Orr-Sommerfeld eq. について

1. $R$ が微少変化に対する 固有値, 固有関数の変化

a) 固有値

b) 平均流の変化

Adjointによる [illegible]

2. $k$ の変化による 固有値の変化

3. $\psi = \int \hat{\psi}(\omega) e^{i\alpha x} \frac{d\alpha}{d\omega} d\omega$ 形式で どうか [illegible]

[illegible]

4. 固有関数の振巾の決定

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② 平均流れとの相互干渉

I. Adjoint eq.

II. 場の表現 — IV 固有値方程式 直交性 / Completeness ?

—(III ~~分母~~ までの [illegible] を [illegible]

III. 可逆定理

IV 固有

$$(\omega - kU)(k^2\phi - \phi_{yy}) - kU_{yy}\phi - i\nu\left(k^2 - \frac{\partial^2}{\partial y^2}\right)^2\phi = 0.$$

$$U \to U + \delta U, \quad \omega = \omega + \delta\omega, \quad \phi \to \phi + \delta\phi.$$

$$(\delta\omega - k\delta U)(k^2\phi - \phi_{yy}) + (\omega - kU)(k^2\delta\phi - \delta\phi_{yy}) - k\delta U_{yy}\phi - kU_{yy}\delta\phi$$

$$- i\nu\left(k^2 - \frac{\partial^2}{\partial y^2}\right)^2\delta\phi = 0$$

$$(\phi\hat\phi)_{yy} = \phi_{yy}\hat\phi + \phi\hat\phi_{yy} + 2\phi_y\hat\phi_y$$

$$\omega\langle k^2\phi\hat\phi + \phi_y\hat\phi_y\rangle - k\langle U(k^2\phi - \phi_{yy})\hat\phi + U_{yy}\phi\hat\phi\rangle - i\nu\langle k^4\phi\hat\phi + 2k^2\phi_y\hat\phi_y + \phi_{yy}\hat\phi_{yy}\rangle = 0$$

$$\langle U(k^2\phi\hat\phi - \cancel{\phi_{yy}\hat\phi} + \cancel{\phi_{yy}\hat\phi} + \phi\hat\phi_{yy} + 2\phi_y\hat\phi_y)\rangle$$

$$\delta\omega\langle k^2\phi\hat\phi + \phi_y\hat\phi_y\rangle + \omega\langle k^2\delta\phi\hat\phi + k^2\phi\delta\hat\phi + \delta\phi_y\hat\phi_y + \phi_y\delta\hat\phi_y\rangle$$

$$\delta\phi(k^2\hat\phi - \hat\phi_{yy}) + \delta\hat\phi(k^2\phi - \phi_{yy})$$

$$-k\langle\delta U(k^2\phi\hat\phi + 2\phi_y\hat\phi_y + \phi\hat\phi_{yy})\rangle - k\langle U\{\delta\phi(k^2\hat\phi + \hat\phi_{yy} - 2\hat\phi_{yy})$$

$$+ \delta\hat\phi(k^2\phi + \phi_{yy} - 2\phi_{yy})\}\rangle$$

$$-i\nu\langle\delta\phi(k^4\hat\phi - 2k^2\hat\phi_{yy} + \hat\phi_{yyyy}) + \delta\hat\phi(k^4\phi - 2k^2\phi_{yy} + \phi_{yyyy})\rangle = 0.$$

$$\delta\omega\langle k^2\phi\hat\phi + \phi_y\hat\phi_y\rangle - k\langle\delta U(k^2\phi\hat\phi + 2\phi_y\hat\phi_y + \phi\hat\phi_{yy})\rangle$$

$$+ \omega\langle\delta\phi(k^2\hat\phi - \hat\phi_{yy}) + \delta\hat\phi(k^2\phi - \phi_{yy})\rangle$$

$$- k\langle U\delta\phi(k^2\hat\phi - \hat\phi_{yy}) + U\delta\hat\phi(k^2\phi - \phi_{yy})\rangle$$

$$- i\nu\left\langle \delta\phi\left(k^2 - \frac{d^2}{dy^2}\right)^2\hat\phi + \delta\hat\phi\left(k^2 - \frac{d^2}{dy^2}\right)^2\phi\right\rangle = 0.$$

$$\therefore \quad \delta\omega\langle k^2\phi\hat\phi + \phi_y\hat\phi_y\rangle = k\langle\delta U(k^2\phi\hat\phi + 2\phi_y\hat\phi_y + \phi\hat\phi_{yy})\rangle$$

$$\langle(\delta\omega - k\delta U)(k^2\phi\hat\phi - \phi_y\hat\phi_y)\rangle + k\langle\phi\hat\phi_y\delta U_y\rangle \quad \ldots \quad (\phi\hat\phi_y)_y$$

$$\delta\omega_r \langle k^2\phi\hat{\phi} + \phi_y\hat{\phi}_y\rangle = k\langle \delta U(k^2\phi\hat{\phi} + 2\phi_y\hat{\phi}_y + \tfrac{1}{2}(\phi\hat{\phi}_{yy} + \hat{\phi}\phi_{yy}))\rangle$$

