Navier-Stokes Hooteisiki no Kai no Sonzai, Itiisei, Anteisei

————— Buturiteki Koosatu.

IMAI, Isao

1. Hasigaki

Nensei-Ryuutai no Undoo wa Navier-Stokes Hooteisiki ni yotte sihai-sareru. Kono Hooteisiki no suugakuteki Seisitu —— Kai no Sonzai, Itiisei, Anteisei —— ga ryuutai-rikigaku-tekini dono yoona Imi o motu ka ni tuite noberu. Suugaku-tekini genmituna Urazuke no nai Okusoku de aru ga, kore ni tuite Suugakusya no go-Iken o o-kiki sitai to omou. Mata, Ryuutai-Rikigaku no Senmonka no naka ni mo, Hissya no Kangae ni kanarazusimo sansei sarenai kata mo sukunaku nai koto to omowareru ga, Wadai o dasu Imi de, Matomari no nai Katati no mama de kozin-tekina Kangae o noberu koto o o-yurusi negaitai. Kono Mondai ni tuite Suugakusya oyobi Ryuutai-Rikigakusya no Kansin o yobiokosu koto ga dekireba saiwai de aru.

2. Navier-Stokes Hooteisiki wa zituzaino Ryuutai no Undoo o arawasu ka?

Zituzaino Ryuutai wa, Ekitai ni sitemo, Kitai ni sitemo, musuuno Bunsi no Syuudan de aru. Ryuutai-Rikigaku dewa korerano Bunsi no Syuudan o tyuusyooka site, renzoku-tekina Baisitu tosite atukau. Tadasi, Tyuusyooka no sai ni, Situryoo, Undooryoo, Enerugii no Hozon-Hoosoku wa sono mama saiyoo-sarete, Ryuutai no Undoo ni taisuru Kiso-Hooteisiki ga mitibikareru. Iwayuru Renzoku no Hooteisiki wa Situryoo no Hozon o, mata Undoo-Hooteisiki wa Undooryoo no Hozon o teisikika sita mono de aru. Renzoku no Hooteisiki

1

oyobi Undoo-Hooteisiki wa sorezore

$$\frac{\partial p}{\partial t} + div\, \rho \mathbf{v} = 0,$$ (1)

$$\rho \frac{D\mathbf{v}}{Dt} = \rho \mathbf{K} + \frac{\partial p_{ik}}{\partial x_k}, \qquad \frac{D}{Dt} \equiv \frac{\partial}{\partial t} + v_k \frac{\partial}{\partial x_k} \qquad i,\ k = 1,\ 2,\ 3$$ (2)

no Katati ni arawasareru. Kokoni ρ wa Mitudo, $\mathbf{K}$ wa (Ryuutai no Tan-i Situryoo atarino)Gairyoku, p_{ik} wa Ryuutai no nakani sonzaisuru Ooryoku de aru. (1), (2) wa nin-ino Ryuutai ni tuite naritatu node aru ga, tokuni Ooryoku p_{ik} ni taisite

$$p_{ik} = -p\,\delta_{ik} + \tau_{ik},$$ (3)

$$\tau_{ik} = \mu \left(\frac{\partial v_i}{\partial x_k} + \frac{\partial v_k}{\partial x_i} \right)$$ (4)

o kateisuru no ga Newton-Ryuutai, sunawati Newton no Nensei-Hoosoku ni sitagau Nensei-Ryuutai de aru. τ_{ik} wa Nensei-Ooryoku, μ wa Nenseiritu de aru. Sarani, Mitudo ρ to Nenseiritu μ o ittei to kateisuru to, (1), (2) wa sorezore

$$div\ \mathbf{v} = 0$$ (5)

$$\frac{D\mathbf{v}}{Dt} = \mathbf{K} - \frac{1}{\rho}\,\text{grad}\ p + \nu \triangle \mathbf{v}, \qquad \nu = \frac{\mu}{\rho}$$ (6)

to kantanni naru. (6) ga hutuuni Navier-Stokes Hooteisiki to yobareru mono de aru. ν wa Undoo-Nenseiritu de aru.

