteria; here both lift & drag direction lock-in are avoided. The tool checks for maximum deflection due to vortex shedding & satisfies the acceptance criteria Ymax< 0.02D, and its Ok.. Maximum deflection due to vortex shedding at resonance is 0.3174 mm.

2.3. Turbulent Buffeting Check:-

The programme calculate mean square response for pinned-pinned span, and checks with recommended acceptance criteria. Here the turbulent buffeting response exceeds the acceptable range. The tool check for turbulent buffeting response mean square response for pinned-pinned span:- 0.435076 mm.

maximum value of deflection :- 0.254 mm. Here the programme calculates mean square response for pinned-pinned span, and checks with recommeded acceptance. The maximum value of deflection is calculated. Here the software is programmed and check acceptance of Yrms< 0.254 mm. Thus the output values are in acceptable range.

2.4. Fluid Elastic Instability Check:-

The Fluid Elastic Instability is avoided and calculates critical flow velocity for the selected tube layout. Here the Software calculates critical flow velocity for selected layout. The fluid elastic response is characterized by critical flow velocity which the amplitude of tube response is small and above which the amplitude becomes large, even with a small increase in velocity. Here the output values of fluid elastic instability are as below the critical flow velocity is 550 mm/sec. whereas minimum value of critical flow velocity is 250 mm/sec. so, as per design check U/Ucr<0.5, hence it is acceptable.

2.5 FIV design check report for Straight Tube Stainless Steel. (18Cr, 8Ni):-

Mechanical Details- Tubes			**Material- Stainless steel (18 Cr, 8 Ni)**		
Tube outside diameter	15.87	mm	Transverse pitch	20	mm
Thickness of Tube	1.6	mm	Longitudinal Pitch	20	mm
Tube Length	2500	mm	Density of Tube fluid	7.30E-10	kg/mm3
Density of tube material	8.00E-06	kg/mm3	Shell side fluid Velocity	250	mm/sec
Per. stress value of tube material	55	N/mm2	Density of shell side fluid	1.00E-06	kg/mm3
Moduls of Elasticity	2.00E+05	N/mm2	Viscosity of fluid	0.3545	
Baffle Thickness	6	mm	Specific heat ratio shell side gas	4.2582	
Baffle Hole Diameter	16.27	mm	Operating shell side pressure	0.1025	Kg/mm2
Baffle Spacing	273.8	mm			
Distance between reflecting wall measured parallel to segmental	450	mm			

Flow Induced Vibration Check

1	**VORTEX SHEDDING**		
	Lowest Natural Frequency (Fn)	1.526814	HZ
	Vortex Shedding(VS)Frequency	10.77586	HZ
	STROUHAL NUMBER	0.684052	
	Reduced Damping Cn	16.48644	
	Check 0.8Vs < Fn < 1.2Vs		
	IF RESONANCE OCCURS		
	Maximum Deflection due to Vortex shedding at resonance	0.3174	MM
2	**TURBULENT BUFFETING**		
	Mean Square Response for Pinned-Pinned span	0.435076	MM
	Maximum Value of Deflection	0.254	MM
3	**FLUID ELASTIC INSTABILITY**		
	Critical Flow Velocity for selected tube layout	194.7912	MM/SEC
	Minimum Value of Critical Flow Velocity	500	MM/SEC
	Reduced velocity Parameter	8.243221	

Fig 5 Design Solution for Straight Tube Stainless Steel. (18Cr, 8Ni)

3.0 Result & Discussion

After studying documented cases of heat exchanger tubes it is observed that the tool generates the result that almost match with the available industrial software HETRAN V.8.0 (ASME 2012).

The detailed observation are as follows:-

(a) For Vortex shedding check:

- The tool calculates strouhal number and vortex shedding frequency the results matches with the value obtained with industrial software HETRAN V8.0.
- The tool calculates the reduced damping parameter Cn and checks for lift and drag condition.
- The tool calculates the lower natural frequency and maximum deflection caused due to vortex shedding.
- It performs the additional check criteria tube deflection; which helps to know whether the deflection of tube due to vortex shedding is in acceptable range.

(b) For Turbulent buffeting check:-

- This is additional check carried out. The tool calculates mean square response for the tube.
- The tool calculates maximum deflection; and compares these value with the acceptance criteria . If the condition is satisfied then the tool generates a dialouge box indicating turbulent buffeting is in acceptable range.

(c) For Fuid Elastic Instability:-

- The tool calculates the critical flow velocity Ucr and checks with the acceptance criteria U/Ucr < 1. The condition is satified and fluid elastic instability is in acceptable range.
- Whereas; in HETRAN V8.0 (ASME 2012) the acceptance criteria is V/Vc >1.0, if the condition satisfies then vibration occurs.

The validation of developed tool using TEMA standards and available researches co-relations has been done.

CONCLUSION

It is to some degree deterring that the 1ist is by and large equivalent to the one created by the HTRI meeting quite a long while back. Of the four momentary examination subjects 1isted in the Theoretical, there has been genuine advancement in fluid elastic flimsiness standards; an exceptionally 1ittle advancement on damping information; practically none on information banks; and extremely 1ittle on normal recurrence estimations for any cylinder groups, 1 et alone U-tubes. For the 1ong term research subjects, there is by all accounts agreement on vibration instruments and their relative significance; a 1ittle advancement on hydrodynamic damping coefficients; problematic information on the connection among vibration and cylinder harm; and a few starter results for two-stage stream. With the exception of instrument and precariousness, each of the eight subjects are still of high need.

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