壓力變動時의 傳熱管內 2相流의 傳達函數

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Transfer Function of Two-phase Flow in a Heating Channel during the Change of System Pressure

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Abstract

Abstract-The pressure change which is often encountered during normal operation by the changes of system load and/or feedwater flow may induce flow oscillations or flow excursion in a heating channel. In this paper the transfer function will be derived to investigate the relationship between two-phase flow and the variation of system pressure under a few feasible assumptions. We got the simplified transfer function which might be possible to analyse the system instabilities qualitatively and quantitatively.

記 號 說 明

L_H	heating length	λ:	nonboiling length
ρ	density	ρ_H:	homogeneous density
g	gravity acceleration	g_c:	9.8
j_f	Volumetric flux	f:	Darcy-Weisbach friction factor
D_H:	hydraulic diameter	P_H:	heated perimeter
V	volume	α:	void fraction
h	enthalpy	Ac:	cross section
v	Specific volume	Ω:	characteristic frequency of phase change
t, T	time	K_i:	local friction factor of inlet
K_e:	local friction factor of exit	G:	mass flux

P: pressure

ρ_{fg}: $\rho_f-\rho_g$

h_{fg}: h_g-h_f

q'': heat flux

ν_{fg}: v_g-v_f

t_b: $t-T_Q$

Subscripts

AC: acceleration

BCY: buoyancy

g: saturated vapour

i: inlet

s: system

Q: liquid

1ϕ: Single-phase

Δ: variation

FR: friction

EXT: external

f: saturated liquid

e: exit

B: boiling

O: initial conditions

2ϕ: two-phase

$\langle\cdot\rangle$ cross-sectional average

Ⅰ. 序 論

原子爐의 倂列管이나 Boiler의 傳熱管은 正常흐름에서는 安全하나 水柱振動이나 2相流의 逸走現象이 일어날 때는 過熱 또는 破損 等의 事故가 發生하며 이러한 2相流의 不安定性은 設計 및 運轉條件의 影響을 받아 일어남으로 이들의 相互關係를 규명할 必要가 있다. 그러나 傳熱管內에서 誘起되는 流體의 不安定現象은 相當히 複雜한 現象이므로 이를 嚴密히 Model化하거나 數式化하는 것은 容易하지 않다.[1),2),3)] 따라서 系統을 單純化하기 위하여서는 若干의 合理的인 가정을 設定해야 되며 Lagrangian 觀點에서 보면 壓力變動과 2相流 사이는 線形化가 可能하고[3)] 또 比較的 간편한 傳達函數을 얻을 수 있으서 이들사이의 質的 및 量的인 解析이 可能해진다. 本 論文에서는 無次元化는 그 物理的인 意味를 상실하기 쉬우므로 될수록 避하기로 하며 다음의 假定下에 理論式을 求하고져 한다.

1. 2相流는 均質이며 一次流이다.
2. 熱流束은 軸方向으로 均一하며 時間的으로 不變한다.
3. 2相流는 非壓縮性이며 熱力學上 平衡狀態에 있다.
4. 磨擦損에 依한 Enthalpy 增加 및 流體粒子의 輸送에 依한 時間遲延은 無視한다.

Ⅱ. 本 論

Ⅱ-Ⅰ. 傳熱管內에서의 壓力緊下

傳熱管內에서의 流體의 壓力降下는 다음 式과 같이 表現할 수 있다.[4),6)]

$$\Delta P_{AC}+\Delta P_{FR}+\Delta P_{LOCAL}-\Delta P_{BCY}=\Delta P_{EXT} \quad\cdots\cdots(1)$$

(1)式의 第1項은 加速度에 依한 壓力降下로 다음과 같이 誘導할 수 있다.

$$\Delta P_{AC}=\Delta_{AC(1\phi)}+\Delta P_{AC(2\phi)}$$

$$=\int_0^{\lambda(t)}\frac{\rho_f}{g_c}\cdot\frac{dji(t)}{dt}dz+\int_{\lambda(t)}^{L_H}\frac{1}{g_c}\frac{\partial}{\partial t}\left[\langle\rho_H\rangle\cdot\langle j\rangle+\frac{\partial}{\partial z}\langle\rho_H\rangle\langle j\rangle^2\right]dz$$