Oyoso Ryuutai no Assyukusei ga musi dekiru baai, mata Nenseiritu o ittei to minasi-uru baai wa, Ryuutai no Undoo wa (5), (6) ni yotte kanzenni arawaseru mono to kitai sareru. Sitagatte, (5), (6) no Renritu-Henbibun-Hooteisiki ($\mathbf{v}$, p o Mitisuu to suru) no suugakuteki Seisitu ga kanzenni sirareru naraba, tizimanai Nensei-Ryuutai no Undoo ga rirontekini kanzenni siriuru hazu de aru. Tatoeba, itiyoona Nagare no naka ni Kyuu o seisi saseta toki, Reynolds-suu ni yotte Nagare no Yoosu wa kiwamete hukuzatuni henkasuru

ga, kore wa N-S Hooteisiki ni yotte kanzenni iiarawaseru hazu de aru. Zissai

soo daroo ka? Reynolds-suu no tiisai baai ni okoru Sooryuu no Zyootai kara

Reynolds-suu no ookii baai no Ranryuu no Zyootai e no Sen-i-Gensyoo ga N-S

Hooteisiki dake o Kiso ni site setumei sareru node aroo ka? Mata, Ranryuu

no Zyootai sono mono mo, N-S Hooteisiki no Suugakuteki-Seisitu dake de kan-

zenni setumei dekiru node aroo ka? Kore ni kotaeru tame niwa, N-S Hooteisiki

ni tuite wareware no genzai motu Tisiki wa amarinimo sukunasugiru. Kono

<u>Note</u> dewa, Ryuutai-Gensyoo ni kansuru Tisiki kara gyakuni, N-S Hooteisiki no

Kai no suugakuteki Seisitu ni tuite dono yoona Kotogara ga soozoo sareru ka

o noberu. Korera no Okusoku ga hatasite tadasii ka, matawa matigatte iru ka?

Suugakusya no katagata ni Kyoomi o motte itadaki, Kaitoo o ataete kudasareba,

makotoni saiwai de aru.

3. Teizyoona Nagare

Mazu, mottomo kantanna baai tosite, Kyookai-Zyooken ga zikantekini

ittei, sunawati "teizyoona Nagare" o kangaeru. Tatoeba, itiyoona Nagare no

naka ni Buttai o seisi saseta toki no Nagare de aru (Zu. 1). Tyokkantekini

wa, kono baai, Nagare wa teizyoo de aroo to kitai sareru. Sunawati, Sokudo

$\mathbf{V}$ wa Zikan t ni wa yoranai daroo.

(Gairyoku $\mathbf{K}$ wa N-S Hooteisiki no Seisitu

ni honsitu-tekina Eikyoo o motanai to yosoo

sareru node, korekarano Giron dewa $\mathbf{K} = 0$

to suru.) Sitagatte, N-S Hooteisiki tosite wa
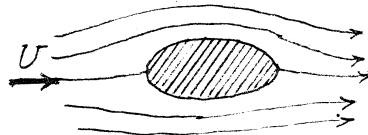
Zu. 1

$$(\mathbf{V} \cdot grad)\mathbf{v} = -\frac{1}{\rho} grad\, p + \nu \triangle \mathbf{v} \tag{7}$$

o saiyoosureba yoi.

Sate, mazu Mondai ni naru no wa, "butturi-tekini tekitoo to kangae-

rareru" Kyookai-Zyooken:

$$\boldsymbol{V} = 0 \qquad \text{Buttai no Hyoomen}$$

(8)

$$\boldsymbol{V} \longrightarrow (U, 0, 0) \qquad \text{Mugen-en}$$

no motoni Renritu-Henbibun-Hooteisiki (5), (7) ga Kai o motu ka, to iu koto
de aru. Kore wa Kai no "Sonzai" no Mondai de aru. Genzai, suugaku-tekini
genmituni ieru no wa, "Reynolds-suu $R = Ul/\nu$ (l wa daihyoo-tekina Nagasa)
ga tekitooni tiisakereba Kai wa sonzaisuru" to iu koto de aru (TAKAMI no
Kaisetu o miyo!). Ryuutai-Rikigakusya tosite siritai no wa, "Kai wa R no
subeteno Atai ni taisite sonzaisuru no ka, soretomo aru Rinkai-ti R_{ex} ga
atte, $R < R_{ex}$ dewa Kai wa sonzaisi, $R > R_{ex}$ dewa sonzaisinai no ka?
Mosi sooda to sureba, R_{ex} no gutaitekina Atai wa nani ka! to iu koto de aru.