$$\delta\omega_i \langle k^2\phi\hat{\phi} + \phi_y\hat{\phi}_y\rangle = \frac{k}{2i}\langle \delta U(\phi\hat{\phi}_{yy} - \hat{\phi}\phi_{yy})\rangle = \frac{k}{2i}\langle \delta U_y(\phi_y\hat{\phi} - \hat{\phi}_y\phi)\rangle$$

$$\phi_y\hat{\phi}_y + \frac{1}{2}(\phi\hat{\phi}_{yy} + \hat{\phi}\phi_{yy}) = \frac{1}{2}(\phi\hat{\phi})_{yy}$$

$$\langle(\delta\omega_r - k\delta U)(k^2\phi\hat{\phi} + \phi_y\hat{\phi}_y)\rangle = \frac{k}{2}\langle \phi\hat{\phi}\,\delta U_{yy}\rangle.$$

$$\omega\langle k^2\phi\hat{\phi} + \phi_y\hat{\phi}_y\rangle = k\langle U(k^2\phi\hat{\phi} + 2\phi_y\hat{\phi}_y + \phi\hat{\phi}_{yy})\rangle$$
$$+ i\nu\langle k^4\phi\hat{\phi} + 2k^2\phi_y\hat{\phi}_y + \phi_{yy}\hat{\phi}_{yy}\rangle$$

$$\omega_r\langle k^2\phi\hat{\phi} + \phi_y\hat{\phi}_y\rangle = k\langle U\{k^2\phi\hat{\phi} + \phi_y\hat{\phi}_y + \tfrac{1}{2}(\phi\hat{\phi})_{yy}\}\rangle$$

$$i\omega_i\langle k^2\phi\hat{\phi} + \phi_y\hat{\phi}_y\rangle = \frac{k}{2}\langle U(\phi\hat{\phi}_{yy} - \hat{\phi}\phi_{yy})\rangle$$
$$+ i\nu\langle k^4\phi\hat{\phi} + 2k^2\phi_y\hat{\phi}_y + \phi_{yy}\hat{\phi}_{yy}\rangle$$

$$\sum \omega_i \overset{|a_k|^2}{\langle k^2\phi\hat{\phi} + \phi_y\hat{\phi}_y\rangle} = 0.$$

$$A + \nu U_{yy} + \frac{1}{4}(\hat{v}\zeta + v\hat{\zeta}) = 0 \quad , \quad A = -\frac{1}{\rho}P_x$$

$$\frac{1}{4}(\hat{v}\zeta + v\hat{\zeta}) = \frac{1}{4}\left(ik\phi(\cancel{k^2}\hat{\phi} - \hat{\phi}_{yy}) - ik\hat{\phi}(k^2\phi - \phi_{yy})\right)$$

$$= \frac{ik}{4}(\hat{\phi}\phi_{yy} - \phi\hat{\phi}_{yy})$$

$$\delta A + \nu\delta U_{yy} = + \frac{ik}{4}(\phi\hat{\phi}_{yy} - \hat{\phi}\phi_{yy}) \longrightarrow \text{Summation}$$

$$\int \phi\hat{\phi}_{yy}\,dy = [\phi\hat{\phi}_y] - \int \phi_y\hat{\phi}_y\,dy$$

$$B + \delta A y + \nu\delta U_y = \frac{ik}{4}(\phi\hat{\phi}_y - \hat{\phi}\phi_y)$$

$y = 0, \ \phi$

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$$u\hat{\zeta}_y + \hat{u}\zeta + (u\hat{u} + v\hat{v})_y = u(\hat{v}_x - \hat{u}_y) + \hat{u}(v_x - u_y)$$
$$+ \cancel{u\hat{u}_y} + \cancel{u_y\hat{u}} + \cancel{v\hat{v}_y} + \cancel{v_y\hat{v}}$$
$$- v\hat{u}_x - \hat{v}u_y$$

$$= u\hat{v}_x - u_x\hat{v} + \hat{u}v_x - \hat{u}_x v$$

$$= \phi_y(k^2\hat{\phi}) - (-ik\phi_y)(ik\hat{\phi}) + \hat{\phi}_y k^2\phi - ik\hat{\phi}_y(ik\phi)$$

$$= 2k^2(\hat{\phi}\phi_y + \phi\hat{\phi}_y) = 2k^2(\phi\hat{\phi})_y$$

$$\frac{1}{\rho}p_y = -\frac{2}{4}k^2(\phi\hat{\phi})_y$$

$$\frac{p}{\rho} = -\frac{k^2}{2}\phi\hat{\phi} - Ax$$

$$A = -\frac{p_x}{\rho} \qquad \frac{p_x}{\rho} = -A - \frac{k^2}{2}\phi\hat{\phi}$$

$\nu U_{yyy}$