윗式을 Lagrangian Form 으로 變換하면[3]

$$\Delta P_{AC}=\int_{o}^{\lambda(t)}\frac{\rho_f}{g_c}\cdot\frac{dj_i(t)}{dt}dz+\int_{\lambda(t)}^{L_H}\frac{1}{g_c}\Big[\langle\rho_H\rangle\cdot\Big(\frac{\partial\langle j\rangle}{\partial t}+\langle j\rangle\cdot\frac{\partial\langle j\rangle}{\partial z}\Big)\Big]dz$$

$$+\int_{\lambda(t)}^{L_H}\frac{\langle j\rangle}{g_c}\Big[\frac{\partial}{\partial t}\langle\rho_H\rangle+\frac{\partial}{\partial z}(\langle\rho_H\rangle\cdot\langle j\rangle)\Big]dz \cdots\cdots(2)$$

定常狀態에서 均質流의 一定流量方程式은 다음과 같다.

$$\frac{\partial}{\partial t}\langle\rho_H\rangle+\frac{\partial}{\partial z}(\langle\rho_H\rangle\cdot\langle j\rangle)=0 \cdots\cdots(3)$$

또
$$\frac{D_j(\ )}{Dt}\triangleq\frac{\partial(\ )}{\partial t}+\langle j\rangle\frac{\partial(\ )}{\partial z} \cdots\cdots(4)$$

로 정의한다면[3] (3)式을 (2)式에 代入하여 다시 整理하면

$$\Delta P_{AC}=\int_{o}^{\lambda(t)}\frac{\rho_f}{g_c}\Big(\frac{dj_i(t)}{dt}dz+\frac{1}{g_c}\int_{\lambda(t)}^{L_H}\langle\rho_H\rangle\cdot\frac{D_j\langle j\rangle}{Dt}dz \cdots\cdots(5)$$

傳熱管內에서 2 相流의 磨擦에 의한 壓力損失을 豫測하는 일은 쉬운 일이 아니지만 簡單의 假定下에서는 近似的으로 다음 式과 같이 表現할 수 있다.

$$\Delta P_{FR}=\Delta P_{FR}(1\phi)+\Delta P_{FR}(2\phi)$$

$$=\frac{f}{2D_H}\cdot\frac{\rho_f}{g_c}\int_{o}^{\lambda(t)}dj_i(t)dz+\frac{f}{2g_c\cdot D_H}\int_{\lambda(t)}^{L_H}\langle\rho_H\rangle\cdot\langle j\rangle dz \cdots\cdots(6)$$

傳熱管內에서 密度差에 依한 壓力變動, 즉 浮力에 依한 壓力變化는 一定流量方程式 및 Energy 保存法則에 依하여 求할 수 있다. 傳熱管內에서 質量損失은 發生하지 않으므로

$$\frac{\partial}{\partial t}\langle\rho_H\rangle+\frac{\partial}{\partial z}(\langle\rho_H\rangle\cdot\langle j\rangle)=\frac{\partial}{\partial t}[\rho_g\langle\alpha\rangle+\rho_f(1-\langle\alpha\rangle)]$$

$$+\frac{\partial}{\partial z}[\rho_g\langle\alpha\rangle+\rho_f(1-\langle\alpha\rangle)][\langle j\rangle]=0 \cdots\cdots(7)$$

均質流에서 Energy 方程式은

$$\frac{\partial}{\partial t}[\rho_g\cdot\langle\alpha\rangle\cdot h_g+\rho_f(1-\langle\alpha\rangle)h_f]+\frac{\partial}{\partial z}[\rho_g\cdot\langle\alpha\rangle\cdot h_g+\rho_f(1-\langle\alpha\rangle)h_f][\langle j\rangle]$$

$$=\frac{q''\cdot P_H}{Ac}+\frac{1}{J}\Big(\frac{\partial P}{\partial t}\Big) \cdots\cdots(8)$$