Zissaino Gensyoo dewa, R ga tiisai toki Nagare wa ippanni Sooryuu,
R ga ookii toki Ranryuu de aru. Sono Sakai no R ga iwayuru Rinkai-Reynolds
suu R_c de aru. Kono R_c ga ueni nobeta R_{ex} ni ittisuru naraba Hanasi
wa kantan de aru. Tumari, Teizyoo-Kai ga sonzaisinai kara Hiteizyoo-Kai ga
arawareru no da, to iesoo de aru.

Sikasi, mosimo $R_{ex} = \infty$, sunawati, Teizyoo-Kai ga tuneni sonzai
suru naraba, koto wa mendoo de aru. Kono baai kangaerareru no wa, Kai no
"Anteisei" no Mondai de aru. Sunawati, aru Reynolds-suu R_{st} ga atte,
$R < R_{st}$, $R > R_{st}$ ni oozite sorezore Kai ga antei aruiwa huantei de aru
koto ga wakaru naraba, ueno R_c o kono R_{st} to kaisyakusuru koto ga dekiyoo.
(Ryuutai-Rikigakusya ni totte wa kono Kaisyaku ga mottomo sizen de aru yooni
omowareru!)

Mada Mondai ga aru. Teizyoo-Kai ga sonzaisuru to site mo, sore
wa kanarazusimo itii-tekini kimaru towa ienai. Hatasite, Kai no "Itiisei"
wa hosyoosareru no ka? Boo ya Ita no Zakutu (buckling) no Rei demo yoku
sirarete iru yooni, hisenkeino Mondai dewa Kai ga itii-tekini kimaranai no

ga musiro hutuu de aru. N-S Hooteisiki no baai wa doo ka? Mosimo Kai ga

2-ko izyoo sonzaisuru naraba, genzituni arawareru no wa dore ka? Sono baai,

Kai no Anteisei ga zyuuyoona Mondai ni naru de aroo. Sunawati, Zissai-Gensyoo

ni taioosuru no wa anteina Kai de aroo. Sitagatte, kazu-ooku sonzaisuru Kai

wa takadaka 1-ko o nozoite subete huantei de aru mono to soozoo sareru.

(Kai ga subete huantei de aru koto mo ariuru. Sono baai Sooryuu wa okori-

enai.)

Soredewa, teizyoona Kyookai-Zyooken ni taisuru Kai wa tuneni

teizyoo de aroo ka? Senkeino Mondai no Keiken kara tanzyunni kangaeru to,

sono yooni soozoo sareru kamo sirenai. Sikasi, hisenkeino Mondai dewa

kanarazusimo soo da towa iikirenai yooni omowareru. Musiro, N-S Hooteisiki

no baai wa, teizyoona Kyookai-Zyooken ni taisite hiteizyoona Kai ga sonzaisi,

sore ga Ranryuu no Zyootai ni taioosuru no dewa nai ka to soozoo sareru.

4. Okusoku

Ima, f(0;E,U,S), f(t;E,U*,S*) no yoona Kigoo o mitibiki-ireru.

Dai-1 no Hikikazu 0, t wa sorezore Teizyoo-Kai, Hiteizyoo-Kai o imisuru.

E, U, S wa sorezore, Sonzai, Itiisei, Anteisei o imisi, * Zirusi wa Hitei

o imisuru. Sitagatte, tatoeba f(0; E, U, S) wa "Teizyoo-Kai ga tada 1-ko

sonzaisite, sore ga antei de aru" koto o imisuru. Mata f(t; E, U*, S*) wa

"Hiteizyoo-Kai ga 2-ko izyoo sonzaisi, sorera wa huantei de aru" koto o imi-

suru. Kono yooni yakusokusureba, wareware no Okusoku wa tugino yooni Hyoo

no Katati ni kakiarawaseru.

