



Flow induced acoustic resonance in tubular heat exchangers

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FLOW INDUCED ACOUSTIC RESONANCE IN TUBULAR HEAT EXCHANGERS

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FLOW INDUCED ACOUSTIC RESONANCE IN TUBULAR HEAT EXCHANGERS

1. NOTATION AND UNITS

		Units	
		SI	British
С	velocity of sound (Equation (4.5))	m/s	ft/s
D	inside diameter of shell of circular duct	m	ft
d	outside diameter of tube	m	ft
f	frequency	Hz	Hz
<i>8</i> _c	constant of proportionality in Newton's second law of motion	_ (1.0)	lb ft/s ² lbf (32.18)
L	rectangular duct dimension	m	ft
М	Mach number, ratio of flow velocity to local speed of sound in fluid medium	_	-
MW	relative molecular mass (molecular weight)	kg/kmol	lb/lbmol
<i>n</i> , <i>m</i> , <i>p</i>	rectangular duct mode numbers for transverse, tube axis and gas flow directions respectively (Equation (4.1))	-	_
Р	pressure	N/m ² (Pa)	lbf/ft ²
р	tube pitch (Sketch 4.3)	m	ft
p_l	longitudinal tube pitch (Sketch 5.1)	m	ft
<i>P</i> _t	transverse tube pitch (Sketch 5.1)	m	ft
R	universal gas constant	J/kg mol K (8314.3)	ft lbf/lb mol°R (1545)
Re	Reynolds number = $\rho V d/\eta$	_	_
S	Strouhal number = $f d/V$	_	_
Т	absolute temperature	К	°R
V	flow velocity based on straight line gap or transverse flow area (Sketch 5.1)	m/s	ft/s
X _l	longitudinal tube pitch ratio, p_l/d (Sketch 5.1)	-	-

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X _t	transverse tube pitch ratio, p_t/d (Sketch 5.1)	_	_
x _g	vapour mass fraction (mass flow rate of vapour/total mass flow rate)	_	-
Ζ	gas compression factor	_	_
γ	ratio of gas specific heat capacities	_	_
Δ^*	Fitzpatrick's acoustic damping parameter, defined in Equation (6.3)	_	_
η	dynamic viscosity of gas	kg/m s	lb/ft s
λ	mode constant (Equation (4.3))	_	_
ρ	density	kg/m ³	lb/ft ³
ρ_g, ρ_l	gas and liquid phase densities respectively in a two-phase vapour-liquid flow	kg/m ³	lb/ft ³
σ	bundle solidity (Sketch (4.3))	_	_
Ψ	Chen's acoustic damping parameter, defined in Equation (6.2)	-	_

Extra subscripts

a	acoustic
е	excitation
eff	effective
g	gas or vapour phase
tp	two-phase
x, y, z	rectangular duct dimensions in transverse, tube axis and gas flow directions respectively
α	number of diametral pressure nodes in circular duct
β	number of concentric circular pressure nodes in circular duct