(7)式에 h_f 를 곱한 후 (8)式에서 이를 빼고, 또 軸方向의 壓力變化는 系統壓力에 比하여 근소하므로 이를 無視한다면 $\frac{1}{J}\times\frac{\partial P}{\partial t}\triangleq 0$ 이므로

$$\frac{\partial}{\partial t}\langle\alpha\rangle+\frac{\partial}{\partial z}(\langle\alpha\rangle\cdot\langle j\rangle)=\frac{\partial\langle\alpha\rangle}{\partial t}+\langle j\rangle\cdot\frac{\partial\langle\alpha\rangle}{\partial z}+\langle\alpha\rangle\frac{\partial\langle j\rangle}{\partial z}$$

$$=\frac{D_j\langle j\rangle}{\partial t}+\langle\alpha\rangle\Omega=\frac{q''\cdot P_H}{\rho_g\cdot Ac\cdot h_{fg}}=\frac{\nu_g}{\nu_{fg}}\Omega \cdots\cdots(9)$$

여기에서[8]

$$\Omega=\frac{\partial\langle j\rangle}{\partial z}=\frac{q''\cdot P_H\cdot\nu_{fg}}{Ac\cdot h_{fg}}$$

위 式은 Lagrangian 見地에서 常微分方程式으로 보고 解를 다음과 같이 求할 수 있다.

$$\alpha(z\cdot t_b)=\alpha(t_b)=\frac{\nu_g}{\nu_{fg}}(e^{-\Omega t_b}) \quad \cdots\cdots(10)$$

따라서 傳熱管內에서의 gas 의 總量은 (10)式을 積分하여 얻을 수 있다.

$$V_g=\int_{\lambda(t)}^{L_H}\frac{\nu_g}{\nu_{fg}}(1-e^{-\Omega t_b})dz=\int_{\lambda(t)}^{L_H}\frac{\rho_f}{\rho_{fg}}(1-e^{-\Omega t_b})dz \quad \cdots\cdots(11)$$

gas 와 液體의 比重差에 의한 壓力變動은

$$\Delta P_{BCY}=\frac{g}{g_c}\rho_{fg}\int_{\lambda(t)}^{L_H}\frac{\rho_f}{\rho_{fg}}(1-e^{-\Omega t_b})dz$$

$$=\frac{g}{g_c}\int_{\lambda(t)}^{L_H}\rho_f(1-e^{-\Omega t_b})dz \quad \cdots\cdots(12)$$

萬若 傳熱管의 入口 및 出口에 水柱振動을 防止하기 위한 orifce 를 設置했다면 이들에 依한 局部壓力降下는

$$\Delta P_{LOCAL}=K_i\frac{\rho_f}{2g_c}[j_i(t)]^2+K_e\frac{\langle\rho_H(L_H,t)\rangle}{2g_c}\cdot\langle j(L_H,t)\rangle^2 \quad \cdots\cdots(13)$$

(1)式에 (5), (6)(12), (13)式들을 代入하면 傳熱管內에서 全壓力降下는 (14)式과 같이 求할 수 있다.

$$\Delta P_{EXT}=\int_0^{\lambda(t)}\frac{\rho_f}{g_c}\left(\frac{dj_i(t)}{dt}\right)dz+\frac{1}{g_c}\int_{\lambda(t)}^{L_H}\langle\rho_H\rangle\cdot\frac{D_j\langle j\rangle}{Dt}dz$$

$$+\frac{f}{2D_H}\int_0^{\lambda(t)}\frac{\rho_f}{g_c}ji(t)^2dz+\frac{f}{2D_H}\int_{\lambda(t)}^{L_H}\frac{\langle\rho_H\rangle}{g_c}\cdot\langle j\rangle^2dz$$

$$-\frac{g}{g_c}\int_{\lambda(t)}^{L_H}\rho_f(1-e^{-\Omega t_b})dz+K_i\frac{\rho_f}{2g_c}\cdot j_i(t)^2$$

$$+K_e\frac{\langle\rho_H(L_H,t)\rangle}{2g_c}\cdot\langle j(L_H,t)\rangle^2 \quad \cdots\cdots(14)$$

Ⅱ-Ⅲ. 壓力變動時의 2相流의 傳達函數

그림 1은 傳熱管에 대한 斷面圖이며 $\lambda(t)$는 1ϕ의 液柱높이 이며 L_H는 傳熱管의 全길이 이다. T_Q 및 T_B는 流體粒子가 1ϕ 및 2ϕ를 通過하는데 所要되는 時間이다.