$$f(0; E, U, S) = \text{Sooryuu}, \qquad f(t; E, U, S) = \text{No} \qquad (C1)$$

$$f(0; E, U, S*) = \text{No ?} \qquad f(t; E, U, S*) = \text{No} \qquad (C2)$$

$$f(0; E, U*, S) = \text{Taylor-Uzu etc.} \quad f(t; E, U*, S) = \text{Karman-Uzu etc.} \quad (C3)$$

$$f(0; E, U*, S*) \longrightarrow f(t; E, U*, S*) = \text{Ranryuu} \qquad (C4)$$

$$f(0;\ E^*) \longrightarrow f(t;\ E) \qquad f(t;\ E^*) \longrightarrow f(0;\ E) \qquad (C5)$$

$$f(0;\ E^*)\ =\ No\ ? \qquad (C6)$$

"No" wa "soo iu Baai wa okoranai" to iu Imi de aru. Tatoeba (C6) no

$f(0;\ E^*) = No$ wa "Teizyoo-Kai ga tuneni sonzaisuru" koto o imisuru. Kore

ni taisite, (C5) wa "Teizyoo-Kai ka Hiteizyoo-Kai no dotiraka wa kanarazu

sonzaisuru" koto o imisuru node, Okusoku tosite_wa (C6) yori yowai. (C1),

(C2) no Migigawa o awase-kangaeru to, "$f(t;\ U) = No$" to naru. Tumari,

"(teizyoona Kyookai-Zyooken no moto ni) Hiteizyoo-Kai ga tandokuni sonzai-

suru koto wa arienai." (C3) wa, "anteina Kai ga 2-ko izyoo sonzaisuru baai,

sono naka niwa anteina mono ga ari, Taylor-Uzu (kaitensuru 2-ko no Entoo no

aida ni okoru) ya Karman-Uzu ga sore ni taioosuru" to iu Yosoo o noberu mono

de aru.

5. Taisyoosei no aru Nagare

Kyuu ya Entyuu no mawari no Itiyoo-Ryuu no yooni, Kyookai-Zyooken

ni kikagaku-tekina Taisyoosei ga aru Baai o kangaeru. Kono baai, tyokkan-

tekini wa, Kai mo onazi Taisyoosei o motu to kangaerareru ga, hatasite

hitaisyoona Kai wa sonzai dekinai no daroo ka? Ima $f(0;\ Sym)$, $f(o;\ Sym^*)$

de sorezore taisyoo-teki oyobi hitaisyoo-teki na Teizyoo-Kai o arawasu koto

ni siyoo. (Tatoeba, 2-ko no Kaiten-Entoo no aida no Couette no Nagare wa

$f(0;\ Sym)$ ni, Taylor-Uzu wa $f(0;\ Sym^*)$ ni taioosuru.) Soosureba, $R < R_{sym}$

dewa $f(0;\ E^*,\ Sym^*)$, $R > R_{sym}$ dewa $f(0;\ E,\ Sym^*)$, de aru yoona

Rinkai-Reynolds-suu R_{sym} ga kangaerareyoo. Kono R_{sym} wa $f(0;\ U)$ no

yabureru (tumari Kai no Itiisei no yabureru) Reynolds-suu R_{uni} ni mo

natte iru.

Motto ippantekini itte, 2-zigen no Nagare, ziku-taisyoo no Nagare

dewa Kuukan-Zahyoo no uti 2-ko dake ga arawareru; tumari dai-3 no Zahyoo

niwa yoranai. Kyookai-Zyooken no naka ni dai-3 no Zahyoo ga arawarenai kara

to itte, Kai sono mono nimo arawarenai to iu Hosyoo wa nai. Kono Zizyoo wa

teizyoona Kyookai-Zyooken no moto ni Hiteizyoo-Kai ga sonzaisuru no to onazi

de aru. Iikaereba, Teizyoo-Kai to iu no wa zikan-tekina Taisyoo-Kai de aru.