(1)式을 微分한 후 Laplace 變換하면

$$\delta\Delta P_{EXT(s)}=\delta\Delta_{AC(s)}+\delta\Delta P_{FR(s)}$$

$$+\delta P_{LOCAL(s)}-\delta\Delta P_{BCY(S)} \quad \cdots\cdots(15)$$

여기에서 $\delta\Delta P_{AC(s)}$는 (5)式의 積分方程式을 Leibniz' Rule 에 따라 微分한 후 Laplace 變換하면 얻을 수 있다.

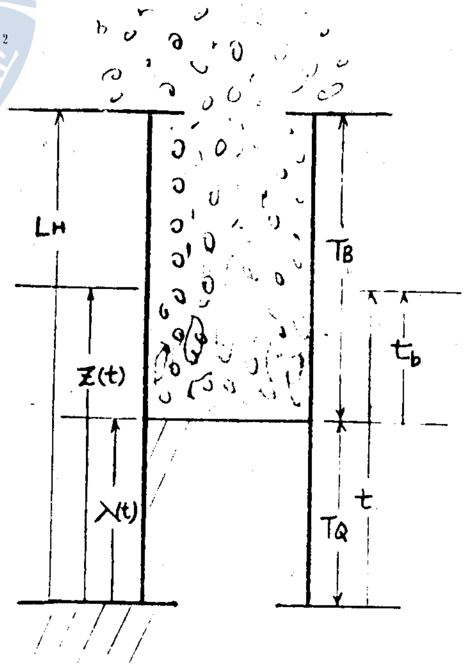

Fig. 1. Cross Section of a Heating Channel

$$\delta\Delta P_{Ac(s)}=\int_0^{\lambda_o}\frac{\rho_f}{g_c}\cdot s\cdot\delta ji_{(s)}dz$$

$$+\int_{\lambda o}^{L_H}\left[\frac{\langle\rho_{HO}(z)\rangle}{g_c}\delta\left(\frac{D_j\langle j(z,s)\rangle}{Dt}\right)\right.$$

$$\left.+\frac{\langle\delta\rho_{H(s)}\rangle}{g_c}\left(\frac{D_j\langle j\rangle}{Dt}\right)_o\right]dz-\frac{\langle\rho_{HO}(z)\rangle}{g_c}\left(\frac{D_j\langle j\rangle}{Dt}\right)_o\delta\lambda(s) \quad \cdots\cdots(16)$$

여기에서[3),7)]

$$\rho_{HO}(z)=\rho_{HO}(z,t_b)=\rho_f\cdot e^{-\Omega t_b} \qquad (17)$$

$$\delta\left(\frac{D_j\langle j(z,s)\rangle}{Dt}\right)=-\Omega^2\delta\lambda(s)+\Omega j_{io}(s)+s\delta j_i(s)$$

$$+[2\Omega(z-\lambda_o)+j_{io}]\left[\frac{q''\cdot P_H}{A_c\cdot h_{fg}}\right]\left[\frac{\partial\nu_{fg}}{\partial P_s}-\frac{1}{h_{fg}}\left(\frac{\partial h_{fg}}{\partial P_s}\right)\right]\delta P_{s(s)} \qquad (18)$$

$$\left(\frac{D_j\langle j\rangle}{Dt}\right)_o=\Omega[\Omega(z-\lambda_o)+j_{io}]=\Omega j_{io}e^{\Omega t_b} \qquad (19)$$

$$\langle\delta\rho_H(s)\rangle=\delta\rho_H(z,s)\rangle=\frac{\rho_f\cdot\Omega\cdot e^{-\Omega t_b}}{j_{io}}\left[\delta\lambda_{(s)}+\frac{(z-\lambda_o)}{j_{io}}\delta j_{i(s)}\right]$$

$$-\frac{\rho_f}{\Omega}(e^{-\Omega t_b}-e^{-2\Omega t_b})\left(\frac{q''\cdot P_H}{A_c\cdot h_{fg}}\right)\left\{\frac{\partial\nu_{fg}}{\partial P_s}-\frac{1}{h_{fg}}\left(\frac{\partial h_{fg}}{\partial P_s}\right)\right\}\delta P_s(s) \qquad (20)$$

$$\delta\lambda_{(s)}=T_Q\delta j_{i(s)}+\frac{\rho_f\cdot A_c\cdot j_{io}}{q''\cdot P_H}\left(\frac{\partial h_f}{\partial P_s}\right)\delta P_s(s) \qquad (21)$$

(17), (18), (19(, (20), (21)式들을 (16)에 代入한 후 다듬은

$$\delta\Delta P_{AC}(s)=\frac{\rho_f}{g_c}(\lambda_o+j_{io}\cdot T_B)s\delta j_{i(s)}+\frac{\rho_f}{g_c}\Omega[(L_H-\lambda_o)-j_{io}T_Q]\delta j_{i(s)}$$

$$+\frac{\rho_f}{g_c}j_{io}\left[\frac{(L_H-\lambda_o)\cdot g''\cdot P_H}{A_c\cdot h_{fg}}\left\{\frac{\partial\nu_{fg}}{\partial P_s}-\frac{1}{h_{fg}}\left(\frac{\partial h_{fg}}{\partial P_s}\right)\right\}\right.$$

$$\left.-\frac{\rho_f\cdot\nu_{fg}\cdot j_{io}}{h_{fg}}\left(\frac{\partial h_f}{\partial P_s}\right)\right]\delta P_{s(s)} \qquad (22)$$

同一한 方法으로 (6)式을 Leibniz' Rule에 따라 微分한 후 Laplace 變換하면

$$\delta\Delta P_{FR(s)}=\int_o^{\lambda_o}\left[\frac{f\cdot\rho_f\cdot j_{io}}{g_c\cdot D_H}\delta j_i(s)\right]dz+\frac{f\cdot\rho_f\cdot j_{io}^2}{2g_c\cdot D_H}\delta\lambda(s)$$

$$+\int_{\lambda_o}^{L_H}\left[\frac{f\cdot G_o}{g_c\cdot D_H}\langle\delta j(z,s)\rangle+\frac{f\langle j_o(z)\rangle^2}{2g_c\cdot D_H}\delta\rho_{H(s)}\right]dz-\frac{f\cdot G_o\cdot\langle j_o\rangle}{2g_c\cdot D_H}\delta\lambda(s) \qquad (23)$$

여기에서[3),7)]

$$\langle\delta j(z,s)\rangle=-\Omega\delta\lambda(s)+\delta j(z,s)$$

$$+\frac{(z-\lambda_o)q''\cdot P_H}{A_c\cdot h_{fg}}\left[\frac{\partial\nu_{fg}}{\partial P_s}-\frac{1}{h_{fg}}\left(\frac{\partial h_{fg}}{\partial P_s}\right)\right]\delta P_s(s) \qquad (24)$$

$$\langle j_o(z)\rangle=\Omega(z-\lambda_o)+j_{io}=j_{io}e^{-\Omega t_b} \qquad (25)$$

(20), (21), (24), (25)式들을 (23)式에 代入한 후 整理하면

$$\delta\Delta P_{FR(s)}=\frac{f\cdot\rho_f\cdot j_{io}}{g_c}\left[\frac{\lambda_o}{D_H}+\frac{(L_H-\lambda_o)}{4D_H}(e^{-\Omega T_B}+3-2\Omega T_Q)\right]\delta j_{i(s)}$$

$$+\left\{\frac{f\cdot\rho_f}{g_c}\cdot\frac{j_{io}(L_H-\lambda_o)^2}{4D_H}\left(\frac{q''\cdot\rho_H}{A_c\cdot h_f}\right)\left\{\frac{\partial\nu_{fg}}{\partial P_s}-\frac{1}{h_{fg}}\left(\frac{\partial h_{fg}}{\partial P_s}\right)\right\}\right.$$

$$\left.-\frac{f\cdot\rho_f^2\cdot j_{io}^2}{g_c\cdot D_H}(L_H-\lambda_o)\left(\frac{\nu_{fg}}{h_{fg}}\right)\left(\frac{\partial h_f}{\partial P_s}\right)\right\}\delta P_s(s) \qquad (26)$$