6. Kusabi-gata Ryooiki de no Nagare

Navier-Stokes Hooteisiki o senkeika sita Stokes Kinzi ni oite mo,

Nensei-Ryuutai no Nagare wa hukuzatuna Yoosu o simesu. Sono yoi Rei wa,

Kusabi-gata Ryooiki de no Nagare de aru.Kore ni tuite wa MOFFATT no kuwasii

Kenkyuu ga aru (ASO no Kaisetu o miyo!). Yooten o noberu to, Kusabi no Kaku

α ga aru Rinkaiti α_1 ika dewa mugenko no Uzu no Retu ga Kusabi no Tyooten

no Hukin ni arawareru to iu no de aru (Zu.2). Kono Zizyoo wa genmituna

Navier-Stokes Hooteisiki ni tuite mo dooyoo de aroo ka? Kantanni kangaeru

to, Kabe no ue dewa Sokudo wa 0 de aru kara, Tyooten no Hukin dewa Sokudo

ga tiisaku, sitagatte Stokes Kinzi ga naritatu yoo ni mo omoeru. Sikasi,

Reynolds-suu ga ookiku naruto, Tyooten kara hanareta Basyo de no Nagare no

Yoosu wa Stokes Kinzi kara hazure, sono Eikyoo ga "gaibu no Kyookai-Zyooken"

tosite Tyooten Hukin no Nagare o sihaisuru koto mo kangaerareru kara, Zizyoo

wa soo kantan de aru to wa ienai yooni omowareru.

Koko dewa kono Ten ni tuite wa

tati-irazu, tada 2-zigen no Stokes Hooteisiki

no Ippan-Kai ni taisuru benrina Hyoosiki o

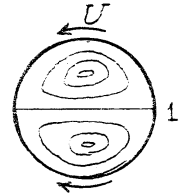ataeru ni todomeru. (IMAI 1957 o miyo!)
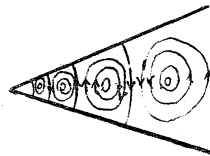
Zu. 2

W = u - iv,   z = x + iy

$W = f'(z) + \overline{z} g'(z) - \overline{g(z)}$,   f, g wa nin-i no Kaiseki-Kansuu

(Rei 1) Entoo-gata no Yooki no naka no Nagare (Zu.3)

$$W = - \frac{U}{2\pi} \bar{z} \left(\log \frac{1+z}{1-z} - \log \frac{1+\bar{z}}{1-\bar{z}} + \pi i \right)$$
$$+ \frac{U}{\pi} \frac{z\bar{z}-1}{z^2-1}$$

(Rei 2) Kusabi-gata no Ryooiki de no Nagare

$$f = \pm Cz^\lambda + \bar{C}z^{\bar{\lambda}}$$

$$f' = (1 \mp \lambda) Cz^\lambda \pm (1 \mp \bar{\lambda}) \bar{C}z^{\bar{\lambda}}$$

$$\frac{\sin \lambda\alpha}{\sin \alpha} = \pm \lambda$$

α : Kusabi no Tyookaku, C: nin-i no Hukuso-suu, λ wa Koyuuti (ueno

Hooteisiki no Kai). $\alpha < \alpha_L = 146°$ ni taisite λ wa Hukuso-suu ni

naru. Kono toki mugenko no Uzu no Retu ga arawareru.

7. R $\longrightarrow$ ∞ ni taisuru Teizyoo-Kai

Mosimo nin-i no Reynolds-suu ni

taisite Teizyoo-Kai ga sonzaisuru naraba,

R $\longrightarrow$ ∞ ni taisite sono Kai wa dono

yoona Nagare o arawasu daroo ka? Kore

wa genzai mada kaiketu sarenai Mondai de

aru. R $\longrightarrow$ ∞ wa $\mu \longrightarrow$ 0 ni taioosuru

kara, Kanzen-Ryuutai no Nagare o arawasu

koto niwa Gimon no Yoti wa nai. Sikasi,

Kanzen-Ryuutai ni taisuru Helmholtz no

Uzu-no-Teiri o tanzyunni tekiyoosite,

uzunasino Nagare (Zu.4, a) ga Zenkin-Kai

de aru to iu no wa Matigai de aru. Buttai

no Hyoomen de no Kyookai-Zyooken (Sokudo = 0)

ga kooryo sarete inai kara de aru. Maeni

Zu. 3
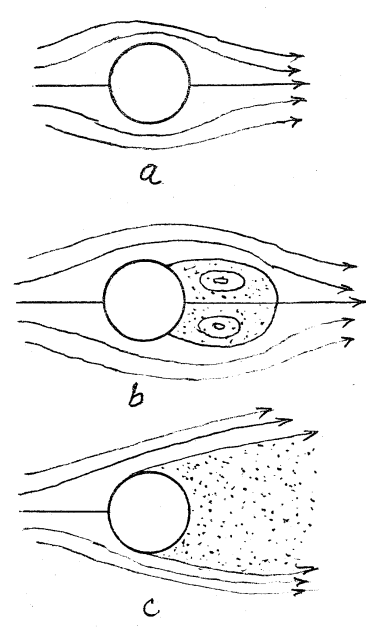
Zu. 4

Hissya (1953) wa Zenkin-Kai wa Kirchhoff-gata no Sisui-Ryooiki o tomonau

Nagare (Zu.4, c) de aroo to yosoosita. Kore ni taisite Batchelor (1956)

wa, itiyoona Uzudo no Bunpu o motu yuukaino Ryooiki o Sanryuu (Wake) to

suru yoona Nagare (Zu.4, b) o teian site iru. b-Zu no yoona tozita Ryuusen

o motu koto ga kakuzituni wakatte iru baai niwa, sono Ryuusen de kakomareta

Ryooiki no naka dewa Uzudo wa tasikani ittei de aru koto ga ieru. ($6 de

noberu Naibu-Mondai dewa kono Katei ga yurusareru yooni mieru. BURGGRAF

(1966) wa Oseen Kinzi ni nita Kaiseki-Keisan to Suuti-Keisan ni yotte kono

Zizitu o urazukeru yoona Kenkyuu o okonatte iru. Saikin, KUWABARA-Kunio

(Toodai Rigakubu) mo Entoo no naka no Nagare ni tuite kuwasii Kenkyuu o

site iru.) Sikasi, Buttai o sugiru itiyoona Nagare no yoona Gaibu-Mondai

dewa, somosomo tozita Ryuusen no Sonzai sonomono ni Utagai ga aru node,

Batchelor no Yosoo wa kanarazusimo tadasii to wa ienai to omowareru. Sisui

no Riron kara wa Buttai no Teikoo wa R $\longrightarrow \infty$ ni taisite yuugen no Atai o

tori, Batchelor no Riron dewa Teikoo wa 0 ni naru. Kore wa 2-tu no Riron

no mottomo itizirusii Tigai de aru. (Ookii Reynolds-suu ni taisuru N-S

Hooteisiki no Suuti-Kai kara, 2-tu no Riron no dotira ga tadasii ka ni tuite

Hantei ga erareru no dewa nai ka to kitai sareru.)

8. Naibu-Mondai to Gaibu-Mondai

Navier-Stokes Hooteisiki no Toriatukai ni saisite, "Naibu-Mondai"

to "Gaibu-Mondai" ni wa zyuuyoona Tigai ga aru yooni omowareru. Naibu-Mondai

to wa, Yooki no naka no Ryuutai no Undoo no yooni, Nagare no Ryooiki ga

yuukai no Baai o iu. Kore ni taisite, Gaibu-Mondai wa, Nagare no Ryooiki

ga mugenni hirogaru Baai de atte, Buttai ni Itiyoo-Ryuu ga ataru Baai ga

sono Rei de aru. Ryuutai-Rikigakusya niwa, kono Gaibu-Mondai ga tokuni

zyuuyoo de aru to omowareru.

Gaibu-Mondai de tyuui sinakereba naranai no wa, Mugen-Enpoo ($r \to$

∞) de no Kyookai-Zyooken de aru. Tatoeba, Buttai ni Itiyoo-Ryuu U ga

ataru baai,

$$r \to \infty \quad \text{no toki} \quad v \to U$$

o Kyookai-Zyooken to suru no ga (Ryuutai-Rikigakusya niwa) sizen de aru.

Tokoroga, suugaku-teki niwa, Kai no Sonzai ya Itiisei o gironsuru baai,

$v \to U$ no Tikazukikata ni tuite nanika hukatekina Katei o mookeru no

ga hutuu no yoo de aru. (Tatoeba, FINN(1965). TAKAMI no Kaisetu o miyo!)