同一한 方法으로 (12)式으로부터 $\delta\Delta P_{BCY}(s)$를 求하면

$$\delta\Delta P_{BCY(s)}=\frac{g}{g_c}\rho_f(L_H-\lambda_o)\left(\frac{\Omega}{j_{io}}\right)e^{-\Omega T_B}\cdot\delta\lambda(s)+\frac{g}{g_c}\rho_f\left[T_B-\frac{(L_H-\lambda_o)}{j_{io}}e^{-\Omega T_B}\right]\delta j_{i(s)}$$

$$+\frac{g}{g_c}\rho_f\left[\frac{(L_H-\lambda_o)}{\Omega}e^{-\Omega T_B}-\frac{j_{io}\cdot T_B}{\Omega}\right]\left(\frac{q_o''\cdot P_H}{A_c\cdot h_{fg}}\right)\left[\frac{\partial\nu_{fg}}{\partial P_s}\right.$$
$$\left.-\frac{1}{h_{fg}}\left(\frac{\partial h_{fg}}{\partial P_s}\right)\right]\delta P_{s(s)} \quad\cdots\cdots(27)$$

$$\delta\lambda(s)=\frac{\delta j_{i(s)}}{S}+\frac{\rho_f\cdot A_c\cdot j_{io}}{q''\cdot P_H}\left(\frac{\partial h_f}{\partial P_s}\right)\delta P_s(s) \quad\cdots\cdots(28)$$

(21), (28)式을 (27)式에 代入하면

$$\delta\Delta\rho_{BCY(s)}=\frac{g}{g_c}\rho_f\left[(L_H-\lambda_o)\left(\frac{\Omega}{j_{io}}\right)e^{-\Omega T_B}+\frac{T_B}{T_G}-\frac{(L_H-\lambda_o)}{j_{io}T_Q}e^{-\Omega T_B}\right]\frac{\delta j_{i(s)}}{S}$$
$$+\frac{g}{g_c}\rho_f(L_H-\lambda_o)e^{-\Omega T_B}\left(\frac{\rho_f\cdot\nu_{fg}}{h_{fg}}\right)\left(\frac{\partial h_f}{\partial P_s}\right)\delta P_s(s)$$
$$+\frac{g}{g_c}\rho_f\left[\frac{(L_H-\lambda_o)}{\Omega}e^{-\Omega T_B}-\frac{j_{io}\cdot T_B}{\Omega}\right]\left[\frac{q''\cdot P_H}{A_c\cdot h_{fg}}\right]$$
$$\left[\frac{\partial\nu_{fg}}{\partial P_s}-\frac{1}{h_{fg}}\left(\frac{\partial h_{fg}}{\partial P_s}\right)\right]\delta P_{s(s)} \quad\cdots\cdots(29)$$

(13)式을 微分한 후 Laplace 變換하면

$$\delta\Delta P_{LOCA(s)}=K_i\frac{\rho_f}{g_c}j_{io}\delta j_{i(s)}+\frac{K_e\cdot\rho_f}{g_c}\left[j_{io}+\frac{\Omega}{2}(L_H-\lambda_o)\right]\delta j_i(s)$$
$$-\frac{G_o}{2g_c}K_e\cdot\Omega\cdot\delta\lambda(s)+\frac{G_o}{g_c}\cdot K_e(L_H-\lambda_o)\left(\frac{q''\cdot P_H}{Ac\cdot h_{fg}}\right)$$
$$\left[\frac{\partial\nu_{fg}}{\partial P_s}-\frac{1}{h_{fg}}\left(\frac{\partial h_{fg}}{\partial P_s}\right)\right]\delta\rho_s(s) \quad\cdots\cdots(30)$$

(30)式을 다시 整理하면

$$\delta\Delta P_{LOCAL}(s)=\left[K_i\frac{\rho_f\cdot j_{io}}{g_c}+\frac{\rho_f}{g_c}K_e\left\{j_{io}+\frac{\Omega}{2}(L_H-\lambda_o)-\frac{\Omega}{2}j_{io}\cdot T_Q\right\}\right]\delta j_i(s)$$
$$+\frac{G_o}{2g_c}K_e\left[(L_H-\lambda_o)\left(\frac{q''\cdot P_H}{A_c\cdot h_{fg}}\right)\left\{\frac{\partial\nu_{fg}}{\partial P_s}-\frac{1}{h_{fg}}\left(\frac{\partial h_{fg}}{\partial P_s}\right)\right\}\right.$$
$$\left.-\left(\frac{\rho_f\cdot j_{io}\cdot\nu_{fg}}{h_{fg}}\right)\times\left(\frac{\partial h_f}{\partial P_s}\right)\right]\delta P_s(s) \quad\cdots\cdots(31)$$