Kai no Sonzai, Itiisei ni tuite no Keturon ga kono yoona hukatekina Katei

ni yotte eikyoosareru no wa, sukunakutomo Ryuutai-Rikigakusya ni totte wa,

omosiroku nai. Musiro, sono yoona Katei o mookeru koto no Hituzensei o

ataete hosii mono to omou.

Kono Ten ni tuite kangaeru beki wa, somosomo teizyoona Itiyoo-Ryuu

ga zissaitekini dono yooni site tukurareru ka to iu koto de aru. Sunawati,

zissaizyoo wa, seisi-Ryuutai no naka de seisi site iru Buttai o, aru Syunkan

kara ugokasi-hazimete itteino Sokudo U o motaseru yooni suru. Tumari,

Hiteizyoo-Undoo no t $\to \infty$ no Kyokugen tosite erareru no ga Teizyoo-

Undoo de aru. Kono Tatiba kara ieba, Ryuutai-Rikigakusya no Taisyoo to

suru Teizyoo-Kai wa zitu wa Hiteizyoo-Kai no t $\to \infty$ ni taisuru Zenkin-Kai

to iu koto ni naru.

Navier-Stokes Hooteisiki no suugakutekina Giron de mottomo Konnan

to sareru no wa R $\to \infty$, $r \to \infty$, t $\to \infty$ no yoona Kyokugen

de no zenkintekina Hurumai de aru. Sikamo, korerano Kyokugen ga, Ryuutai-

Rikigakusya ni totte wa, zitu wa mottomo Kyoomi no hukai Baai de aru koto

ni tyuui sitai.

9. Suuti-Kaihoo no Konnan

Navier-Stokes Hooteisiki no Kaiseki-Kai o motomeru koto wa kiwamete

konnan de aru ga, saikinno Koosoku-Keisanki no Sinpo wa seimituna Suuti-Kai

o motomeru koto o Kanoo ni sita. Sore zisin makotoni kekkoona koto dewa

aru ga, dakara to itte zenmentekini Suuti-Kaihoo ni tayoreba yoi to wa ienai

to omowareru. Tatoeba, f(O; E, U) ga hosyoosareru naraba, nanika tekitoona

Hoohoo de, tonikaku 1-tu Kai o motomereba sorede yoi. Sikasi, f(O; E, U*)

da to suruto, 1-tu Suuti-Kai o motomete mo, zyuuyoona Kai o minogasite iru

Osore ga aru. Tokuni, Reynolds-suu no ookii brai niwa sibasiba Suuti-Kai

no Syuusokusei ga waruku naru koto ga keiker sareru. Kono yoona baai,

Syuusokusei o yoku suru yoona Gikoo o korasite Kai o eta to site mo, sore

wa aruiwa tokubetuna mono de aru ka mo sirenai. Tumari, Syuusokusei no

$$/:f(O; E, S*)/$$

waruku naru koto wa Kai no Huanteisei/ni kankeisuru ka mo sirezu, mata sore

wa Kai no Itiisei ga yabureru koto: f(O; E, U*) ni kankeisuru ka mo sirenai

kara de aru.

Sikasi, tatoe f(O; E, U*) de aru to site mo, mosimo Hiteizyoo-

Kai no t → ∞ ni taisuru Zenkin-Kai tosite Teizyoo-Kai ga erareta to

sureba, sore koso wareware no motomeru "buturi-tekina Kai" o arawasu to

ieru de aroo. Kono Imi de, f(O; E, U) ga hosyoosareru kagiri, Teizyookai

o motomeru Suuti-Keisanhoo tosite wa musiro Hiteizyoo-Kai no t → ∞

ni taisuru Kyokugen tosite motomeru Hoosiki ga susumerareru no dewa nakaroo

ka?

$6 de nobeta Kusabi-gata Ryooiki no Nagare de mugenko no Uzu no

Retu ga arawareru koto wa, Suuti-Kaihoo, tokuni Sabun-hoo ni yotte seimituna

Kai o motomeyoo to suru baai 1-tu no Konnan o ataeru mono to omowareru.

Nao, Reynolds-suu no ookii baai ni Kyookaisoo no arawareru koto mo, Sabun-

hoo ni yoru Keisan o mendoo ni suru de aroo.

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