(22), (26), (29), (31)式들을 (15)式에 代入하면 願하는 傳達函數를 얻을 수 있다.

$$\delta\Delta P_{EXT(s)}=\left(AS+B+\frac{C}{S}\right)\delta j_i(s)+D\delta P_s(s)$$

다시 쓰면

$$\delta j_i(s)=\frac{S[\delta\Delta P_{EXT(s)}-D\delta P_s(s)]}{AS^2+BS+C} \quad\cdots\cdots(32)$$

萬若 正常運轉中 出力變動으로 系統壓力만이 變한다면 (32)式은

$$\frac{\delta j_i(s)}{\delta P_s(s)}=\frac{-DS}{As^2+Bs+C} \quad\cdots\cdots(33)$$

여기에서

$$A=\frac{\rho_f}{g_c}(\lambda_o+j_{io}\cdot T_B)$$

$$B=\frac{\rho_f}{g_c}\Big[\Omega\{(L_H-\lambda_o)-j_{io}\cdot T_Q\}+f\cdot j_{io}\Big\{\frac{\lambda_o}{D_H}+\frac{(L_H-\lambda_o)}{2D_H}\Big(\frac{e^{\Omega T_B}}{2}+\frac{3}{2}-\Omega T_Q\Big)$$

$$+K_i\cdot j_{io}+\frac{K_e}{2}\{\Omega(L_H-\lambda_o)+j_{io}(2-\Omega T_Q)\}\Big]$$

$$C=\frac{\rho_f}{g_c}\cdot g\Big[(L_H-\lambda_o)\Big(\frac{\Omega}{j_{io}}\Big)e^{-\Omega T_B}+\frac{T_B}{T_Q}-\frac{(L_H-\lambda_o)}{j_{io}\cdot T_Q}e^{-\Omega T_B}\Big]$$

$$D=\frac{\rho_f}{g_c}\Big[\Big\{-\rho_f j_{io}^2\Big\{1+\frac{f\cdot(L_H-\lambda_o)}{2D_H}+\frac{K_e}{2}\Big\}+\rho_f\cdot g\,(L_H-\lambda_o)e^{-\Omega T_B}\Big\}\Big\{\frac{\nu_{fg}}{h_{fg}}\Big\}\Big(\frac{\partial h_f}{\partial P_s}\Big)$$

$$+\Big\{j_{io}(L_H-\lambda_o)+\frac{f\cdot j_{io}}{4D_H}(L_H-\lambda_o)^2+g\Big[\frac{(L_H-\lambda_o)}{\Omega}e^{-\Omega T_B}-\frac{j_{io}\cdot T_B}{\Omega}\Big]$$

$$+\frac{K_e}{2}j_{io}(L_H-\lambda_o)\Big\}\Big\{\frac{q''\cdot P_H}{A_c\cdot h_{fg}}\Big\}\Big\{\frac{\partial\nu_{fg}}{\partial P_s}-\frac{1}{h_{fg}}\Big(\frac{\partial h_{fg}}{\partial P_s}\Big)\Big\}\Big]$$

Ⅲ. 結　　論

傳熱管內에서의 流體의 흐름은 數式으로 表現하기에는 複雜하지만 약간의 合理的인 假定을 두게 되면 Leibniz' Rule에 따라 線形化할 수 있고, 또 質的 및 量的인 分析이 可能한 2次系로 近似시킬 수 있다. 求하여진 傳達函數로 보아 傳熱管兩端의 壓力變化나 系統壓力變化 等에 依하여 流體振動이나 逸走現象이 若起될 것으로 豫想되며 따라서 原子爐의 一次系統의 순환 pump나 原子爐 및 Boiler의 出力變化, 給水量, 溫度變化 等에 의하여 2相流의 不安定現象이 發生하여 Burnout이 일어날 수 있을 것이다. 이를 防止하기 위하여서는 設計時 設計 및 運轉條件에 依하여 決定되는 係數 A, B, C, D에 對하여 充分히 考慮하여야 할 것으로 생각된다.

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